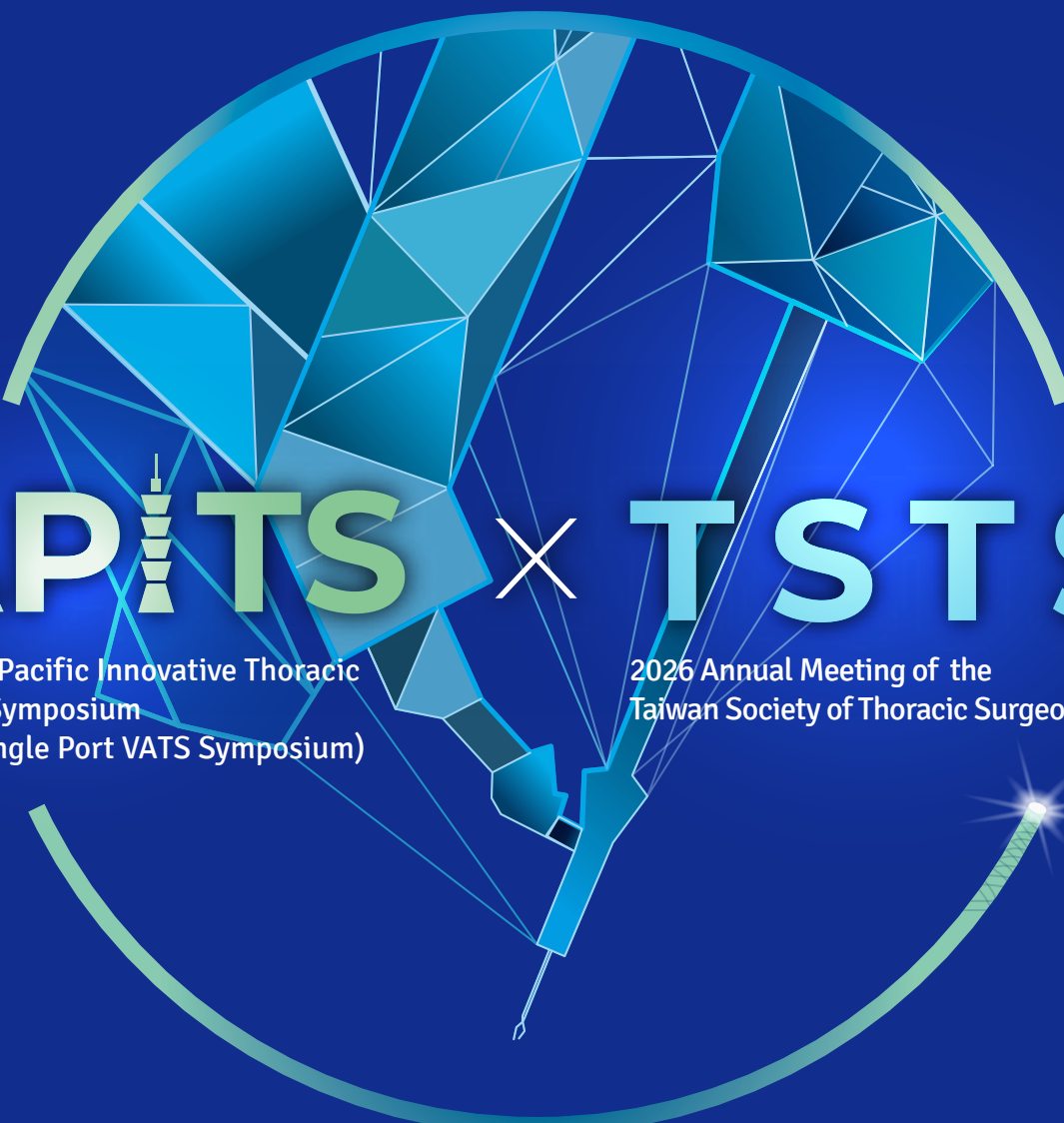


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# APITS × TSTS

The Asia-Pacific Innovative Thoracic  
Surgery Symposium  
(Asian Single Port VATS Symposium)

2026 Annual Meeting of the  
Taiwan Society of Thoracic Surgeons

July 11-12, 2026

📍 Taipei International Convention Center

**ABSTRACT BOOK**





# TABLE OF CONTENTS

002 **Invitees**

.....

002 **Free Paper Presentation**

.....

002 **APITS Poster Walk Presentation**

.....

002 **TSTS Poster Walk Presentation**

.....

002 **Poster Presentation**

.....



# Invitees

MINIMALLY INVASIVE  
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## Room 102 (English) | Saturday, July 11, 2026

### Plenary Session

Time: 09:30-10:00 (GMT+8)

|    |             |           |                                                                                                                    |
|----|-------------|-----------|--------------------------------------------------------------------------------------------------------------------|
|    |             | Chair(s): | Jin-Shing Chen (Taiwan)<br>Han-Shui Hsu (Taiwan)                                                                   |
| P1 | 09:30-10:00 |           | <b>Empowering Surgical Innovation: Government Policy and the Future of Healthcare</b><br>Chung-Liang Shih (Taiwan) |

## **Empowering Surgical Innovation: Government Policy and the Future of Healthcare**

**Chung-Liang Shih**

*Ministry of Health and Welfare*

Facing the arrival of a super-aged society, Taiwan's healthcare system is encountering unprecedented challenges, including population aging, the increase of chronic diseases, shortages in medical manpower, and the rapid development of emerging medical technologies. In 2025, Taiwan officially became the super-aged society, with National Health Insurance (NHI) expenditures continuing to grow. Balancing healthcare quality, innovation and the sustainability of NHI has become a top priority in government health policy.

Accordingly, Taiwan is actively promoting a transformation in healthcare delivery models—shifting from disease treatment to health management, from hospital-centered care to community- and patient-centered care, and adopting value-based payment to enhance overall healthcare effectiveness.

This presentation will highlight Taiwan's achievements in driving surgical innovation through NHI, including policies supporting robotic-assisted surgery and Enhanced Recovery After Surgery (ERAS). By establishing a reimbursement mechanism grounded in Health Technology Assessment (HTA), Taiwan ensures clinical effectiveness, patient safety, and optimal allocation of medical resources. At the same time, NHI is advancing home-based care, telemedicine, and other innovative care models to strengthen system resilience and improve accessibility of services.

Looking ahead, the government will continue to deepen the development of value-based and precision medicine, integrating medical technology innovation, cross-disciplinary collaboration, and international exchange. The goal is to build a patient-centered healthcare system that embodies quality, efficiency, and sustainability—working together to meet the health challenges of a super-aged society.

## Room 102 (English) | Saturday, July 11, 2026

### Session A

#### Frontiers in Robotic Thoracic Surgery and Emerging Surgical Platforms

**Time: 10:30-11:30 (GMT+8)**

|     |             |                                                                                                                 |
|-----|-------------|-----------------------------------------------------------------------------------------------------------------|
|     |             | Yin-Kai Chao (Taiwan)<br>Chair(s): Han-Shui Hsu (Taiwan)<br>Takashi Suda (Japan)                                |
| A-1 | 10:30-10:42 | <b>The New Era of Robotic Thoracic Surgery: From Multiport to Single-Port Systems</b><br>Yin-Kai Chao (Taiwan)  |
| A-2 | 10:42-10:54 | <b>The Future of Minimally Invasive Thoracic Surgery: What is Expected of a Robot?</b><br>Takashi Suda (Japan)  |
| A-3 | 10:54-11:06 | <b>From Science Fiction to Reality: The Impact of Robotic Systems in Thoracic Surgery?</b><br>Wilson Tsai (USA) |
| A-4 | 11:06-11:18 | <b>Davinci 5: Game Changer for Thoracic Surgery?</b><br>Seong Yong Park (Republic of Korea)                     |
| A-5 | 11:18-11:30 | <b>Beyond the Robot: The Next Frontier in Thoracic Surgery</b><br>Diego Gonzalez Rivas (Spain)                  |

## **The New Era of Robotic Thoracic Surgery: From Multiport to Single-Port Systems**

**Yin-Kai CHAO**

*Chang Gung Memorial Hospital*

Robotic thoracic surgery has entered a new era, evolving from the establishment of multiport techniques to the emergence of single-port platforms that are reshaping surgical access and procedural design. Multiport robotic systems have provided the foundation for complex minimally invasive thoracic surgery through enhanced visualization, instrument dexterity, and procedural precision. The introduction of single-port technology represents not merely a reduction in the number of incisions, but an opportunity to reconsider how thoracic operations are approached, standardized, and integrated into contemporary surgical practice.

Taiwan provides a unique perspective on this evolution. With a high burden of thoracic malignancies, widespread adoption of minimally invasive surgery, and a strong culture of surgical innovation, Taiwanese thoracic surgeons have rapidly advanced robotic applications across pulmonary, mediastinal, and esophageal procedures. The transition from multiport systems to reduced-port and single-port strategies has been accompanied by innovations in intercostal, subcostal, and subxiphoid access, reflecting a broader shift from platform-driven surgery toward anatomy- and patient-tailored approaches.

This presentation will provide an overview of the evolution of robotic thoracic surgery, highlighting Taiwan's experience in translating technological advances into clinical practice, education, and procedural innovation. Particular attention will be given to the complementary roles of multiport excellence and single-port innovation, as well as the importance of structured training, collaborative learning, and regional knowledge exchange. As robotic technology continues to evolve, the next era will be defined not by port number alone, but by how effectively new platforms can expand minimally invasive options, improve surgical care, and foster an integrated ecosystem of innovation.

## **The Future of Minimally Invasive Thoracic Surgery: What is Expected of a Robot?**

**Takashi Suda**

*Fujita Health University Okazaki Medical Center*

Robotic surgery is now widely performed. The advantage of robotic surgery is that it enables minimally invasive surgery with high precision that cannot be performed by human hands. Current disadvantages of robotic surgery include high costs, the need for more port insertions than VATS, the potential for increased postoperative pain, and a lack of evidence of patient benefits that outweigh these drawbacks. However, robots may offer advantages, such as enabling highly challenging procedures that previously could not be performed endoscopically by human hands, and the potential for robotic precision to contribute to safety and complication reduction.

In recent years, uniportal robotic surgery has become popular. It is expected to be an ideal minimally invasive, high-precision procedure that combines the minimally invasiveness of uniportal surgery with the superior operability of robotic surgery. Additionally, several new robotic systems are being marketed, leveraging their respective capabilities. Recently, autonomous robotic cholecystectomy, which does not require human intervention, has been reported. This may help address physician shortages and healthcare disparities. In the future, the use of robots, coupled with advances in robotics and the use of AI, may create a world in which more precise and minimally invasive surgery is available to everyone.



## From Science Fiction to Reality: The Impact of Robotic Surgery in Thoracic Surgery

**Wilson S. Tsai, MD**

*CEO, Prometheus Medical Innovations*

In this lecture, we will discuss and demonstrate the role of robotic surgery in highly complex cases other than lung cancer. We will explore in detail the advantages of robotic surgery in esophagectomies, tracheobronchoplasties, and diaphragm plications

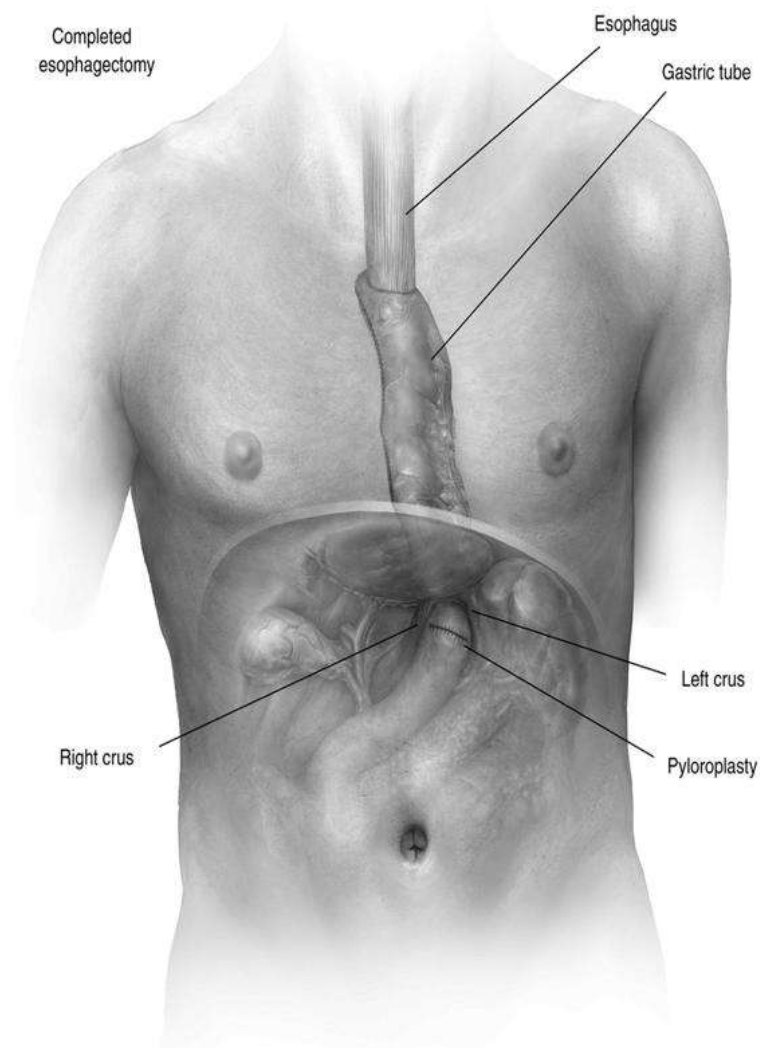


Figure 1: Esophagectomy

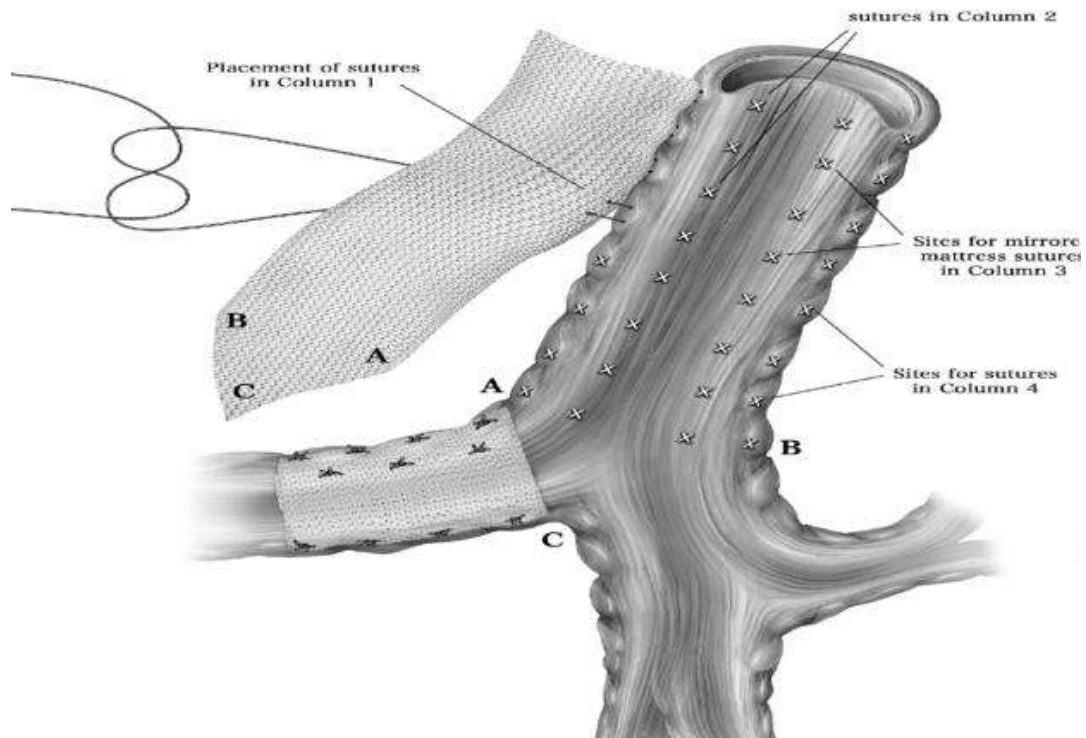


Figure 2: Tracheobronchoplasty

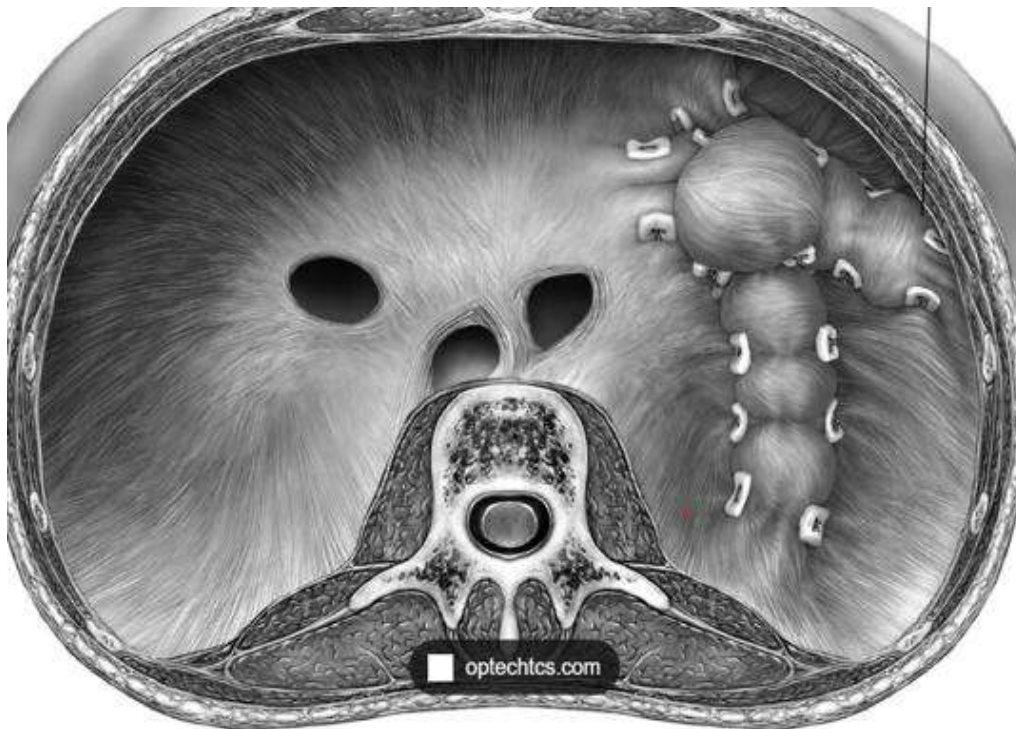


Figure 3: Diaphragm Plication

## Da Vinci 5: Game Changer for Thoracic Surgery?

**Seong Yong Park, MD, PhD**

*Department of Thoracic and Cardiovascular Surgery  
 Samsung Medical Center, Sungkyunkwan University School of Medicine  
 Seoul, Korea*

Since its clinical introduction in 1999, the da Vinci system has progressively reshaped thoracic surgery by enabling enhanced visualization, articulated instrument motion, and meticulous dissection in deep and narrow anatomical spaces. The 2024 launch of the da Vinci 5 (DV5) platform represents the most substantial generational advance to date, introducing three transformative features: integrated force feedback (FFB), a digital platform capable of capturing high-resolution intraoperative data, and a markedly expanded computing architecture.

In terms of overall surgical workflow, ergonomics, and instrument articulation, DV5 is largely comparable to the fourth-generation Xi system, and many routine thoracic procedures such as standard lobectomy may not derive substantial clinical benefit from the new platform. The distinctive value of DV5 emerges in technically demanding operations that require fine, force-sensitive dissection around critical neurovascular structures. Robot-assisted minimally invasive esophagectomy (RAMIE) is a prototypical example. RAMIE generates the highest tissue manipulation forces among thoracic robotic procedures, and recurrent laryngeal nerve (RLN) palsy—the most consequential complication affecting voice, swallowing, and quality of life—is mechanistically linked to traction and compression during paratracheal lymph node dissection. Preclinical studies have demonstrated that FFB reduces intraoperative forces by 20–43% across all surgeon experience levels, and the presenter's institutional experience corroborates a measurable downstream clinical effect: in a preliminary comparison of 25 DV5 and 119 Xi RAMIE cases at Samsung Medical Center, the DV5 cohort showed a trend toward reduced overall complications (56.0% vs. 74.0%) and lower RLN palsy rates (13.8% vs. 28.7%). Personal force-reduction data during esophagectomy further demonstrated 16–17% lower forces with Maryland bipolar and Cadiere forceps when FFB was activated. While these findings require prospective validation, they suggest that for high-morbidity, force-sensitive thoracic procedures, FFB may translate force reduction into meaningful clinical benefit.

Beyond haptics, the DV5 digital platform represents a parallel and potentially more far-reaching evolution. Every operation is now accompanied by a rich stream of digital data—video, instrument kinematics, path lengths, energy activation patterns, and phase-level event logs—captured continuously at high resolution. With computing capacity approximately 100-fold greater than Xi, of which only about 10% is currently utilized, DV5 establishes a foundation upon which AI-based phase recognition, anatomy segmentation, intraoperative navigation, and ultimately semi-autonomous or "auto-pilot" surgical assistance may be developed. These capabilities position DV5 as the entry point into augmented surgery and AI-driven surgical intelligence rather than merely a refined mechanical platform.

In conclusion, DV5 is unlikely to be a universal game changer across all thoracic procedures, but it offers compelling advantages in technically demanding, force-sensitive operations such as RAMIE, where force feedback may meaningfully reduce complications. Equally important, its digital platform

lays the groundwork for the next era of augmented and AI-assisted thoracic surgery, redefining the surgeon–robot relationship over the coming decade.

## **Beyond the Robot: The Next Frontier in Thoracic Surgery**

**Diego Gonzalez Rivas**

*Coruña University Hospital, Coruña*

### **Keypoints**

The next frontier in thoracic surgery involves integrating tele-surgery with advanced single-port robotic platforms such as the Shurui system. In April 2025, we achieved a historic milestone by performing the world's first transcontinental thoracic surgery, operating on a lung cancer patient in Bucharest, Romania, from Suzhou, China, over 8,000 km away. This breakthrough demonstrates the evolution from multiportal robotics toward pure Uniportal Robotic-Assisted Thoracic Surgery (URATS) and the potential of 5G technology to eliminate geographical barriers in surgical care.

### **Abstracts**

This session explores the paradigm shift from traditional robotic assistance to the next generation of surgical frontiers: tele-robotics and specialized single-port systems. Centered on the landmark 2025 transcontinental lung lobectomy, the discussion highlights how the combination of the URATS technique and high-speed digital connectivity allows for a robot's "eyes and arms" to operate with precision within the thoracic cavity from thousands of miles away. The presentation outlines the future of surgery as one characterized by global medical resource sharing and the continued minimization of surgical trauma through innovative platforms like Shurui.

## Room 102 (English) | Saturday, July 11, 2026

### Session B The Outside-Cage Revolution in Intrathoracic Operations

**Time: 11:30-12:30 (GMT+8)**

|     |             |                                                                                                                                      |
|-----|-------------|--------------------------------------------------------------------------------------------------------------------------------------|
|     |             | Takeo Fujita (Japan)<br>Chair(s): Tsai-Wang Huang (Taiwan)<br>Hung-I Lu (Taiwan)                                                     |
| B-1 | 11:30-11:42 | <b>Technical Aspects and Short-Term Outcomes of Robot-Assisted Transcervical Esophagectomy (RACE)</b><br>Takeo Fujita (Japan)        |
| B-2 | 11:42-11:54 | <b>Robotic Subcostal Esophagectomy Using SP System</b><br>Hyun Koo Kim (Republic of Korea)                                           |
| B-3 | 11:54-12:06 | <b>Robot-Assisted Thoracic Surgery Through an Outside-the-Cage Approach: Patient Selection and Outcomes</b><br>Yin-Kai Chao (Taiwan) |
| B-4 | 12:06-12:18 | <b>Recent Advancement of Submucosal Endoscopy: Peroral Endoscopic Myotomy</b><br>Ching-Tai Lee (Taiwan)                              |
| B-5 | 12:18-12:30 | <b>The Evolving Landscape of Esophageal ESD: A Thoracic Surgeon's Perspective</b><br>Tzu-Ping Chen (Taiwan)                          |

## **Technical Aspects and Short-Term Outcomes of Robot-Assisted Transcervical Esophagectomy (RACE)**

**Takeo Fujita**

*Division of Esophageal Surgery, National Cancer Center Hospital East, Japan  
6-5-1 Kashiwanoha, Kashiwa, Japan*

Transcervical surgery has been expected to reduce postoperative respiratory complications, and robotic assistance may further improve precision around the recurrent laryngeal nerve. We developed robot-assisted cervical esophagectomy with a transhiatal abdominal approach (RACE) and evaluated its safety and feasibility.

We retrospectively analyzed 80 patients who underwent RACE between 2023 and 2025. The procedure consisted of bilateral robotic transcervical mediastinal dissection with intraoperative nerve monitoring, followed by robotic transhiatal lower mediastinal dissection. The mean patient age was 73.1 years, and over 75% had respiratory comorbidities. No intraoperative adverse events occurred, and conversion to thoracoscopic surgery was required in one case. Surgical mortality was 0%. Postoperative recurrent laryngeal nerve palsy (Clavien–Dindo grade  $\geq 1$ ) occurred in 11.3%, and pneumonia (grade  $\geq 2$ ) in 7.5%.

RACE was shown to be a feasible and reproducible minimally invasive procedure with favorable short-term outcomes, enabling precise mediastinal lymph node dissection through robotic assistance. Further evaluation of long-term oncological outcomes is warranted.

### **References**

- [1] Short-term outcomes of robot-assisted transcervical esophagectomy for thoracic esophageal carcinoma. Fujita T, et al. Surg Endosc. 2025 Sep;39(9):5733-5741.
- [2] Robot-assisted cervical esophagectomy with simultaneous transhiatal abdominal procedure for thoracic esophageal carcinoma. Fujita T, et al. Surg Endosc. 2024 Nov;38(11):6413-6422



## **Robotic Subcostal Esophagectomy Using the SP System: The Outside-Cage Revolution in Intrathoracic Operations**

**Hyun Koo Kim\*, Jun Hee Lee, Byung Mo Gu**

*Department of Thoracic and Cardiovascular Surgery, Guro Hospital, Korea University College of Medicine, Seoul, Republic of Korea*

The evolution of minimally invasive esophagectomy has progressively focused on reducing surgical trauma while maintaining oncologic radicality. Recently, the da Vinci Single-Port (SP) robotic system has enabled novel extrathoracic and extrapulmonary approaches that challenge the conventional transthoracic paradigm of esophageal surgery. These “outside-cage” approaches, including subcostal and transcervical access, aim to minimize intercostal nerve injury and pulmonary trauma while preserving precise mediastinal dissection.

Single-port robot-assisted minimally invasive esophagectomy (SRAMIE) using the SP robotic system was performed through a 4-cm subcostal incision combined with a 12-mm assistant port. Carbon dioxide insufflation enabled creation of a subcostal tunnel and capnothorax, allowing complete thoracic esophageal mobilization without conventional intercostal robotic ports. The fully articulating SP camera and wristed instruments facilitated precise recurrent laryngeal nerve lymph node dissection and mediastinal lymphadenectomy even within narrow intrathoracic spaces.

In our initial experience, SRAMIE demonstrated perioperative outcomes comparable to multi-port robotic and thoracoscopic esophagectomy, while showing advantages in postoperative recovery. Compared with video-assisted esophagectomy, SRAMIE resulted in lower postoperative pain, shorter chest tube duration, and reduced hospital stay. No conversion to thoracotomy occurred. In addition, precise robotic suturing enabled safe partially stapled intrathoracic anastomosis and effective upper mediastinal dissection.

Recent European experiences with SP robotic esophagectomy further support the feasibility of extrapulmonary approaches. The transcervical SP RACE technique demonstrated complete extrapulmonary mediastinal dissection without transthoracic access or single-lung ventilation, potentially expanding surgical indications for patients with compromised pulmonary function. Similarly, the SP subcostal RAMIE experience from Mainz showed excellent short-term outcomes, including R0 resection in all patients, high lymph node yield, low postoperative pain, rapid mobilization, and zero 30- and 90-day mortality.

These emerging SP robotic approaches represent a paradigm shift in esophageal surgery. By moving surgical access “outside the rib cage,” surgeons may reduce access trauma while maintaining oncologic quality and precise mediastinal lymphadenectomy. Future technological advances, including robotic staplers and advanced energy devices, together with multicenter prospective studies, will further define the role of SP robotic extrapulmonary esophagectomy in modern thoracic surgery.

### **References**

- [1] Lee JH, Hong JI, Jang YJ, Kim HK. Single-port plus one port subcostal robotic-assisted minimally invasive McKeown esophagectomy using the da Vinci Single-Port surgical system. *Interdiscip CardioVasc Thorac Surg.* 2023;36(6).
- [2] Lee JH, Gu BM, Song HH, Jang YJ, Kim HK. Single-Port Robot-Assisted Minimally Invasive Esophagectomy Using the Single-Port Robotic System via the Subcostal Approach: A Single-Center Retrospective Study. *Cancers.* 2025;17:1052.
- [3] Renger F, Bellaio L, Hadzijušufovic E, et al. Single-port robot-assisted cervical esophagectomy



(SP RACE): Combining precision mediastinal lymphadenectomy and complete extrapulmonary dissection. JTCVS Techniques. 2025;34:249-252.

[4]Lozanovski VJ, Bellaio L, Hadzijasufovic E, et al. Da Vinci single-port-assisted subcostal esophagectomy (SP SC RAMIE) – a promising SP approach. Surg Endosc. 2026;40:1321-1329.

## **Robot-Assisted Thoracic Surgery Through an Outside-the-Cage Approach: Patient Selection and Outcomes**

**Yin-Kai CHAO**

*Chang Gung Memorial Hospital*

Conventional minimally invasive thoracic surgery has predominantly relied on intercostal access, with the rib cage defining instrument trajectories and operative geometry. The development of advanced robotic platforms, particularly single-port systems, has created new opportunities to approach the thoracic cavity through non-intercostal pathways. Subcostal and subxiphoid access represent an “outside-the-cage(OTC)” strategy that may reduce intercostal trauma while providing alternative operative trajectories for pulmonary and mediastinal procedures. However, these approaches also introduce distinct technical constraints, and appropriate patient selection remains essential.

This presentation reviews the evolution of robot-assisted thoracic surgery through OTC access, with particular emphasis on patient selection and clinical outcomes. The selection of subcostal, subxiphoid, or conventional intercostal access should be guided by target anatomy, tumor location, body habitus, intrathoracic working distance, and procedural complexity. While outside-the-cage approaches may be particularly advantageous for selected lower thoracic and mediastinal targets, longer trajectories to the hilum or apex, challenging proximal vascular control, and unfavorable anatomy may limit their application. These considerations have led to a transition from a universal access strategy toward a tailored, anatomy-driven approach.

## **Recent Advancement of Submucosal Endoscopy: Peroral Endoscopic Myotomy**

**Lee Ching-Tai, M.D.**

*Chief, Division of Digestive Endoscopy, E-Da Hospital and I-Shu University*

Peroral Endoscopic Myotomy (POEM) has evolved from a novel intervention for achalasia into a cornerstone of "Third-Space Endoscopy." This presentation explores recent technical advancements and the expanding therapeutic landscape, including G-POEM for gastroparesis, Z-POEM for Zenker's diverticulum, and notably gastric antral myotomy for obesity management (BEAM & GEM). Despite high clinical success, the focus has shifted toward refining safety and long-term outcomes. We discuss two major complications: Gastroesophageal Reflux Disease (GERD) and Blow-out Myotomy (BOM). While GERD remains a prevalent long-term challenge necessitating surveillance and anti-reflux strategies, BOM represents a critical intraoperative concern related to muscular layer integrity and unintended transmural extension. Addressing these issues through standardized tunneling and tailored myotomy lengths is essential for optimizing patient safety. In conclusion, as POEM-derived techniques proliferate, mastering the balance between maximal efficacy and the prevention of both acute and chronic complications remains the frontier of submucosal endoscopy.

### **References**

- [1] Gastrointest Endosc 2021; 94(5): 930-942.
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- [3] Surg Endosc. 2024; 38(7): 3503–3519.
- [4] Gastroenterology 2024;167(7):1483–1490.
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- [6] Gastroenterology 2026;170(7):1588–1591.
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- [8] Gastrointest Endosc. 2024;100(4): 741-744.

## **The Evolving Landscape of Esophageal ESD: A Thoracic Surgeon's Perspective**

**Tzu-Ping Chen, MD.**

*Department of Thoracic and Cardiovascular Surgery Chang-Gung Memorial Hospital, Keelung*

The management of superficial esophageal neoplasia is rapidly evolving from a traditional “surgery versus endoscopy” model toward a precision-based strategy integrating advanced staging, artificial intelligence (AI), robotics, and hybrid multidisciplinary treatment approaches. For thoracic surgeons, understanding the expanding role of endoscopic submucosal dissection (ESD) has become increasingly important in determining optimal patient selection and preserving organ function whenever oncologically appropriate.

Recent evidence suggests that conventional endoscopic ultrasound (EUS) may overstage superficial lesions, while advanced optical technologies—including magnifying narrow-band imaging, confocal laser endomicroscopy, and volumetric laser endomicroscopy—provide increasingly accurate assessment of invasion depth. Diagnostic endoscopic resection itself is emerging as a critical staging modality for selected early lesions. In parallel, AI-assisted systems now demonstrate high accuracy in lesion delineation, incision guidance, and workflow recognition, potentially reducing operator variability and democratizing ESD expertise across centers.

Technical innovations are further expanding the boundaries of endoscopic therapy. Robotic ESD systems and third-space endoscopic techniques such as submucosal tunneling endoscopic resection (STER) improve procedural precision, facilitate en-bloc resection, and may reduce complications in technically challenging esophageal lesions. These developments increasingly challenge the conventional indications for esophagectomy. Despite these advances, surgery remains essential for patients with deep submucosal invasion, lymphovascular invasion, poor differentiation, or non-curative endoscopic resection. The future paradigm will likely involve diagnostic and therapeutic ESD integrated with AI-based risk stratification, selective surgical intervention, and multidisciplinary decision-making.

This presentation reviews the latest technological advances, current limitations, and future directions of esophageal ESD from a thoracic surgeon's perspective, emphasizing how surgeons can adapt to the changing landscape while maintaining oncologic safety and optimizing patient quality of life.

## Room 102 (English) | Saturday, July 11, 2026

### Industry Sponsored Lunch Symposium (Intuitive Surgical Sarl Taiwan Branch (Switzerland))

**Time: 12:30-14:00 (GMT+8)**

Chair(s): Wilson Tsai (USA)

|       |             |                                                                                                                                                               |
|-------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| LS1-1 | 12:30-14:00 | <b>Expanding the Value of Robotic Thoracic Surgery: From Multi-Port<br/>Excellence to SP Innovation and Integrated Thoracic Care</b><br>Yin-Kai Chao (Taiwan) |
|-------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|

## **Expanding the Value of Robotic Thoracic Surgery: From Multi-Port Excellence to SP Innovation and Integrated Thoracic Care**

**Yin-Kai CHAO**

*Chang Gung Memorial Hospital*

Robotic thoracic surgery has evolved beyond the simple translation of conventional minimally invasive procedures to a robotic platform. While multi-port robotic systems have established excellent visualization, instrument dexterity, and procedural precision, the true value of robotic surgery may become most apparent when anatomical complexity is coupled with procedural risk. This presentation introduces a practical conceptual framework that maps thoracic procedures according to anatomical difficulty and procedural risk, distinguishing cases that are technically demanding but forgiving from those that are both difficult and unforgiving. Through selected surgical videos, the potential impact of robotic assistance will be illustrated in terms of reducing conversion, mitigating complications, and improving surgeon ergonomics and quality of life.

Building on the excellence achieved with multi-port robotic surgery, the emergence of the single-port (SP) platform further expands the boundaries of minimally invasive thoracic surgery. Innovations in intercostal, subcostal, and subxiphoid access enable tailored approaches to pulmonary, mediastinal, and complex thoracic procedures while minimizing access trauma and optimizing operative geometry. Rather than viewing SP surgery as simply a reduction in port number, its value lies in redesigning surgical access according to anatomy, procedural objectives, and patient-specific needs.

Ultimately, the future of robotic thoracic surgery extends beyond individual procedures or platforms toward integrated thoracic care. By matching technology, access strategy, and surgical expertise to the complexity and risk profile of each case, robotic surgery can evolve from a technical innovation into a comprehensive strategy for safer, less invasive, and more sustainable thoracic surgical care.

## Room 102 (English) | Saturday, July 11, 2026

### Session C Innovations and Future Direction in Esophageal Surgery

**Time: 14:00-15:00 (GMT+8)**

|     |             |                                                                                                                            |
|-----|-------------|----------------------------------------------------------------------------------------------------------------------------|
|     |             | Po-Kuei Hsu (Taiwan)<br>Chair(s): Chang Hyun Kang (Republic of Korea)<br>Jang-Ming Lee (Taiwan)                            |
| C-1 | 14:00-14:08 | <b>Recent Innovation in Esophageal Surgery</b><br>Po-Kuei Hsu (Taiwan)                                                     |
| C-2 | 14:08-14:20 | <b>How Robotics Refines Surgical Techniques in Esophagectomy</b><br>Chang Hyun Kang (Republic of Korea)                    |
| C-3 | 14:20-14:32 | <b>Single-Port Robotic-Assisted Esophagectomy</b><br>Jang-Ming Lee (Taiwan)                                                |
| C-4 | 14:32-14:44 | <b>Single vs Multi-Port Esophagectomy: Comparative Insights</b><br>Seong Yong Park (Republic of Korea)                     |
| C-5 | 14:44-14:56 | <b>Current Status of Esophageal Cancer Surgery in Japan and Actual Treatment Strategy in NCCHE</b><br>Takeo Fujita (Japan) |
|     | 14:56-15:00 | <b>Discussion</b>                                                                                                          |

## **Recent Innovations in Esophageal Surgery**

**Po-Kuei Hsu MD, PhD**

*Division of Thoracic Surgery, Department of Surgery, Taipei Veterans General Hospital*

Esophageal surgery has entered a new era driven by advances in imaging technology, artificial intelligence (AI), and robotic platforms. These innovations are reshaping surgical decision-making, improving precision, and paving the way toward more personalized and minimally invasive treatment. This presentation will highlight three major areas of innovation. First, fluorescence-guided surgery using indocyanine green (ICG) has expanded beyond assessment of conduit perfusion. Emerging applications include lymphatic mapping, sentinel lymph node navigation, and intraoperative identification of the thoracic duct, offering new opportunities for precision lymphadenectomy while reducing procedure-related complications.

Second, AI is rapidly transforming the operating room. Deep learning algorithms can automatically recognize anatomical structures, identify surgical phases in real time, and provide objective assessment of surgical performance. AI-assisted navigation has the potential to enhance intraoperative decision-making, standardize complex procedures, facilitate surgical education, and improve quality assurance.

Finally, advances in surgical platforms continue to redefine the technical boundaries of esophagectomy. Robotic-assisted surgery has improved dexterity and visualization during complex mediastinal dissection. The emergence of single-port robotic systems further minimizes surgical access while maintaining operative precision. In parallel, endoluminal robotic technologies are creating new possibilities for intraluminal interventions for early esophageal neoplasia.

Together, these innovations are shifting esophageal surgery toward a future characterized by precision guidance, intelligent assistance, and less invasive intervention. Their integration promises not only improved surgical safety and oncologic quality but also more individualized treatment for patients with esophageal disease.



## How Robotics Refines Surgical Techniques in Esophagectomy

**Chang Hyun Kang**

*Seoul National University Hospital*

Esophagectomy remains one of the most technically demanding procedures in surgical oncology, requiring meticulous dissection in the mediastinum and a high-quality lymphadenectomy while carrying a considerable risk of postoperative morbidity. Since its introduction decades ago, robotic surgery for esophageal cancer has evolved substantially, and robot-assisted minimally invasive esophagectomy (RAMIE) has become one of the standard surgical treatments.

Nevertheless, reported outcomes of RAMIE remain heterogeneous, largely reflecting differences in institutional surgical policies and technical approaches rather than the technology itself. In this lecture, we present three key technical advances in RAMIE based on our institutional experience.

First, dissection along the recurrent laryngeal nerve enables a more complete upper mediastinal lymphadenectomy—an important determinant of oncologic outcome in esophageal squamous cell carcinoma—while minimizing the risk of nerve injury. Second, robotic esophagogastric anastomosis aims to reduce both anastomotic leakage and stricture, addressing a well-recognized limitation of thoroscopic techniques. Third, the robotic abdominal procedure allows consistent and reliable gastric graft preparation.

Together, these refinements illustrate how technical progress in RAMIE translates into improved early outcomes and long-term survival, and we discuss the practical considerations required to implement them safely and reproducibly.

### References

[1] Grimmer KBF et al. Worldwide Techniques and Outcomes in Robot-assisted Minimally Invasive Esophagectomy (RAMIE): Results From the Multicenter International Registry. *Ann Surg.* 2022, 276(5), e386-e39.

## Single-port Robotic-Assisted Minimally Invasive Esophagectomy

**Jang-Ming Lee**

*Department of Surgery, National Taiwan University Hospital and National Taiwan University  
College of Medicine, Taipei, Taiwan*

Robotic-assisted minimally invasive esophagectomy has improved perioperative outcomes; increased surgical proficiency has promoted interest in uniportal techniques. We aimed to evaluate the short-term outcomes of a novel uniportal robotic-assisted minimally invasive esophagectomy performed through an intercostal incision using the da Vinci Xi system.

**Methods:** We retrospectively reviewed patients who underwent uniportal robotic-assisted minimally invasive esophagectomy performed by a single surgeon between September 2024 and May 2026. The primary outcome was the complete resection rate with microscopically negative margins (R0). Secondary outcomes included perioperative parameters, including operative time, lymph node yield, blood loss, conversion rate, postoperative pain scores, complication rates, chest tube duration, and hospital stay.

**Results:** Thirty-six patients (median age: 64 years; 89% male) underwent uniportal robotic-assisted minimally invasive esophagectomy. Squamous cell carcinoma was the most common histology (83%); 50% had stage III–IV disease, and 67% received neoadjuvant therapy. The McKeown and Ivor-Lewis procedures were performed in 56% and 44% of cases, respectively; complete resection was achieved in 89%. The median lymph node yield and blood loss were 38 and 352.5 mL, respectively. One patient (2.8%) required conversion.

**Conclusions:** Uniportal robotic-assisted minimally invasive esophagectomy is safe and feasible while maintaining surgical quality as performed by other routine surgical approaches.

## Single-port Robotic-Assisted Minimally Invasive Esophagectomy

**Jang-Ming Lee**

*Department of Surgery, National Taiwan University Hospital and National Taiwan University  
College of Medicine, Taipei, Taiwan*

Robotic-assisted minimally invasive esophagectomy has improved perioperative outcomes; increased surgical proficiency has promoted interest in uniportal techniques. We aimed to evaluate the short-term outcomes of a novel uniportal robotic-assisted minimally invasive esophagectomy performed through an intercostal incision using the da Vinci Xi system.

### **Methods:**

We retrospectively reviewed patients who underwent uniportal robotic-assisted minimally invasive esophagectomy performed by a single surgeon between September 2024 and May 2026. The primary outcome was the complete resection rate with microscopically negative margins (R0). Secondary outcomes included perioperative parameters, including operative time, lymph node yield, blood loss, conversion rate, postoperative pain scores, complication rates, chest tube duration, and hospital stay.

### **Results:**

Thirty-six patients (median age: 64 years; 89% male) underwent uniportal robotic-assisted minimally invasive esophagectomy. Squamous cell carcinoma was the most common histology (83%); 50% had stage III–IV disease, and 67% received neoadjuvant therapy. The McKeown and Ivor-Lewis procedures were performed in 56% and 44% of cases, respectively; complete resection was achieved in 89%. The median lymph node yield and blood loss were 38 and 352.5 mL, respectively. One patient (2.8%) required conversion.

### **Conclusions:**

Uniportal robotic-assisted minimally invasive esophagectomy is safe and feasible while maintaining surgical quality as performed by other routine surgical approaches.

## Single vs. Multi-Port Esophagectomy: Comparative Insights

**Seong Yong Park, MD, PhD**

*Department of Thoracic and Cardiovascular Surgery  
 Samsung Medical Center, Sungkyunkwan University School of Medicine  
 Seoul, Korea*

Robot-assisted minimally invasive esophagectomy (RAMIE) using multi-port (MP) platforms has become the established standard for esophageal cancer surgery, offering well-documented advantages in lymph node dissection, recurrent laryngeal nerve preservation, and pulmonary complications compared with open and thoracoscopic approaches. The introduction of the da Vinci single-port (SP) system, first approved for thoracic surgery in South Korea, has expanded the technical possibilities of minimally invasive thoracic operations and raised the question of whether SP esophagectomy can serve as a meaningful alternative or complement to the MP approach. This lecture provides a comparative perspective on the technical characteristics, clinical evidence, and practical role of SP versus MP RAMIE.

The SP system differs fundamentally from MP platforms in that all instruments and the articulating camera are introduced through a single 25 mm cannula with internal triangulation, in contrast to the four separate trocars and external triangulation of MP systems. This design requires multiple access strategies such as subcostal, subxiphoid, transcervical, and intercostal approaches—each suited to different anatomical targets and clinical scenarios in thoracic surgery. For esophagectomy, however, the requirement for complete upper mediastinal lymphadenectomy including bilateral recurrent laryngeal nerve nodes imposes anatomical demands that exceed the 27 cm working reach of the SP system from subcostal approaches, particularly in tall patients. Accordingly, the presenter prefers the intercostal transthoracic approach in the semi-prone position as the most appropriate SP strategy for esophageal cancer surgery, preserving the oncologic principles of radical esophagectomy while leveraging the SP system's unique instrument architecture.

It is essential to recognize that esophagectomy remains one of the most invasive operations in thoracic surgery, with substantial morbidity and mortality even at high-volume centers. The fundamental objective—regardless of platform—is to achieve an oncologically complete resection with the lowest possible morbidity and mortality. The distinction between MP and SP is secondary to this overarching principle, and any potential advantages of the SP system can be meaningfully realized only after this prerequisite is satisfied. The presenter's personal experience comparing MP and SP transthoracic RAMIE for esophageal cancer suggests that, when this principle is upheld, the SP approach achieves comparable oncologic outcomes—

including R0 resection, total lymph node yield, and overall complication rates—while showing favorable trends in blood loss and recurrent laryngeal nerve palsy in selected patients. These findings are concordant with early reports from other groups using subcostal and transcervical SP approaches, which have likewise demonstrated reduced postoperative pain and shorter chest tube duration compared with conventional minimally invasive techniques. Nevertheless, the SP approach is associated with technical limitations including potential rib collision and postoperative intercostal neuralgia.

Taken together, the current evidence supports SP RAMIE as a technically feasible and oncologically sound option in carefully selected patients, while MP RAMIE remains the standard for the broader patient population. SP esophagectomy is best positioned as a complementary tool within a comprehensive minimally invasive esophageal surgery program, with its long-term clinical advantages still to be confirmed by prospective evaluation.

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## **Current status of esophageal cancer surgery in Japan and actual treatment strategy in NCCHE**

**Takeo Fujita**

*Division of Esophageal Surgery, National Cancer Center Hospital East, Japan  
 6-5-1 Kashiwanoha, Kashiwa, Japan*

Since insurance coverage was introduced in Japan, robot-assisted esophagectomy (RAMIE) has rapidly expanded and is increasingly replacing conventional thoracoscopic esophagectomy (MIE), particularly in East Asia. However, important issues remain unresolved, including its long-term outcomes and safety for advanced esophageal cancer.

At the same time, mediastinoscopic surgery, originally developed in Japan, is gaining global attention as a less invasive approach. Although conventional transcervical mediastinoscopy has been associated with recurrent laryngeal nerve palsy due to limited instrument maneuverability, robotic assistance may improve precision around the recurrent nerve. Robotic transcervical mediastinoscopy is therefore considered a promising future direction.

In addition, the introduction of immune checkpoint inhibitors (ICI) has expanded treatment options for advanced esophageal cancer. While perioperative evidence such as CM-577 has shown promising results, questions remain regarding its applicability in Japan, where highly advanced surgical strategies including three-field lymphadenectomy are routinely performed.

Based on these developments, I would like to discuss the current status and future perspectives of esophageal cancer treatment in East Asia, where squamous cell carcinoma predominates.

### **References**

- [1] Circulating Tumor DNA Assessment to Predict Risk of Recurrence after Surgery in Patients with Locally Advanced Esophageal Squamous Cell Carcinoma: A Prospective Observational Study. Takei S, Fujita T, et al. Ann Surg. 2025.
- [2] Prognostic Indicators of Preoperative Fluorouracil, Leucovorin, Oxaliplatin, and Docetaxel Efficacy in Locally Advanced Gastroesophageal and Gastric Cancer: Integrating Biomarker Analysis and Clinicopathological Factors. Jubashi A, Fujita T, et al. JCO Precis. 2025

## Room 102 (English) | Saturday, July 11, 2026

### Session D

**Advanced Lung Surgery with VATS and RATS: Evidence-Based Practice, Complex Procedures, and Intraoperative Crisis Management**

**Time: 15:30-17:10 (GMT+8)**

Firas Abu Akar (Israel)  
Yih-Gang Goan (Taiwan)  
Chair(s): Jiun-Yi Hsia (Taiwan)  
Yau-Lin Tseng (Taiwan)  
Ming-Ho Wu (Taiwan)

#### (I) Debate: VATS vs Robotic Lung Surgery-Precision or Pragmatism?

|     |             |                                                                                            |
|-----|-------------|--------------------------------------------------------------------------------------------|
| D-1 | 15:30-15:42 | <b>Robotics Defines the Next Era of Lung Cancer Surgery</b><br>Christopher Cao (Australia) |
| D-2 | 15:42-15:54 | <b>VATS Remains the Gold Standard for Safety and Value</b><br>Diego Gonzalez Rivas (Spain) |
|     | 15:54-16:00 | <b>Discussion</b>                                                                          |

#### (II) The Ultimate Uniportal Challenge: Sleeve Resection by VATS, Robotic Xi, and Robotic SP

|     |             |                                                        |
|-----|-------------|--------------------------------------------------------|
| D-3 | 16:00-16:08 | <b>Xi Approach</b><br>Yau-Lin Tseng (Taiwan)           |
| D-4 | 16:08-16:16 | <b>SP Approach</b><br>Hyun Koo Kim (Republic of Korea) |
| D-5 | 16:16-16:24 | <b>VATS Approach</b><br>Firas Abu Akar (Israel)        |
|     | 16:24-16:30 | <b>Discussion</b>                                      |

#### (III) Crisis and Recovery in Minimally Invasive Thoracic Surgery: From VATS to RATS

|     |             |                                                                                                    |
|-----|-------------|----------------------------------------------------------------------------------------------------|
| D-6 | 16:30-16:40 | <b>Troubleshooting Intraoperative Challenges in VATS</b><br>Hong Kwan Kim (Republic of Korea)      |
| D-7 | 16:40-16:50 | <b>Managing Intraoperative Emergencies in Robotic Lung Surgery</b><br>Aneez D.B. Ahmed (Singapore) |

#### (IV) The Art of Decision: Integrating Van Gogh into the Robotic Era of Lung Surgery

|     |             |                                                                                                                                   |
|-----|-------------|-----------------------------------------------------------------------------------------------------------------------------------|
| D-8 | 16:50-17:00 | <b>Integrating Van Gogh into Robotic and Minimally Invasive Lung Surgery: From Biopsy to Decision Making</b><br>Wilson Tsai (USA) |
|-----|-------------|-----------------------------------------------------------------------------------------------------------------------------------|

#### (V) Pediatric VATS

|     |             |                                                              |
|-----|-------------|--------------------------------------------------------------|
| D-9 | 17:00-17:10 | <b>Uniport VATS in Pediatrics</b><br>Firas Abu Akar (Israel) |
|-----|-------------|--------------------------------------------------------------|



D-1

## **Robotics Defines the Next Era of Lung Cancer Surgery**

**Christopher Cao**

*Royal Prince Alfred Hospital, Sydney University*

## **VATS remains the Gold Standard for Safety and Value**

**Diego Gonzalez Rivas**

*Coruña University Hospital, Coruña*

### **Key Points:**

Despite advances in robotic technology, Uniportal VATS (UVATS) remains the global benchmark for safety and cost-effectiveness. Clinical data indicate that UVATS offers superior or equivalent outcomes, including reduced patient pain, shorter hospital stays, and lower complication rates, compared with multiportal or robotic approaches. Its pragmatic value is best exemplified by the Diego González Rivas Foundation's work in resource-limited regions, such as Africa, where “Mobile Surgical Units” provide state-of-the-art minimally invasive care without the prohibitive costs and infrastructure required for robotic systems.

### **Abstract:**

This session evaluates the enduring role of Uniportal VATS as the "gold standard" in thoracic surgery, emphasizing its balance of clinical safety and global accessibility. Through a comparative analysis of postoperative recovery metrics—including shorter chest drain durations and reduced surgical stress—the presentation argues for the continued dominance of UVATS in routine practice. Furthermore, it addresses the concept of "value" in healthcare, illustrating how UVATS serves as a resilient and cost-effective solution for lung cancer treatment worldwide, ensuring that high-quality surgical intervention remains accessible to patients in both advanced and developing medical systems.

## Left Main Bronchus Sleeve Resection with the da Vinci Xi Surgical System

**Prof. Yau-Lin Tseng, MD, PhD**

*Director, Thoracic Division, Department of Surgery, National Cheng Kung University Hospital, Tainan, Taiwan*

Using left main bronchus sleeve resection with the Intuitive Surgical Da Vinci Xi system is among the most technically demanding procedures in robotic thoracic surgery(1). The major challenges involve surgical exposure, airway control, bronchial reconstruction, and maintenance of oncological safety.

We present the case of a 69-year-old man with a history of stage III (T2aN1M0) colon cancer who underwent left hemicolectomy with lymph node dissection in 2017. Two years later, pulmonary metastasis developed, and he subsequently received a left upper lobe trisegmentectomy in 2020. Despite systemic chemotherapy and anti-angiogenic therapy, he developed persistent hemoptysis in 2023. Multiple local treatments, including three sessions of cryotherapy, one session of argon plasma coagulation laser therapy, and radiotherapy, failed to eradicate the lesion located at the left main bronchus with partial carinal involvement. Hemoptysis therefore persisted.

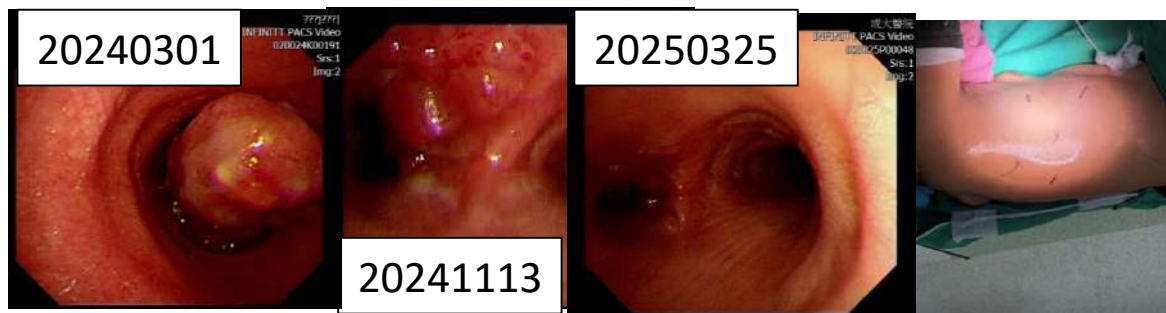
Robotic left main bronchus sleeve resection was performed on April 11, 2025. Under extracorporeal membrane oxygenation (ECMO) support, a four-arm robotic approach was established through the 7th and 8th intercostal spaces. Mediastinal and subcarinal lymph nodes issection was performed first, followed by exposure of the trachea and left main bronchus. The involved left main bronchus and part of the carina were resected en bloc. Airway reconstruction was completed smoothly using continuous 3-0 Prolene sutures.

The patient was successfully extubated the following morning and discharged on postoperative day 7. Follow-up bronchoscopy and chest imaging demonstrated a patent airway without anastomotic complications.

This procedure was successfully accomplished using a multiport robotic approach.

The additional technical challenges and feasibility of applying a uniportal robotic approach for this highly complex airway reconstruction will also be discussed during the meeting.

**Figure 1:** Colon cancer with intrabronchial metastasis. The position, ECMO and port selection for Robotic left main sleeve resection.



## References

[1] Iriarte F, Abbas A, Petrov R, et al.  
Right transthoracic approach for robotic left mainstem bronchus sleeve resection.  
*JTCVS Techniques*. 2021;10:572–574.

## **SP Approach for Complex Pulmonary Resection: Expanding the Boundaries of Uniportal Robotic Surgery**

**Hyun Koo Kim, Jun Hee Lee, Byung Mo Gu**

*Department of Thoracic and Cardiovascular Surgery, Korea University Guro Hospital,  
Korea University College of Medicine, Seoul, Republic of Korea*

The evolution of minimally invasive thoracic surgery has progressed from multi-port video-assisted thoracic surgery (VATS) to uniportal approaches and, more recently, to single-port (SP) robotic surgery. The da Vinci SP robotic system enables a true uniportal robotic platform with fully articulating instruments and a flexible endoscope through a single subcostal incision. This approach may overcome the technical limitations of conventional uniportal surgery while preserving the advantages of reduced access trauma and improved postoperative recovery.

We developed a subcostal SP robotic approach for pulmonary resection using the da Vinci SP system. Through a 4-cm subcostal incision, a subcostal tunnel was created under thoracoscopic guidance, followed by docking of the SP robotic platform with carbon dioxide insufflation. Complete hilar dissection, fissure division, and mediastinal lymphadenectomy were performed using articulating robotic instruments introduced through a single access port. Endoscopic staplers were introduced through the assistant channel without additional robotic ports.

In a propensity score-matched comparison of SP robotic lobectomy versus conventional intercostal multi-port robotic lobectomy, the SP approach demonstrated shorter operative and console times, reduced postoperative drainage, significantly lower postoperative pain scores, and faster pulmonary function recovery, while maintaining comparable oncologic outcomes and mid-term survival. The learning curve of SP robotic lobectomy also appeared relatively short, with procedural stabilization achieved after approximately 19 cases.

The SP platform also facilitated complex pulmonary resections after neoadjuvant chemoimmunotherapy. Despite severe hilar fibrosis and obliteration of tissue planes, SP robotic pulmonary resection achieved acceptable perioperative outcomes without increased morbidity. The articulating robotic instruments, enhanced visualization, and use of adjunctive techniques such as Penrose-guided stapling enabled safe vascular and bronchial handling even in technically demanding cases.

The SP robotic approach represents a next-generation evolution of uniportal thoracic surgery. By combining the minimally invasive advantages of uniportal access with the precision and articulation of robotic technology, SP robotic surgery may expand the indications for complex thoracic procedures, including sleeve resections and post-induction surgery. Further multicenter studies are required to validate long-term oncologic and functional outcomes.

### **References**

- [1]Lee JH, Gu BM, Choi J, et al. Single-Port Robotic Pulmonary Resection for Non-Small-Cell Lung Cancer After Neoadjuvant Chemoimmunotherapy. *Eur J Cardiothorac Surg.* 2026;68(Suppl 1).
- [2]Lee JH, Gu BM, Choi J, et al. Subcostal single-port versus intercostal multi-port robotic lobectomy for non-small cell lung cancer: a retrospective propensity score-matched cohort study. *Int J Surg.* 2026;112:7362-7372.
- [3]Gu BM, Lee JH, Kim HK. Robotic right lower lobe sleeve lobectomy using the single-port robotic system: Challenging case after immunotherapy. *JTCVS Tech.* 2025;34:235-236.

## **Advanced Lung Surgery with VATS and RATS: Evidence-Based Practice, Complex Procedures, and Intraoperative Crisis Management**

**Firas Abu Akar\***

*Department of Thoracic Surgery, The Edith Wolfson Medical Center, Affiliated to the Gray  
Faculty of Medical and Health Sciences, Tel Aviv University, Tel Aviv, Israel*

Minimally invasive thoracic surgery has evolved rapidly over the past two decades, with video-assisted thoracoscopic surgery (VATS) and robotic-assisted thoracic surgery (RATS) becoming integral approaches in modern lung surgery. Current evidence demonstrates that both techniques are associated with reduced postoperative pain, shorter hospital stay, faster recovery, and improved perioperative outcomes when compared with open thoracotomy, while maintaining oncologic efficacy in appropriately selected patients.

This lecture will review the evidence-based role of VATS and RATS in advanced pulmonary surgery, including segmentectomy, sleeve resections, complex hilar dissections, reoperative thoracic surgery, and management of locally advanced disease.

Special attention will be given to intraoperative crisis management during minimally invasive thoracic surgery. Practical approaches to prevention, rapid decision-making, team communication, and crisis preparedness will be highlighted through real-world surgical experience and contemporary literature.

As technology and surgical expertise continue to advance, mastery of both VATS and RATS is becoming increasingly important in delivering safe, effective, and patient-centered thoracic surgical care.

## Troubleshooting Intraoperative Challenges in VATS

**Hong Kwan Kim** \*

*Department of Thoracic and Cardiovascular Surgery  
 Sungkyunkwan University School of Medicine  
 Samsung Medical Center*

Video-assisted thoracic surgery (VATS) has become the standard of care for anatomic pulmonary resection, and the technical envelope has continued to widen as surgeons take on more complex lesions—central tumors, post-induction cases, and patients with calcified or matted hilar lymph nodes. With this expanding scope, however, comes an increased exposure to intraoperative challenges that can convert an otherwise routine lobectomy into a true crisis within seconds. This lecture is built on a single premise: most intraoperative disasters in VATS are not the result of poor judgment about whether to operate, but of small, preventable mistakes in instrument handling, combined with an unstructured response when something goes wrong. Recognizing the mechanisms, mastering the preventive maneuvers, and rehearsing a clear troubleshooting algorithm are the three pillars that allow the modern thoracic surgeon to remain in command when bleeding, bronchial injury, or lymphatic leakage occurs—whether the operation is being performed through a VATS or a robotic-assisted (RATS) platform. The talk first dissects the mechanisms of intraoperative bleeding, the most feared complication of VATS lobectomy. In our experience, the great majority of pulmonary artery injuries can be traced back to inadequate manipulation of four instrument families: graspers, right-angle clamps, electrocautery devices, and endoscopic staplers. Excessive traction with a grasper, especially when the surgeon's eyes are fixed on a distant target, can avulse an "out-of-sight" pulmonary artery branch. Right-angle clamps advanced without first identifying the correct perivascular plane can puncture the artery from behind. Spatula-tip electrocautery generates more lateral thermal spread than the hook tip, and inadvertent contact with thin-walled vessels can rapidly create a hole that the cautery itself cannot close. Finally, staplers passed at the wrong angle, through too narrow a window, or with a jerky firing motion remain the single most catastrophic source of bleeding. Newer powered articulating platforms such as the Signia system reduce shaft tremor and provide a more stable firing motion, which has practical value when residents are at the console; the Ligasure Maryland device has similarly become a "game changer" for safe perivascular and peribronchial dissection, combining strong jaws with limited thermal spread. The second part of the lecture focuses on prevention through safe and effective perivascular dissection. Several practical maneuvers are illustrated with intraoperative video. Gentle grasping—holding the vessel "as a lioness holds her cub"—improves exposure of the behind surface, where most unseen injuries occur. Holding the instrument shaft short reduces the fulcrum effect and makes fine motion more precise. Bimanual dissection, lifting with the cautery tip or suction, digging or tunneling along an identified plane, and spreading the jaws of a grasper all facilitate safe exposure of the structure that is to be encircled. Two principles deserve special emphasis. First, the "sand-tunnel" concept: when the fissure is incomplete, the surgeon should dissect bidirectionally and verify the plane from both sides before passing any clamp, as one



would dig a tunnel through sand without collapsing it. Second, peribronchial lymph node dissection should be performed as a deliberate strategy, because completing a clean nodal dissection automatically delivers a clean perivascular plane. Calcified, adherent nodes deserve a separate algorithm: when they are suspected on preoperative CT, VATS should not be attempted; when they are unexpectedly encountered, early conversion is appropriate; and when the surgeon elects to persist with VATS, options include distal-branch dissection, direct division of the node with sharp instruments, or, in highly selected cases, simultaneous stapling of bronchus and vessel. The third and most clinically important section presents a structured four-step troubleshooting algorithm for when bleeding actually occurs. Step 1—Compress and calm down. The bleeding focus is compressed gently but securely; excessive pressure enlarges the tear, and a topical hemostatic such as oxidized cellulose or a polyglycolic-acid felt (e.g., TachoSil) can slow or completely arrest the bleeding while the team regroups. Step 2—Alert everyone in the operating room. The anesthesiologist is asked to prepare for massive transfusion and to monitor hemodynamics closely; scrub and circulating nurses ready themselves for possible open conversion and bring out endoscopic suturing materials, vascular clamps, and additional hemostatic agents. Step 3—Decide on whether to convert or not. "Do not panic —just open it" is the operative phrase: VATS lobectomy is not a competition, and thoracotomy is never a failure. Extension of the existing utility incision is usually sufficient. Step 4—Control the bleeding. Depending on injury size and location, options range from topical PGA felt application, to primary repair with fine non-absorbable suture under VATS, to proximal vascular control with an endoscopic clamp on the main pulmonary trunk. The lecture closes with a brief discussion of other intraoperative challenges—bronchial stump dehiscence, which can often be sutured under VATS with non-absorbable interrupted stitches, and intraoperative chylous leak, which can be definitively managed by thoracic-duct ligation just adjacent to the azygos vein. These vignettes reinforce a single message that applies equally to VATS and to RATS: meticulous dissection technique, a stable instrumentation strategy, and a rehearsed crisis-management algorithm are what convert an intraoperative disaster from a career-defining event into a recoverable incident. As we move along the continuum from VATS to RATS, the platform changes but the principles do not; the surgeon's ability to anticipate, prevent, and recover from intraoperative challenges remains the true measure of mastery in minimally invasive thoracic surgery.

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D-7

## **Managing Intraoperative Emergencies in Robotic Lung Surgery**

**Aneez D.B. Ahmed**

*International Centre for Thoracic Surgery*

## **Integrating Van Gogh into Robotic and Minimally Invasive Lung Surgery: From Biopsy to Decision Making**

**Wilson S. Tsai, MD**

*CEO, Prometheus Medical Innovations*

In this lecture, we will explore the role of dynamic cell imaging technology in improving the efficiency and diagnostic power of lung biopsies. This could potentially facilitate faster treatment and cure rates when combined with Single Anesthetic Bronchoscopic Resection Events (SABRE).

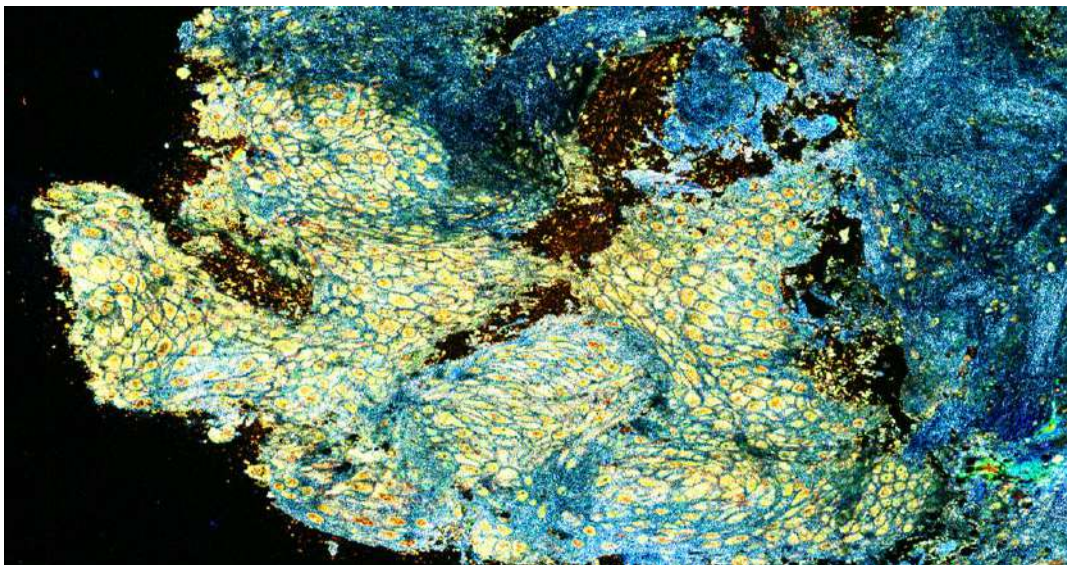


Figure 1: Van Gogh images of malignant cells



Figure 2: Single Anesthetic Bronchoscopic Resection Event for Stage 1a Lung cancer



## **Pediatric VATS: Uniport VATS in Pediatrics**

**Firas Abu Akar\***

*Department of Thoracic Surgery, The Edith Wolfson Medical Center, Affiliated to the Gray  
Faculty of Medical and Health Sciences, Tel Aviv University, Tel Aviv, Israel*

Video-assisted thoracoscopic surgery (VATS) has transformed pediatric thoracic surgery by reducing operative trauma and improving postoperative recovery. More recently, uniportal VATS (U-VATS) has emerged as an evolution of minimally invasive surgery, offering the potential advantages of decreased postoperative pain, improved cosmetic outcomes, shorter hospital stay, and faster return to normal activity. However, adoption in pediatric patients remains technically challenging because of limited intrathoracic working space and the need for specialized instrumentation and surgical expertise.

This lecture will review the current role of uniportal VATS in pediatric thoracic surgery, including its technical considerations, perioperative management. Emphasis will be placed on the feasibility and safety of U-VATS in children undergoing procedures for pulmonary lesions, empyema, mediastinal masses, and other thoracic conditions. Current evidence from recent pediatric surgical series suggests that uniportal approaches can achieve outcomes comparable to multiport VATS while potentially enhancing postoperative recovery and patient satisfaction. Uniportal VATS represents an important step toward less invasive pediatric thoracic surgery and may become an increasingly valuable approach in specialized pediatric centers.

## Room 102 (English) | Sunday, July 12, 2026

### Session E

#### Transforming Thoracic Care: Breakthroughs in Bronchoscopy and Interventional Pulmonology

Time: 09:30-10:30 (GMT+8)

|           |             |                                                                                                                                              |
|-----------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
|           |             | Wen-Chien Huang (Taiwan)                                                                                                                     |
| Chair(s): |             | Calvin S.H. Ng (Hong Kong)                                                                                                                   |
|           |             | Shun-Mao Yang (Taiwan)                                                                                                                       |
| E-1       | 09:30-09:40 | <b>Experience of a National Lung Center with One-Stop Image-Guided Procedures in a Thoracic Hybrid OR</b><br>Edmund Villaroman (Philippines) |
| E-2       | 09:40-09:50 | <b>Transbronchial Tumor Ablation: State of Art</b><br>Calvin S.H. Ng (Hong Kong)                                                             |
| E-3       | 09:50-10:00 | <b>Robotic Bronchoscopy for Diagnosis and Treatment of Peripheral Lung Lesions</b><br>Kelvin Lau (UK)                                        |
| E-4       | 10:00-10:10 | <b>Navigational Bronchoscopy and Techniques for Trans-Parenchymal Nodule Access</b><br>Hui-Hsuan Shih (Taiwan)                               |
| E-5       | 10:10-10:20 | <b>Intrapulmonary Fine Adjustment for Precise Lung Nodule Diagnosis and Treatment</b><br>Shun-Mao Yang (Taiwan)                              |
|           | 10:20-10:30 | <b>Discussion</b>                                                                                                                            |



## Experience of a National Lung Center with One-Stop Image-Guided Procedures in a Thoracic Hybrid Operating Room

**Edmund E. Villaroman, MD, MBA**

*Chairman, Department of Thoracic Surgery and Anesthesia, Lung Center of the Philippines,  
Quezon City, Philippines*

### Abstract

The increasing detection of small pulmonary nodules through low-dose CT screening, advances in imaging technology, and artificial intelligence has created new challenges in lesion localization and timely management. Conventional workflows often require separate diagnostic, localization, and surgical procedures performed in different locations, resulting in treatment delays, repeated patient transfers, increased complication rates, and workflow inefficiencies. The development of a Thoracic Hybrid Operating Room (THOR) enables these steps to be integrated into a single environment, providing a one-stop strategy for image-guided thoracic interventions.

The Lung Center of the Philippines established a dedicated THOR program centered on real-time cone-beam computed tomography (CBCT) guidance and multidisciplinary collaboration among thoracic surgeons, interventional pulmonologists, anesthesiologists, and radiologists. The program integrates advanced imaging technologies with minimally invasive thoracic surgery to perform diagnosis, localization, treatment, and confirmation within a single anesthetic session. This approach reduces CT-to-body divergence through intraoperative imaging, improves localization accuracy, minimizes complications associated with patient transfer, and streamlines procedural workflow. Core principles include **One-Stop Strategy**, **Reducing Time-at-Risk**, and **Co-localization**, combining complementary imaging modalities and localization techniques to enhance procedural precision.

Current THOR services include image-guided video-assisted thoracic surgery (iVATS), augmented fluoroscopic bronchoscopy (AFB/VAL-MAP), image-guided thermal ablation (IGTA), image-guided combined ablation and resection in thoracic surgery (iCART), CBCT-guided airway stenting for central airway obstruction, and CBCT-guided chest wall reconstruction. These procedures exemplify how advanced imaging platforms can extend beyond pulmonary nodule localization to support a comprehensive spectrum of thoracic interventions.

This lecture reviews the rationale, workflow, and early experience of a national specialty center implementing a Thoracic Hybrid Operating Room. It highlights how integrating diagnosis and treatment into a single image-guided platform enhances precision, reduces delays and complications, improves patient experience, and provides a scalable model for modern thoracic surgery in the Asia-Pacific region.

## **Transbronchial Tumor Ablation: State of Art**

**Calvin S.H. Ng \***

*Division of Cardiothoracic Surgery, The Chinese University of Hong Kong.*

Bronchoscopic ablative therapy is a form of local therapy for management of lung tumours. Use of ablation energy delivered by catheters or needles to central airways by fiberoptic bronchoscopy or via percutaneous route to treat lung tumours and pathology has been around for several decades. One of the drawbacks of percutaneous route is the high risk of pleural based complications of pneumothorax and bronchopleural fistula of 11–52% (Hiraki T, et al. Semin Intervent Radiol 2013;30:169-75). Recent advances in navigation bronchoscopy in the form of virtual airway anatomy and electromagnetic navigation, as well as intraoperative imaging have allowed clinicians to reach distal areas of the lung with greater accuracy for diagnostic and therapeutic purposes. The recent development of robotic-assisted bronchoscopy with additional shape-sensing technology and image-integrated navigation correction (Digital tomograph, mobile CT, CBCT) for CT-body divergence also aids in precision navigation. The options for ablating peripheral (and central) tumours have grown lately, with the “traditional” radiofrequency ablation (RFA), and microwave ablation (MWA) remaining the predominant players. Single arm retrospective studies have shown transbronchial MWA ablation of lung tumours to be safe and effective, with local recurrence rate of around 8% at follow-up of up to 5-years (median FU 2.3 years), that is comparable to radiation therapy.

Other ablation options that are available through the transbronchial route include; saline “infused” RFA (Broncus), cryoablation (for example Accutarget), pulsed electric field (PEF) (Galvanize) or IRE, vapor (steam) ablation (Broncus), photodynamic therapy (PDT) and laser ablation. Currently, many of these still lack robust evidence and long term data and require careful consideration. Nevertheless, some of these ablative “energy” options may provide potential advantages such as immune stimulation (local & systemic) and abscopal effects. Other “ablative” options being investigated include local brachytherapy by implantation of radiation seeds into tumour, and injection of pharmacological agents to produce direct cancer toxic effects or to augment the efficacy of adjunct treatment (e.g. radiosensitizers). Large prospective comparative studies are needed to better delineate the role of these ablative technologies and select appropriate patients.

## Ablation

### Transbronchial “Ablative” options : now or soon

- |                                                                                                                                                                                                                |                                                                                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Thermal :</b></p> <ul style="list-style-type: none"> <li>● RFA (2<sup>nd</sup> generation) saline infusion</li> <li>● Microwave</li> <li>● Steam (Broncus)</li> <li>● Laser</li> </ul>                   | <p><b>Local Drugs:</b></p> <p>Chemotherapy depot</p> <p>CAR-T / cytokine (IL-28)</p> <ul style="list-style-type: none"> <li>● Radioenhancers (NBTxR3)</li> </ul> |
| <p><b>Non-Thermal +/- immunogenic :</b></p> <ul style="list-style-type: none"> <li>● Cryoablation (Accutarget)</li> <li>● Electroporation (PEF, Galvanize-Energenx)</li> <li>● Photodynamic therapy</li> </ul> | <p><b>Peripheral local radiation:</b></p> <p>Local brachytherapy (Alphadart)</p>                                                                                 |



Figure: Some of the transbronchial lung ablative options

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## **Robotic Bronchoscopy for Diagnosis and Treatment of Peripheral Lung Lesions**

**Kelvin K.W. Lau**

*Clinical Director and Consultant Thoracic Surgeon, St Bartholomew's Hospital, London*  
*Consultant Thoracic Surgeon, Cleveland Clinic, London*

Over the last decade, the spectrum of lung cancer has changed. What used to be a disease identified in incurable advanced stages is now one that is much more frequently curable. As the use of CT scanning increases exponentially in all specialties, incidental findings of lung nodules are daily occurrences. The rollout of lung cancer screening following the success of the NLST and NELSON trials also helps find lung cancer in higher risk population at a curable stage, reducing lung cancer related deaths.

However, the radiological identification of lung nodules is only half the story. There is still a need to sort the chaff from the wheat, to identify which nodules are cancerous and which doesn't need treatment. Historically lung biopsies are invasive and risky. Percutaneous biopsy punctures the chest wall and pleura and carries a high pneumothorax rate which is poorly tolerated in this population of smokers with poor lung function. There are also risks of haemoptysis and respiratory compromise, intercostal vessel injury and pleural seeding of cancer, Surgical biopsy is invasive and carries risks which are unwelcomed in those cases which are benign.

Peripheral guided bronchoscopy such as ultrathin bronchoscopy combined with radial EBUS, and navigation bronchoscopy, was introduced over 2 decades ago to avoid breaching the pleural and chest wall. They have been proven to be much safer than percutaneous CT guided biopsy but its adoption was plagued by a low diagnostic yield due to CT to body divergence, lack of precise articulation, and instability of the catheter.

Shape-sensing robotic bronchoscopy combined with cone beam CT finally eliminates CT to body divergence, imprecision and instability. Diagnostic yield finally reached over 90% and is on par with the gold standard CT guided biopsy, but with far fewer complications. At Barts, it has transformed our lung cancer pathway. When in doubt, nodules are biopsied and patients receive treatment for cancer with no delay.

With such accuracy and stability, the promise of technically easy bronchoscopic treatment of lung cancer becomes a reality. It is now possible to navigate accurately, safely and quickly to a lesion, place an ablation catheter precisely through the centre of the lesion and ablate a tumour within minutes. We are at an early stage in the development of this treatment but it has already offered a chance of cure to some medically inoperable patients. There is a lot of interest in this field as we see the number of publications grow in recent years.

## **Navigational Bronchoscopy and Techniques for Trans-Parenchymal Nodule Access**

**Hui-Hsuan Shih, Wen-Chien Huang\***

*Division of Chest Medicine, Department of Internal Medicine, MacKay Memorial Hospital, Taipei City, Taiwan*

*\*Division of Thoracic Surgery, Department of Surgery, MacKay Memorial Hospital, Taipei City, Taiwan*

Virtual Bronchoscopic Navigation (VBN) uses preoperative CT scans to construct a 3D model of the airway. This generates an avascular, software-guided path to safely access the target lesion. If the lung nodule does not possess a bronchus sign, transparenchymal tunneling (BTPNA) will be performed to create an invisible, off-road tunnel directly through the lung parenchyma to make a diagnosis. It provided real-time guidance combination with cone-beam CT and radial endobronchial ultrasound (R-EBUS) to make sure tool-in-lesion and avoid pneumothorax and hemothorax. In addition to diagnosis, it also can be applied for nodule ablation and pre-operative localization.

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E-5

## **Intrapulmonary Fine Adjustment for Precise Lung Nodule Diagnosis and Treatment**

**Shun-Mao Yang**

*National Taiwan University Hospital, Hsin-Chu Branch*

## Room 102 (English) | Sunday, July 12, 2026

### Session F Delving into the Mystery of Thymus

**Time: 11:00-12:30 (GMT+8)**

|     |             |                                                                                                                                           |
|-----|-------------|-------------------------------------------------------------------------------------------------------------------------------------------|
|     |             | Chien-Sheng Huang (Taiwan)<br>Chair(s): Yasushi Shintani (Japan)<br>Yi-Ting Yen (Taiwan)                                                  |
| F-1 | 11:00-11:13 | <b>Development of Minimally Invasive Thymic Surgery: Past, Present, and Future</b><br>Takashi Suda (Japan)                                |
| F-2 | 11:13-11:26 | <b>Management of Thymic Epithelial Tumors Based on the Pathobiology</b><br>Masayoshi Inoue (Japan)                                        |
| F-3 | 11:26-11:39 | <b>Current Status and Perspectives of Immunologic Profile in Thymoma</b><br>Yasushi Shintani (Japan)                                      |
| F-4 | 11:39-11:52 | <b>Current Concerns for Early Stage Thymoma Without Myasthenia Gravis Treated by Limited Resection</b><br>Ping-Chung Tsai (Taiwan)        |
| F-5 | 11:52-12:05 | <b>The Impact of Lymph Node Dissection on the Surgical Management for Thymic Epithelial Tumors</b><br>Chang Hyun Kang (Republic of Korea) |
| F-6 | 12:05-12:18 | <b>Neoadjuvant Treatment for Locally Advanced Thymic Epithelial Tumors</b><br>Wei-Li Ma (Taiwan)                                          |
|     | 12:18-12:30 | <b>Discussion</b>                                                                                                                         |



## **Development of Minimally Invasive Thymic Surgery: Past, Present, and Future**

**Takashi Suda**

*Fujita Health University Okazaki Medical Center*

Traditionally, thymectomy, performed via median sternotomy, has recently been performed endoscopically. Endoscopic thymectomy, which avoids sternal incision, includes the transcervical approach, in which the thymus is removed through a neck incision; the lateral thoracic approach, in which the thymus is removed via the lateral intercostal space; and the subxiphoid approach. The lateral thoracic approach is commonly used, but the subxiphoid uniportal approach is the least invasive approach, avoiding intercostal nerve injury. While subxiphoid uniportal thymectomy is considered a challenging procedure, the recent emergence of uniportal robotic approaches has made minimally invasive uniportal thymectomies easier to perform.

Furthermore, anterior mediastinal tumors sometimes invade the lung, pericardium, left brachiocephalic vein, or superior vena cava, often necessitating combined resection. The subxiphoid approach allows a camera to be inserted through the midline of the body, allowing for a safer surgical procedure that allows for the entire SVC and left brachiocephalic vein to be viewed. When vascular anastomosis becomes necessary, the combination of a robotic system allows for precise anastomosis and suturing. Robotic-assisted surgery using the subxiphoid approach allows for almost all combined resections, including those of the lung, pericardium, left brachiocephalic vein, and superior vena cava, and may in the future eliminate the need for median sternotomy.

## **Management of Thymic Epithelial Tumors Based on the Pathobiology**

**Masayoshi Inoue**

*Division of Thoracic Surgery, Department of Surgery  
 Kyoto Prefectural University of Medicine, Graduate School of Medical Sciences*

Thymomas are well known to be associated with various autoimmune diseases. Incomplete T cell development is observed in thymoma, which may affect patients' autoimmunity. Type AB, B1, and B2 thymomas harbor abundant immature T cells, which cannot act as effector T cells in treatment using immune checkpoint inhibitors. Neoplastic thymic epithelial cells express PD-L1 at varying levels, and frequent genetic aberrations are observed according to WHO classification. Germinal center formation in the surrounding thymus may have a clinical role in thymoma-associated MG. Regarding surgical treatment, radical minimally invasive thymectomy using robotic technology is available. Effective molecular-targeted and ICI therapies have recently been introduced in thymic carcinoma. WHO histological subtypes and inflammatory biomarkers are practically useful for determining the treatment strategy. A fundamental understanding of pathobiology is crucial for the appropriate management of thymic epithelial tumors.

## Current Status and Perspectives of Immunologic Profile in Thymoma

**Yasushi Shintani\*, Toru Kimura, Kenji Kimura, Yoko Yamamoto, Hiroto Ishida**

*Department of General Thoracic Surgery, The University of Osaka*

Thymic epithelial tumors (TETs) are rare malignancies arising from the thymic epithelium and represent the most common neoplasms of the anterior mediastinum<sup>[1]</sup>. Complete surgical resection remains the standard treatment for resectable disease; however, optimal systemic therapies for advanced TETs have not been established because of their rarity, histological heterogeneity, and unique immunological background. Unlike most solid tumors, TETs originate in the thymus, an organ essential for T-cell differentiation and central tolerance, resulting in a highly distinctive tumor immune environment.

Intratumoral lymphocytes in thymoma are predominantly immature CD4<sup>+</sup>CD8<sup>+</sup> double-positive T cells, which are not directly involved in antitumor immunity. In contrast, emerging evidence highlights the importance of CD4<sup>+</sup> and CD8<sup>+</sup> single-positive T (SPT) cells in shaping tumor immunity in TETs. Phenotypic and functional analyses of surgically resected specimens have demonstrated that thymoma type B3 and thymic carcinoma (B3/C) exhibit an immunologically “hot” microenvironment, characterized by increased frequencies of Tim-3–positive, CD103-positive, and regulatory T cells among SPT populations<sup>[2]</sup>. These tumors also show enhanced cytokine production and cytotoxic activity of SPT cells, particularly in response to immune checkpoint blockade, indicating a strong correlation between immune profiles and pathological classification.

Recent immunogenomic studies using T-cell receptor repertoire analysis and transcriptomic profiling further revealed that B3 thymomas display high T-cell clonality, expanded public clonotypes, and poorer prognosis, suggesting antigen-driven immune responses accompanied by immune exhaustion<sup>[3]</sup>. In parallel, advances in spatial transcriptomics have uncovered disease-specific immune niches within thymomas,

particularly in medullary regions associated with autoimmunity such as myasthenia gravis, providing critical spatial context to tumor–immune interactions.

Future integrative immune profiling combining gene expression analysis, T-cell receptor repertoire analysis, spatial transcriptomics, and whole-genome sequencing is expected to elucidate the complex immune landscape of thymoma in greater detail<sup>[4]</sup>. Such approaches may enable prediction of immunotherapy efficacy, identification of patients at risk for immune-related adverse events, and discovery of tumor-specific antigens, thereby supporting the development of precision immunotherapy for TETs.

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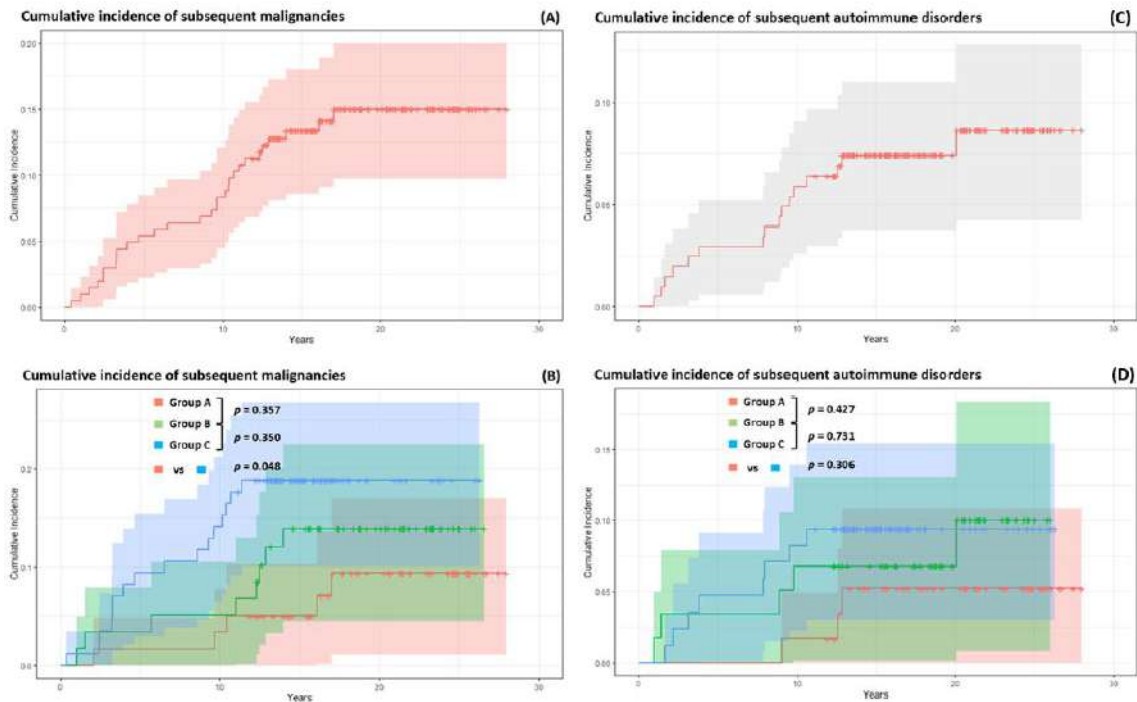
## **Current Concerns for Early Stage Thymoma Without Myasthenia Gravis Treated by Limited Resection**

**Ping-Chung Tsai, Han-Shui Hsu\***

*Division of Thoracic Surgery, Department of Surgery, Kaohsiung Veterans General Hospital,  
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The adult thymus may involve in sustaining immune competence and overall health in recent research <sup>[1]</sup>. The standard surgical goal for early-stage or resectable thymoma is total thymectomy and complete tumour excision with or without signs and symptoms of myasthenia gravis (MG) based on Clinical Practice Guidelines <sup>[2]</sup>. However, limited resections are not routinely recommended but may be considered for clinical early-stage thymoma if all oncologic goals can be met as in standard procedures. In our previous study <sup>[3]</sup>, patients with early-stage non-myasthenic thymoma who underwent limited resection without complete excision of the thymus achieved similar oncologic outcomes during the long-term follow-up. Furthermore, we further investigated and presented the incidence of subsequent malignancies and autoimmune disorders in patient with stage I thymoma underwent limited resection or thymectomy

Figure: These patients were divided into thymoma with myasthenic gravis (MG) underwent thymectomy (Group A), thymoma without MG underwent thymectomy (Group B) or limited resection (Group C)



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## **The Impact of Lymph Node Dissection on the Surgical Management for Thymic Epithelial Tumors**

**Chang Hyun Kang**

*Seoul National University Hospital*

Thymic epithelial tumors (TETs) are rare mediastinal neoplasms, and the role of lymph node (LN) dissection remains incompletely defined. The AJCC 8th/9th edition nodal map (N1 anterior, N2 deep regions) provides a staging framework, but the evidence supporting its clinical application remains limited. This lecture reviews the incidence and prognostic impact of LN metastasis in TETs based on large Asian databases (KART, JART, and ChART) and an updated single-center retrospective cohort of 969 surgical patients (2010–2023), of whom 475 (49%) underwent LN dissection. LN metastasis was associated with WHO histologic type, tumor size, and T stage. Nodal involvement was uncommon in conventional thymoma but clinically meaningful in B3 thymoma, thymic carcinoma, and neuroendocrine tumors. When performed selectively in patients with higher-risk disease and in open procedures, LN dissection improved prognostic stratification; however, indication bias and tumor-biology confounding limit causal inference regarding survival benefit. The prognostic distinction between N1 and N2 disease remains controversial. Therefore, a risk-adapted strategy for nodal assessment, rather than routine lymphadenectomy for all TETs, appears to be a more evidence-aligned approach. LN dissection contributes to accurate staging and recurrence-risk stratification, while its therapeutic impact should be further evaluated in prospective studies, particularly in the context of minimally invasive surgery.

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F-6

## **Neoadjuvant Treatment for Locally Advanced Thymic Epithelial Tumors**

**Wei-Li Ma**

*National Taiwan University Hospital*



## Room 102 (English) | Sunday, July 12, 2026

### Industry Sponsored Lunch Symposium (Medtronic Taiwan Ltd.)

**Time: 12:30-13:30 (GMT+8)**

Chair(s): Han-Shui Hsu (Taiwan)

|       |             |                                                                                                                                  |
|-------|-------------|----------------------------------------------------------------------------------------------------------------------------------|
| LS3-1 | 12:30-13:30 | <b>Development of Minimally Invasive Thoracic Surgery : Transmit<br/>Japanese Traditional Techniques</b><br>Takashi Suda (Japan) |
|-------|-------------|----------------------------------------------------------------------------------------------------------------------------------|

LS3-1

## **Development of Minimally Invasive Thoracic Surgery : Transmit Japanese Traditional Techniques**

**Takashi Suda**

*Fujita Health University Okazaki Medical Center*

## Room 102 (English) | Sunday, July 12, 2026

### Session G Oncology: Turning Impossible into Possible

Time: 13:30-15:00 (GMT+8)

|     |             |                                                                                                                                    |
|-----|-------------|------------------------------------------------------------------------------------------------------------------------------------|
|     |             | Chair(s):<br>Hong Kwan Kim (Republic of Korea)<br>Kuang-Tai Kuo (Taiwan)<br>Yu-Wei Liu (Taiwan)<br>Yu-Chung Wu (Taiwan)            |
| G-1 | 13:30-13:42 | <b>Robotic Thoracic Surgery for Primary Lung Cancer: Insights from Japan</b><br>Yukio Sato (Japan)                                 |
| G-2 | 13:42-13:54 | <b>From Unresectable to Resectable: Immunotherapy-Enabled Surgery in Advanced Lung Cancer</b><br>Hong Kwan Kim (Republic of Korea) |
| G-3 | 13:54-14:06 | <b>Multiple Primary Lung Cancer: Diagnosis, Treatment Strategies, and Evolving Perspectives</b><br>Mong-Wei Lin (Taiwan)           |
| G-4 | 14:06-14:18 | <b>Lung Cancer Surgery after Neoadjuvant Immunotherapy: State of the Art</b><br>Yasushi Shintani (Japan)                           |
| G-5 | 14:18-14:30 | <b>Thoracoscopic Multiple Segmentectomy and Lobectomy for Multiple Primary Lung Cancer</b><br>Ying-Yuan Chen (Taiwan)              |
| G-6 | 14:30-14:42 | <b>RATS Segmentectomy: Mastering Precision and Outcomes with Advanced Robotic Stapling</b><br>Seiichiro Sugimoto (Japan)           |
| G-7 | 14:42-14:54 | <b>Role of Surgical Resection in Oligometastatic Non-Small Cell Lung Cancer</b><br>Seong Yong Park (Republic of Korea)             |
|     | 14:54-15:00 | <b>Discussion</b>                                                                                                                  |

## Robotic Thoracic Surgery for Primary Lung Cancer: Insights from Japan

**Yukio Sato**

*Department of Thoracic Surgery, University of Tsukuba*

In Japan, robot-assisted thoracic surgery (RATS) was approved for insurance coverage in 2018, and currently nearly 30% of lung cancer surgeries are performed using this approach. The characteristics of robotic systems—including articulated instruments, motion scaling, tremor filtration, and high-definition three-dimensional visualization—enable extremely precise intrathoracic manipulation and have significantly enhanced the quality of thoracic surgical procedures.

### **1. Improved Precision in Vascular Dissection**

The articulated robotic instruments and motion-scaling technology allow meticulous dissection of the pulmonary arteries and veins. Precise dissection at the level of the vascular sheath minimizes intraoperative bleeding while maintaining a clear anatomical view, thereby achieving both safety and technical accuracy.

### **2. Enhanced Operability in the Deep Mediastinum**

Even in deep and confined spaces such as the upper mediastinum and subcarinal region, robotic instruments can accurately identify and maintain the correct dissection planes between the esophagus, trachea, and major vessels. Delicate manipulation around the recurrent laryngeal nerve is also feasible, enabling radical lymph node dissection while avoiding organ and nerve injury—areas that were previously considered highly challenging with conventional thoracoscopic surgery.

### **3. Application to Segmentectomy and Subsegmentectomy**

The high precision of RATS is not limited to the pulmonary hilum but also proves advantageous in the management of peripheral intrapulmonary vessels and bronchi. Even in cases with complex branching patterns, distal structures can be reliably traced and dissected, making anatomically accurate segmentectomy and subsegmentectomy realistic and viable surgical options.

### **Conclusion**

The refined dissection capabilities offered by robot-assisted surgery enhance the precision of pulmonary vascular and bronchial management, improve the quality of deep mediastinal lymphadenectomy, and elevate thoracic surgery to a new level of advancement.

## From Unresectable to Resectable :Immunotherapy-Enabled Surgery in Advanced Lung Cancer

**Hong Kwan Kim \***

*Department of Thoracic and Cardiovascular Surgery  
 Sungkyunkwan University School of Medicine  
 Samsung Medical Center*

Locally advanced non-small cell lung cancer (NSCLC), particularly stage III disease involving bulky mediastinal nodal involvement or tumors with direct invasion of adjacent structures, has long been considered beyond the reach of curative surgical resection. For decades, definitive concurrent chemoradiotherapy (dCCRT) remained the standard of care for these patients, with surgery reserved only for highly selected cases at experienced centers. The advent of immune checkpoint inhibitors (ICIs) has fundamentally altered this paradigm. By combining platinum-doublet chemotherapy with PD-1/PD-L1 inhibitors in the neoadjuvant setting — a strategy now widely referred to as neoadjuvant chemoimmunotherapy (nCIT) — a meaningful subset of patients initially deemed unresectable have demonstrated sufficient tumor regression to become eligible for curative-intent surgery. This lecture examines the growing body of evidence supporting immunotherapy-enabled surgical resection, the selection criteria that define ideal candidates, the surgical challenges inherent to this approach, and the unresolved questions that will shape future clinical practice.

The biological rationale for nCIT is compelling. Preoperative immunotherapy leverages an intact tumor microenvironment to prime a systemic antitumor immune response, while platinum-based chemotherapy simultaneously induces immunogenic cell death, augmenting ICI efficacy. Pathological response — measured by pathological complete response (pCR) and major pathologic response (MPR, defined as  $\leq 10\%$  viable tumor at resection) — serves as a validated surrogate for long-term survival. Across pivotal phase III trials — CheckMate 816, KEYNOTE-671, AEGEAN, and CheckMate 77T — pCR rates of 17–25% and MPR rates of 30–37% were consistently demonstrated in the nCIT arm, compared with 2–5% and 8–12%, respectively, in the chemotherapy-alone arm. Event-free survival hazard ratios ranged from 0.58 to 0.68, and the 5-year overall survival data from the CheckMate 816 update confirmed durable survival benefit.

The transformative question addressed in this lecture, however, extends beyond patients enrolled in these trials — all of whom harbored technically resectable tumors by design. The more clinically provocative scenario is whether nCIT can convert initially unresectable disease into a surgically resectable state. Emerging real-world data provide preliminary answers. Deng and colleagues reported that among 51 patients with initially unresectable stage IIIB NSCLC, 61% proceeded to curative resection following nCIT, with the majority undergoing lobectomy rather than pneumonectomy. A larger multicenter cohort study by Ricciuti and colleagues (JAMA Oncology, 2025), encompassing 112 patients with T4 and/or N2–N3 stage III NSCLC, demonstrated that 75% underwent surgical resection following nCIT, achieving a pCR rate of 29% and an MPR rate of 42.2%, with a median event-free survival of 52.6 months. These data are striking, and suggest that for select patients with advanced-stage disease, nCIT may render surgery not only feasible but oncologically meaningful.

Patient selection, however, remains the central challenge. The definition of "resectability" itself lacks international consensus and is acknowledged to be substantially subjective — a finding confirmed by a recent EORTC survey demonstrating wide variation in how thoracic surgeons and radiation oncologists assess resectability. Several clinical and molecular variables are relevant to this determination. Regarding disease extent, patients with single-station N2 involvement (N2a) represent

more favorable candidates than those with multi-station N2 disease (N2b), in whom the probability of early systemic recurrence limits the oncological benefit of surgery even when technical resection is achieved. Evidence from CheckMate 77T subgroup analyses and meta-analyses suggests diminishing benefit from nCIT in stage IIIB disease. PD-L1 expression, while the most extensively studied biomarker, has proven an imperfect predictor — all major trials demonstrate attenuated but nonetheless present event-free survival benefit even in PD-L1-negative tumors, likely reflecting the limitations of PD-L1 testing including spatial heterogeneity and archived tissue discordance. EGFR-mutant tumors present a particular challenge, especially in East Asian populations where EGFR mutation prevalence is substantially higher than in Western cohorts. Current data do not support routine nCIT for EGFR-mutant NSCLC, and institutional protocols in Korea generally favor neoadjuvant concurrent chemoradiotherapy or upfront surgery with adjuvant EGFR-TKI for this population, with ongoing trials exploring optimal perioperative strategies.

Surgical attrition is a clinically significant concern that demands careful preoperative counseling and planning. Approximately 20% of patients who initiate nCIT do not proceed to surgery — due to disease progression, treatment-related toxicity, or decline in performance status. Crucially, those who do not undergo surgery face substantially worse survival outcomes, as demonstrated in the CheckMate 816 data. Identifying preoperative predictors of surgical attrition — including baseline performance status, pulmonary function, PET-CT metabolic parameters, lymph node morphology on CT, and emerging radiomic and circulating tumor DNA (ctDNA) signatures — is therefore an active area of investigation with direct clinical implications.

From a surgical perspective, the technical demands of operating after nCIT deserve explicit discussion. Therapy-induced fibrosis and inflammatory adhesions alter tissue planes around the pulmonary artery and bronchus, making individual broncho-vascular dissection challenging, particularly in patients with clinical N1 involvement or pronounced nodal response (short-axis nodal reduction >30%). Energy devices can facilitate dissection but carry the risk of inadvertent vascular injury; accordingly, early proximal control and vessel looping of the pulmonary artery are strongly recommended when dense hilar fibrosis is anticipated. In the current era of minimally invasive surgery, uncontrolled intraoperative hemorrhage carries life-threatening risk; prompt conversion to thoracotomy should therefore be recognized as a prudent and clinically sound decision rather than a failure. Sleeve resection represents a valuable lung-preserving strategy after nCIT when pneumonectomy would otherwise be required, and has been shown feasible with acceptable morbidity in experienced hands. Despite these technical challenges, major trials confirm that R0 resection rates, pneumonectomy rates, and thoracotomy conversion rates remain comparable between nCIT and chemotherapy-alone arms — a testament to the capacity of experienced surgical teams to navigate these obstacles safely.

The debate between nCIT-plus-surgery and dCCRT for borderline or initially unresectable stage III NSCLC remains unresolved. Proponents of dCCRT emphasize that the definition of resectability is subjective and that patients deemed unresectable may carry higher operative risk than trial populations. Proponents of surgery argue that planned resection after nCIT provides superior locoregional control compared with radiation, reduces the incidence of isolated locoregional failure, and avoids the morbidity of salvage resection. National Cancer Database analyses suggest a significant overall survival advantage for nCIT-plus-surgery over adjuvant chemoimmunotherapy, and a separate comparison of nCIT-plus-surgery versus concurrent chemoradiotherapy-plus-ICI similarly favored the surgical approach. The ongoing MDT-BRIDGE trial, employing an adaptive design with multidisciplinary tumor board reassessment after two cycles of nCIT, is prospectively addressing this question and will provide critical data to guide clinical decision-making.

Looking forward, several priorities will define the evolution of this field. Standardized, internationally agreed-upon definitions of resectability are urgently needed. Biomarker-driven patient selection — integrating PD-L1 expression, ctDNA dynamics, tumor mutational burden, radiomics, and emerging immune profiling modalities — will be essential to identify which patients with advanced or marginally resectable disease are most likely to benefit from nCIT-enabled surgery versus definitive radiotherapy. Novel combinations, including CTLA-4 inhibition for

KEAP1/STK11-mutated tumors, STING agonists, and antibody-drug conjugates, hold promise for improving pCR rates and expanding the population eligible for surgical downstaging. Finally, the role of adjuvant immunotherapy following nCIT and surgery remains an open question — de-escalation trials in pCR-achieving patients are needed to balance survival benefit against the cumulative toxicity and cost of extended immunotherapy.

In conclusion, neoadjuvant chemoimmunotherapy is reshaping the surgical boundaries of advanced NSCLC. What was once deemed unresectable is increasingly becoming a surgical opportunity for carefully selected patients. Realizing this potential demands rigorous multidisciplinary collaboration, standardized surgical expertise, and a commitment to prospective research that places the individual patient — their biology, their anatomy, and their goals — at the center of every treatment decision.

## **Multiple Primary Lung Cancer: Diagnosis, Treatment Strategies, and Evolving Perspectives**

**Mong-Wei Lin, MD, PhD**

*Professor, Department of Surgery, National Taiwan University  
 Chief, Division of Thoracic Surgery, National Taiwan University Hospital  
 Vice Chief, School of Medicine, National Taiwan University*

### **Abstract:**

The incidence of multiple primary lung cancers (MPLCs) is rising significantly, particularly among non-smoking Asian females. A major clinical challenge lies in accurately distinguishing MPLCs from intrapulmonary metastasis, a crucial step that dictates patient prognosis and management. In this presentation, we will explore the latest diagnostic approaches to differentiate these two entities. Furthermore, we will delve into contemporary surgical treatment strategies for MPLCs, sharing clinical insights on optimizing surgical approaches, balancing oncological clearance with the preservation of pulmonary function, and ultimately achieving better patient outcomes.



## Lung Cancer Surgery after Neoadjuvant Immunotherapy: State of the Art

**Yasushi Shintani\*, Naoko Ose, Takashi Kanou, Toru Kimura, Kenji Kimura, Hideki Nagata, Yudai Miyashita**

*Department of General Thoracic Surgery, The University of Osaka*

Neoadjuvant immunotherapy combined with chemotherapy has emerged as a key treatment strategy for resectable non-small-cell lung cancer (NSCLC), demonstrating significant improvements in pathological response and survival outcomes and reshaping perioperative management [1]. As a result, thoracic surgeons are increasingly required to perform lung resection following immune checkpoint inhibitor (ICI)-based neoadjuvant therapy. However, this approach introduces unique surgical and perioperative challenges that remain incompletely defined.

From a surgical perspective, neoadjuvant ICI may induce marked immune-mediated inflammation and fibrosis around the primary tumor and metastatic lymph nodes, particularly in the hilar and mediastinal regions [2]. These changes can complicate dissection of pulmonary vessels and bronchi, occasionally necessitating bronchovascular reconstruction or conversion to open surgery. Importantly, the extent of fibrosis and technical difficulty is often unpredictable and does not consistently correlate with pretreatment imaging findings, and bulky nodal disease cannot always be reliably anticipated before therapy.

In addition to technical issues, perioperative immune-related adverse events (irAEs) represent a critical concern. irAEs may delay surgery, worsen perioperative risk, or in some cases lead to cancellation of planned resection [3]. Careful perioperative assessment, timing of surgery, and close collaboration with medical oncologists are therefore essential. Conversely, compared with chemoradiotherapy, neoadjuvant chemoimmunotherapy may preserve tissue planes in selected patients, enabling minimally invasive approaches, including robotic-assisted surgery.

Another unresolved issue is the role of postoperative ICI following neoadjuvant immunotherapy and surgery. The indication, duration, and patient selection for adjuvant ICI remain controversial, particularly in patients achieving major pathological response or experiencing perioperative complications [4].

Thus, surgical strategy after neoadjuvant immunotherapy must be individualized, taking into account tumor characteristics, nodal status, biomarker information, patient condition, and perioperative risks. This presentation reviews the current state of the art in lung cancer surgery after neoadjuvant immunotherapy and discusses remaining challenges and future directions for optimizing perioperative treatment strategies.

### References

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[4] Zhao, Z. R.; Yan, W. P.; Yu, X. Y.; Zhang, J. B.; Fang, Y. F.; Ma, K.; Luo, Q. Q.; Long, H.; Chen, K. N.; Jiang, L., Adjuvant immunotherapy does not improve survival in non-small cell lung cancer with major/complete pathologic response after induction immunotherapy. J Thorac Cardiovasc Sur 2025, 169 (6).

## **Thoracoscopic Multiple Segmentectomy and Lobectomy for Multiple Primary Lung Cancer**

**Ying-Yuan Chen, MD, PhD**

*Department of Surgery, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan*

The increasing detection of multiple primary lung cancers—frequently presenting as multifocal ground-glass or part-solid nodules across different lobes—has reshaped surgical priorities toward achieving oncologic adequacy while maximizing parenchymal preservation. As thoracoscopic segmentectomy becomes increasingly adopted, surgeons are more often confronted with scenarios requiring extended parenchyma-sparing resections, including multiple segmentectomies across different lobes and selected combinations with lobectomy driven by the dominant invasive lesion. However, evidence guiding indications, technical standardization, and outcome reporting for thoracoscopic multiple anatomical resections remains limited and heterogeneous.

In this invited presentation, we provide an evidence-informed overview of contemporary surgical strategies for multiple primary lung cancer, focusing on the evolving role of thoracoscopic multiple segmentectomy and its integration with lobectomy when indicated. We highlight practical considerations for procedure selection in multifocal disease and discuss how current literature informs real-world decision-making. We also incorporate our institutional experience as a practical perspective on current directions, feasibility, and peri-operative considerations, and share how outcomes may be summarized in a standardized manner to facilitate cross-institutional comparison. Overall, thoracoscopic multiple segmentectomy—with selective lobectomy when indicated—represents a feasible lung-preserving strategy for carefully selected patients with multiple primary lung cancer. We emphasize pragmatic patient selection and consistent reporting as key steps toward improving comparability across studies and supporting future collaborative efforts.

## **RATS Segmentectomy: Mastering Precision and Outcomes with Advanced Robotic Stapling**

**Seiichiro Sugimoto\***

*Department of General Thoracic Surgery and Organ Transplant Center,  
Okayama University, Okayama, Japan*

Following the publication of recent pivotal clinical trials, the role of segmentectomy for early-stage non-small cell lung cancer has markedly expanded. In Japan, robot-assisted thoracoscopic surgery (RATS) lobectomy was covered by the national health insurance system in 2018, and RATS segmentectomy was subsequently approved in 2020. Consequently, the number of RATS segmentectomies at our institution has steadily increased each year. In 2025, RATS accounted for nearly 70% of surgeries for primary lung cancer, while segmentectomy reached 44% of all primary lung cancer surgeries. RATS segmentectomy has therefore become one of the standard procedures that thoracic surgeons should master. In segmentectomy, accurate intersegmental division is essential to prevent postoperative complications such as prolonged air leakage, reduce the risk of local recurrence, and maximize preservation of pulmonary function. Preoperatively, three-dimensional computed tomography (3D-CT) is routinely used to evaluate the anatomical relationships between the tumor and hilar structures, enabling precise surgical planning. When tumor localization is difficult, marking techniques are selected according to institutional expertise. Given our experience, CT-guided short hookwire placement is routinely adopted to ensure accurate intraoperative identification of small or deeply located lesions. If securing an adequate oncological margin is anticipated to be challenging, combined additional wedge resection or adjacent subsegmentectomy is planned to ensure oncological margins from the tumor. Intraoperatively, after division of the hilar structures according to the preoperative plan, indocyanine green (ICG) fluorescence imaging is used to identify and mark the intersegmental plane during RATS segmentectomy. Denuding of the hilar structures facilitates smooth stapler insertion during intersegmental division. The intersegmental plane is then divided using staplers to avoid prolonged air leakage. Because the intrathoracic working space is limited, the lung should be efficiently positioned within the opened stapler jaws in close coordination with the assistant. Carbon dioxide insufflation helps secure an adequate working space and facilitates smooth stapler manipulation. In this presentation, a standardized RATS segmentectomy technique is described, and intermediate-term surgical and oncological outcomes are reported.

## Role of Surgical Resection in Oligometastatic Non-Small Cell Lung Cancer

**Seong Yong Park, MD, PhD**

*Department of Thoracic and Cardiovascular Surgery  
 Samsung Medical Center, Sungkyunkwan University School of Medicine  
 Seoul, Korea*

Oligometastatic non-small cell lung cancer (NSCLC) refers to an intermediate biological state in which the disease has spread to a limited number of sites—typically fewer than three to five lesions across no more than a few organs—lying conceptually between truly localized disease and widespread metastatic dissemination. This concept has gained substantial clinical importance in recent years, driven by converging advances in three domains: the development of effective systemic therapies, including molecularly targeted agents and immune checkpoint inhibitors that can achieve durable disease control; the refinement of high-precision radiation techniques such as stereotactic ablative body radiotherapy (SABR); and the maturation of minimally invasive thoracic surgery, which has lowered the morbidity threshold for offering operative intervention in advanced disease. Importantly, accumulating evidence demonstrates that survival within stage IV NSCLC is not uniform but varies meaningfully according to metastatic burden, with patients harboring fewer metastatic sites achieving substantially longer overall survival than those with polymetastatic disease. This biological heterogeneity provides the rationale for aggressive local consolidative therapy (LCT) in carefully selected patients.

Randomized data from Gomez and colleagues, together with multiple retrospective series, have demonstrated improved progression-free and overall survival when LCT is added to systemic therapy. Notably, patterns-of-failure analyses in patients receiving EGFR-TKIs or immune checkpoint inhibitors reveal that disease progression occurs most frequently at the original primary site, providing a strong biological rationale for controlling the primary lesion. Among the available local modalities, surgery offers several distinct advantages over non-surgical approaches: superior local control, the opportunity for systematic mediastinal lymph node dissection, intraoperative assessment for occult pleural or parenchymal disease, and acquisition of tissue for comprehensive molecular profiling to guide subsequent therapy.

To further clarify the role of surgery in this setting, the presenter conducted a meta-analysis of 20 studies encompassing 3,256 patients who underwent primary pulmonary resection for oligometastatic NSCLC. The pooled 3-year overall survival was 48.1% (95% CI: 40.3–56.0%), and primary pulmonary resection was associated with significantly improved survival compared with non-surgical management (pooled HR: 0.673, 95% CI: 0.638–0.710). R0 resection was achieved in 91% of patients, lobectomy was the most commonly performed procedure (73.9%), and perioperative mortality was low at 1.4% (95% CI: 0.7–2.8%). These results indicate that primary pulmonary resection in oligometastatic NSCLC is associated with acceptable perioperative outcomes and potential long-term survival benefits, supporting its role within a multidisciplinary treatment framework, although careful patient selection and prospective validation remain warranted.

The presenter's personal experience (n=67) is consistent with these pooled estimates, demonstrating a 3-year overall survival of 69.5% with an R0 resection rate of 95.5% and acceptable morbidity. Nevertheless, surgery for oligometastatic NSCLC remains underutilized in clinical practice, owing to limited awareness of contemporary surgical outcomes, resource prioritization toward early-stage disease, and patient hesitation regarding aggressive treatment in the metastatic setting. While further prospective evidence is needed, pulmonary resection represents a clinically viable and increasingly important option for highly selected patients with oligometastatic NSCLC, and the thoracic surgeon

plays an essential role within the multidisciplinary care team.

## Room 102 (English) | Sunday, July 12, 2026

### Session H From Virtuality to Surgery: Artificial Intelligence (AI) and Augmented Reality (AR) Shaping the Future of Thoracic Surgery

**Time: 15:30-16:30 (GMT+8)**

|     |             |                                                                                                                                     |
|-----|-------------|-------------------------------------------------------------------------------------------------------------------------------------|
|     |             | Mei-Lin Chan (Taiwan)<br>Chair(s): Hsu-Kai Huang (Taiwan)<br>Yun-Hen Liu (Taiwan)                                                   |
| H-1 | 15:30-15:42 | <b>Integrating Augmented Reality into Thoracic Surgical Practice</b><br>Ding-Han Wang (Taiwan)                                      |
| H-2 | 15:42-15:54 | <b>Bringing the Discipline of AI in Thoracic Surgery</b><br>Aneez D.B. Ahmed (Singapore)                                            |
| H-3 | 15:54-16:04 | <b>Re-Imaging Surgical Training: How 3D Technology Transforms Learning and Practice</b><br>Kuan-Hsun Lin (Taiwan)                   |
| H-4 | 16:04-16:14 | <b>Dynamic Digital Radiography(DDR) in Thoracic Surgery: Clinical Applications and Future Directions</b><br>Yu-Hsiang Chen (Taiwan) |
| H-5 | 16:14-16:24 | <b>Integrating Virtual and Reality: Metaverse-Assisted Surgical Applications</b><br>Xu-Heng Chiang (Taiwan)                         |
|     | 16:24-16:30 | <b>Discussion</b>                                                                                                                   |

## Integrating Augmented Reality into Thoracic Surgical Practice

**Ding-Han Wang<sup>1</sup>, Kuan Hsun Lin<sup>2</sup>, Zhen-Chian Chen<sup>3</sup>**

<sup>1</sup>College of Dentistry, National Yang Ming Chiao Tung University, Taipei, Taiwan

<sup>2</sup>Division of Thoracic Surgery, Department of Surgery, Tri-Service General Hospital, National Defense Medical University, Taipei, Taiwan

<sup>3</sup>Division of Thoracic Surgery, MacKay Memorial Hospital, Taipei, Taiwan

Augmented reality (AR) has emerged as a promising technology for enhancing communication and visualization in thoracic surgery. Our initial work demonstrated that patient-specific AR models significantly improved patient understanding and facilitated shared decision-making during thoracic surgical consultation through a randomized clinical study[1]. Despite these encouraging outcomes, routine implementation remains limited because each patient-specific three-dimensional model requires labor-intensive reconstruction and technical expertise. To address this bottleneck, we developed MDforg, a free cloud-based medical imaging platform that streamlines image processing, three-dimensional reconstruction, visualization, and deployment into mixed reality (MXR) environments. By simplifying the modeling workflow, MDforg enables broader adoption of AR-assisted visualization in clinical practice. Finally, we will present our ongoing exploratory work on QR code-assisted surgical localization as a future extension of AR beyond communication toward intraoperative applications. Although technical challenges remain, this work illustrates a practical pathway for integrating augmented reality into thoracic surgical practice through evidence-based validation, accessible digital workflows, and continuous clinical innovation.

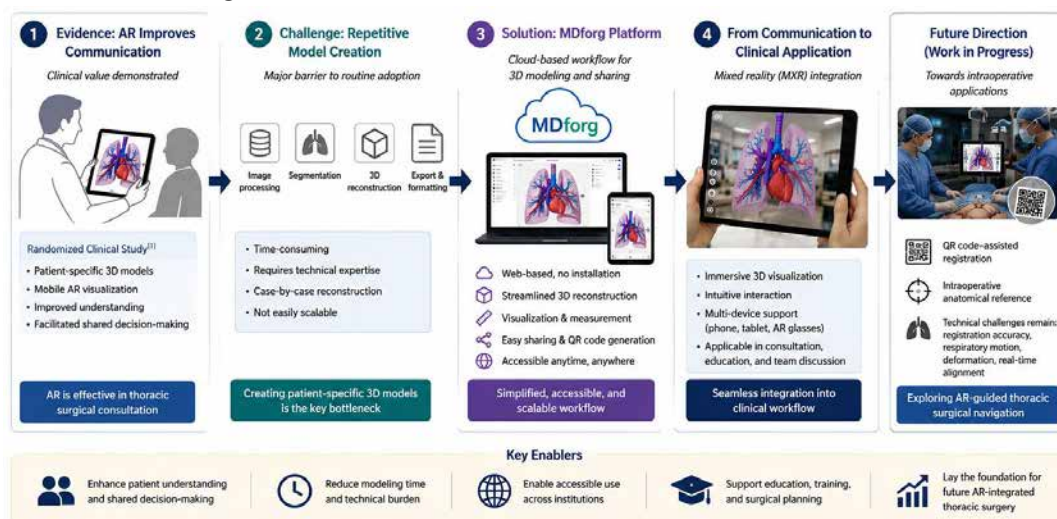


**Figure.** Framework for integrating augmented reality into thoracic surgical practice.

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- [1] Wang, D.-H.; et al. Mobile Augmented Reality–Assisted Three-Dimensional Visualization Improves Patient Understanding and Shared Decision-Making in Thoracic Surgery: A Randomized Clinical Study. *JMIR mHealth uHealth* 2025, 13, e79632..



## **Bringing the Discipline of AI in Thoracic Surgery**

**Aneez D.B. Ahmed**

*International Centre for Thoracic Surgery*

## **Re-Imaging Surgical Training: How 3D Technology Transforms Learning and Practice**

**Kuan-Hsun Lin**

*Tri-Service General Hospital*

## **Dynamic Digital Radiography(DDR) in Thoracic Surgery: Clinical Applications and Future Directions**

**Yu-Hsiang Chen**

*Attending Physician, Division of Thoracic Surgery, Department of Surgery, MacKay Memorial Hospital, Taipei, Taiwan*

Dynamic Digital Radiography (DDR) is an emerging imaging technology that enables real-time visualization of respiratory motion with substantially lower radiation exposure than conventional fluoroscopy. Unlike static chest radiography, DDR provides functional information regarding lung expansion, diaphragmatic motion, and pulmonary ventilation during normal respiration. Recent advances in image processing and artificial intelligence have further expanded the potential clinical applications of DDR. In thoracic surgery, DDR has demonstrated value in the assessment of diaphragmatic dysfunction, evaluation of postoperative pulmonary recovery, and functional monitoring following lung resection. Quantitative parameters including lung field area change and diaphragmatic excursion can be automatically measured, providing objective information regarding respiratory mechanics. These measurements may complement conventional pulmonary function testing and offer additional insights into regional lung function. Recent studies have explored the integration of machine learning algorithms with DDR to predict pulmonary function parameters and differentiate normal, obstructive, and restrictive respiratory physiology. Such developments suggest that DDR may evolve from a purely imaging-based modality into a functional biomarker platform capable of supporting clinical decision-making. This presentation reviews the fundamental principles of DDR, summarizes current clinical applications in thoracic surgery, and discusses future directions including quantitative functional assessment, postoperative recovery monitoring, and artificial intelligence-assisted pulmonary function evaluation. Representative DDR analysis demonstrating automated measurement of lung field area and diaphragmatic excursion during tidal respiration.

### **References**

[1]Hida T, Yamada Y, Ueyama M, et al. Dynamic Digital Radiography and Its Clinical Application in Thoracic Imaging. Radiographics. 2022, 42(4), 1049–1063.

## **Integrating Virtual and Reality: Metaverse-Assisted Surgical Applications**

**Xu-Heng Chiang**

*National Taiwan University Hospital*

Traditional surgical planning, medical education, and patient consultations heavily rely on two-dimensional CT scans, which fail to convey complex three-dimensional anatomy. To address this clinical pain point, we introduce OpVerse, a clinical-grade metaverse surgical platform developed via Taiwan's strategic academic-industry-government Triple Helix ecosystem. By constructing high-fidelity digital twin organs, OpVerse translates medical imaging into immersive extended reality (XR) environments. Across clinical evaluations, OpVerse demonstrated usability and utility superior to conventional 3D reconstruction software[1]. Preoperatively, XR field-of-view simulation for single-port video-assisted thoracic surgery (VATS) enables precise incision planning and significantly shortens surgical times. Intraoperatively, XR-guided lung nodule localization provides highly accurate, radiation-reducing, and cost-effective navigation for sublobar resections, offering a budget-friendly alternative to expensive hybrid operating suites. Furthermore, the platform has successfully expanded to multidisciplinary clinical scenarios, including bypass surgery for moyamoya disease, and pelvis fixation. Ultimately, OpVerse establishes a blueprint for the future operating room by integrating mixed reality and real-time navigation to empower clinical excellence.

### **References**

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## Room 101C (English) | Saturday, July 11, 2026

### SEATS/SECT/KSTS/TSTS Joint Meeting

**Time: 10:30-12:30 (GMT+8)**

|         |             |                                                                                                                                                                                            |
|---------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|         |             | Shah-Hwa Chou (Taiwan)<br>Hyun Koo Kim (Republic of Korea)<br>Chair(s): Wu-Wei Lai (Taiwan)<br>Seong Yong Park (Republic of Korea)<br>Punnarerk Thongcharoen (Thailand)                    |
| SEATS-1 | 10:30-10:42 | <b>Challenges of Robotic Surgery for Locally Advanced NSCLC after Adjuvant Immunotherapy</b><br>Aneez D.B. Ahmed (Singapore)                                                               |
| SEATS-2 | 10:42-10:54 | <b>VATS for Local Tumor Recurrence after Lung Resection for NSCLC</b><br>Soon Sing Yang (Malaysia)                                                                                         |
| SEATS-3 | 10:54-11:06 | <b>VATS/RATS For Post Infectious/Inflammatory Lung Disease</b><br>Edmund Villaroman (Philippines)                                                                                          |
| SECT-1  | 11:06-11:18 | <b>The Development and Refinement of Minimally Invasive Thoracic Surgery Techniques</b><br>Juan Carlos Trujillo-Reyes (Spain)                                                              |
| KSTS-1  | 11:18-11:30 | <b>Minimally Invasive Lung Transplantation</b><br>Samina Park (Republic of Korea)                                                                                                          |
| KSTS-2  | 11:30-11:42 | <b>Synergy of 3D CT Reconstruction and Robotic Systems for Complex Lung Segmentectomy</b><br>Woosik Yu (Republic of Korea)                                                                 |
| KSTS-3  | 11:42-11:54 | <b>Histology-Driven Surgical Strategies in Thymic Epithelial Tumors: Lymph Node Management and Extent of Resection in Early Thymoma</b><br>Jae Kwang Yun (Republic of Korea)               |
| TSTS-1  | 11:54-12:05 | <b>Prognostic Significance of Circulating Tumor Cells in Patients with Esophageal Cancer Who Attained Pathological Complete Response after Neoadjuvant Therapy</b><br>Chuan Cheng (Taiwan) |
| TSTS-2  | 12:05-12:16 | <b>Preliminary Real-World Outcomes of Adjuvant Immunotherapy in Resected Esophageal Cancer: A Retrospective Study from Taiwan</b><br>Chia Liu (Taiwan)                                     |
| TSTS-3  | 12:16-12:27 | <b>The Current Consensus on Salvage Surgery after Targeted Therapy for Advanced EGFR-Mutant Non-Small Cell Lung Cancer</b><br>Yu-Wei Liu (Taiwan)                                          |
|         | 12:27-12:30 | <b>Best JCS Award Ceremony</b>                                                                                                                                                             |

SEATS-1

## **Challenges of Robotic Surgery for Locally Advanced NSCLC after Adjuvant Immunotherapy**

**Aneez D.B. Ahmed**

*International Centre for Thoracic Surgery*

SEATS-2

## **VATS for Local Tumor Recurrence after Lung Resection for NSCLC**

**Soon Sing Yang**

## **VATS/RATS For Post Infectious/Inflammatory Lung Disease**

**Edmund E. Villaroman, MD, MBA**

*Chairman, Department of Thoracic Surgery and Anesthesia, Lung Center of the Philippines,  
Quezon City, Philippines*

### **Purpose**

Post-infectious and inflammatory lung diseases remain a major indication for pulmonary resection in many Asian countries because of the persistent burden of tuberculosis, bronchiectasis, aspergilloma, and chronic pulmonary infections. Unlike pulmonary malignancy, these conditions present unique technical challenges including dense pleural adhesions, contracted pleural cavities, obliterated fissures, calcified hilar lymphadenopathy, distorted hilar anatomy, chronic inflammation, and residual pleural space, making minimally invasive pulmonary resection considerably more demanding.

This lecture reviews the fundamental differences between post-infectious lung disease and lung cancer from a thoracic surgeon's perspective and presents practical strategies for overcoming these challenges using both video-assisted thoracoscopic surgery (VATS) and robotic-assisted thoracic surgery (RATS). Drawing upon the experience of the Lung Center of the Philippines, where nearly half of anatomic pulmonary resections are performed for infectious lung disease, the lecture highlights ten common intraoperative challenges and corresponding technical solutions. Topics include individualized port placement guided by computed tomography and thoracic ultrasound, extrapleural access, advanced adhesiolysis techniques, fissure-less lobectomy, management of calcified hilar lymph nodes and frozen hilum, vascular control, robotic-specific operative tips, and management of residual pleural space following resection.

Current evidence supporting minimally invasive surgery for infectious lung disease, including findings from the **VATS versus Open Lobectomy for Infectious Lung disease (VIOLINstudy)**, will be reviewed together with the emerging role of robotic surgery in complex inflammatory pulmonary resections. Representative operative videos and technical illustrations will be used to demonstrate key operative principles.

By the end of this lecture, participants will understand the unique anatomical and technical challenges of post-infectious lung disease, recognize appropriate patient selection for VATS and RATS, and acquire practical operative strategies to safely perform minimally invasive pulmonary resection in this challenging patient population.



## **The Development and Refinement of Minimally Invasive Thoracic Surgery Techniques**

**Juan Carlos Trujillo Reyes, MD; PhD**

*Hospital del Mar*

Minimally invasive thoracic surgery has undergone a profound evolution over the last decades, moving from conventional thoracotomy toward increasingly refined approaches aimed at reducing surgical trauma while maintaining oncological quality and procedural safety. The development of multiportal video-assisted thoracic surgery (VATS), uniportal techniques, robotic-assisted surgery, and more recently single-port robotic platforms has progressively transformed the surgical management of thoracic diseases.

This presentation will review the key milestones in the evolution of minimally invasive thoracic surgery and discuss how technological innovation has modified surgical philosophy, ergonomics, precision, and perioperative outcomes. Particular attention will be paid to the transition from reducing incision number to optimizing tissue preservation, postoperative recovery, and reproducibility of complex procedures.

Current challenges, including learning curves, instrumentation, stapling limitations, and the need for structured training pathways, will also be addressed.

Finally, future perspectives involving image-guided surgery, artificial intelligence, and personalized minimally invasive approaches will be explored as the next step in thoracic surgical refinement.

## **Minimally Invasive Lung Transplantation**

**Samina Park**

*Seoul National University Hospital*

Minimally invasive lung transplantation represents an evolving surgical strategy aimed at reducing operative trauma while preserving the fundamental principles of transplantation. Building on our experience, we have adopted a hybrid video-assisted thoracic surgery (VATS) approach that avoids full clamshell incision and rib spreading, while maintaining adequate exposure for safe bronchovascular anastomoses. In our program, intraoperative extracorporeal membrane oxygenation (ECMO) is routinely applied to provide hemodynamic stability and facilitate a controlled operative field. This strategy enables precise dissection and implantation through limited incisions, even in patients with advanced lung disease. Technical modifications, including tailored hilar handling and stepwise anastomosis under thoracoscopic guidance, have been essential to ensure procedural safety. Our early experience demonstrates that minimally invasive lung transplantation is feasible and reproducible, with potential benefits in postoperative recovery and pain reduction. While challenges remain—particularly in exposure, size matching, and complex recipient anatomy—careful patient selection and team experience are critical to success. This approach reflects a transitional step toward less invasive transplantation, suggesting that minimally invasive techniques can be integrated into routine practice without compromising surgical outcomes.

## **Synergy of 3D CT Reconstruction and Robotic Systems for Complex Lung Segmentectomy**

**Woosik Yu**

*Department of Thoracic and Cardiovascular Surgery, Ajou University School of Medicine, Suwon,  
Republic of Korea*

Anatomical segmentectomy is now an established option for small peripheral non-small-cell lung cancer (NSCLC), supported by randomized evidence of non-inferior—and, in one trial, superior—survival with greater preservation of functional lung.[1] In practice, however, complex segmentectomy remains technically demanding: deeply located segments (e.g., S9/S10), lesions lying at segmental borders, and tumors for which an adequate margin cannot be confidently predicted on two-dimensional CT. Confronted with this ambiguity, surgeons often default to lobectomy and sacrifice healthy parenchyma.

This Presentation describes a workflow that pairs preoperative three-dimensional CT reconstruction with the robotic platform to close that gap. Patient-specific reconstruction maps the segmental arteries, veins, and bronchi and simulates the resection margin before incision, turning variable anatomy into an explicit operative plan; the wristed instruments and magnified stereoscopic view of the robotic system then translate that plan into precise intersegmental dissection.

Two cases illustrate the approach: (1) a deep left-lower-lobe S10 segmentectomy for a 5-mm pulmonary metastasis in a patient requiring maximal lung preservation, and (2) a combined subsegmentectomy for a part-solid nodule spanning subsegmental borders—each planned in 3D and executed robotically. In a consecutive, non-selected series, resection margins were uniformly negative with no conversion to thoracotomy, while operative time remained stable as case complexity rose.

By minimizing the distance between surgical plan and execution, the synergy of 3D reconstruction (planning) and robotics (execution) extends precise, parenchyma-sparing resection to complex and combined segmentectomies that would otherwise become lobectomies—and can compress the learning curve.

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## **Histology-Driven Surgical Strategies in Thymic Epithelial Tumors: Lymph Node Management and Extent of Resection in Early Thymoma**

**Jae Kwang Yun\***

*Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan  
 College of Medicine, Seoul, Republic of Korea*

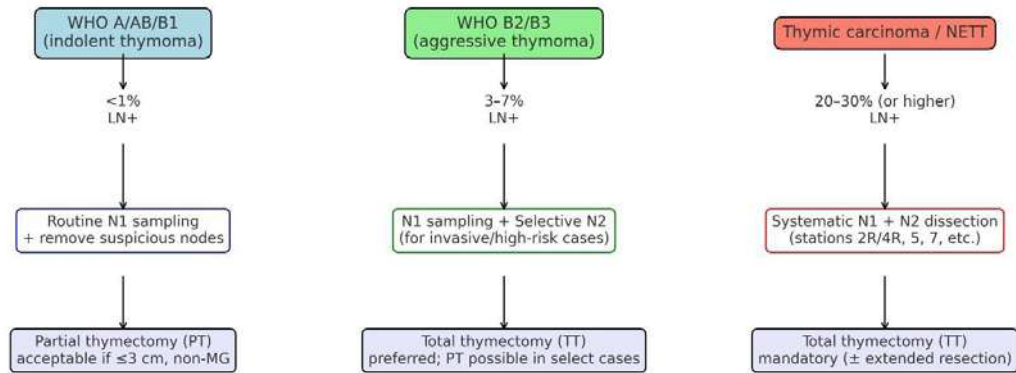
Thymic epithelial tumors (TETs) are biologically heterogeneous, ranging from indolent thymomas (WHO A, AB, B1) to more aggressive thymomas (B2, B3) and thymic carcinoma/neuroendocrine thymic tumors (TC/NETT). Lymph node (LN) metastasis is rare in low-risk thymomas (<1%), intermediate in B2/B3 (3–7%), and frequent in TC/NETT (20–30%). Tumor size (>5–6 cm) and advanced stage further increase LN positivity.

International Thymic Malignancy Interest Group (ITMIG) and European Society for Medical Oncology (ESMO) guidelines now recommend histology-based LN management: (i) routine anterior mediastinal (N1) node sampling for all resections, (ii) selective deep intrathoracic (N2) sampling for invasive or high-risk thymomas, and (iii) systematic N1+N2 dissection for TC/NETT. While systematic LN dissection improves staging accuracy and identifies occult disease, survival benefit remains unproven in thymoma; prognostic impact is greater in TC/NETT.

Another controversy involves the extent of thymectomy in early-stage thymomas. Retrospective series, propensity-matched cohorts, and meta-analyses demonstrate no significant difference in recurrence or overall survival (OS) between total thymectomy (TT) and partial thymectomy (PT) for small ( $\leq 3$  cm), encapsulated, non-myasthenic thymomas. PT offers lower perioperative morbidity and is technically advantageous in minimally invasive surgery (MIS). However, TT remains standard in patients with myasthenia gravis (MG) or invasive features.

Emerging concerns about long-term systemic sequelae of TT further complicate decision-making. A recent cohort (NEJM 2023) reported higher risks of all-cause mortality, second malignancy, and autoimmune disease after TT, though subsequent critical reviews (ITMIG 2024–25) questioned causality due to confounding. These findings highlight the need for balancing oncologic radicality against potential immune preservation.

In conclusion, histology and clinical context should guide surgical strategies in TETs. Selective LN dissection is sufficient in indolent thymomas, while systematic N1+N2 dissection is warranted in TC/NETT. For small, non-MG thymomas, PT appears oncologically equivalent to TT and may reduce long-term immune-related risks, supporting a more individualized approach.



## **Prognostic Significance of Circulating Tumor Cells in Patients with Esophageal Cancer Who Attained Pathological Complete Response after Neoadjuvant Therapy**

**Chuan Cheng<sup>1,2</sup>, Yin-Kai Chao<sup>2</sup> \***

<sup>1</sup>*Division of Thoracic Surgery, New Taipei Municipal Tu-Cheng Hospital, New Taipei City, Taiwan*

<sup>2</sup>*Division of Thoracic Surgery, Chang Gung Memorial Hospital-Linkou, Chang Gung University, Taoyuan, Taiwan*

### **Background**

Pathological complete response (pCR) indicates no remaining tumor cells after neoadjuvant chemoradiotherapy (nCRT) and correlates with favorable outcomes. However, 25–33% of such cases still experience disease recurrence. The objective of this study was to investigate the value of circulating tumor cells (CTCs) for prognostic stratification of patients with esophageal carcinoma (EC) who attained pCR following nCRT.

### **Methods**

We measured the post-nCRT CTCs count in the peripheral blood of patients with EC who achieved pCR after undergoing nCRT. We subsequently analyzed the influence of CTCs count on survival, considering the potential confounding influences of established clinical and pathological risk factors.

### **Results**

The study comprised 24 patients, of whom 18 (75%) had detectable CTCs. The mean CTCs concentration amounted to 5.1 per mL of blood. Univariable Cox regression analysis revealed that the CTCs count was the sole independent predictor of disease-free survival (HR = 1.113, 95% CI = 1.008–1.229,  $p = 0.034$ ). Receiver operating characteristic curve analysis identified an optimal cutoff value of 4.5 CTCs per mL. The 3-year disease-free survival was significantly higher in the low CTCs group (92.9%) than the high CTCs group (50.0%,  $p = 0.032$ ).

### **Conclusion**

In patients with EC who achieve pCR following nCRT, CTCs quantification may aid in identifying those with poor survival outcomes.

## **Preliminary Real-World Outcomes of Adjuvant Immunotherapy in Resected Esophageal Cancer: A Retrospective Study from Taiwan**

**Chia Liu 1 2, Yi-Chen Yeh 2 3, Ling-I Chien 4, Chien-Sheng Huang 1 2, Han-Shui Hsu 1 2, Po-Kuei Hsu\* 1 2**

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*2School of Medicine, National Yang Ming Chiao Tung University, Taipei, Taiwan.*

*3Department of Pathology and Laboratory Medicine, Taipei Veterans General Hospital, Taipei, Taiwan.*

*4Department of Nursing, Taipei Veterans General Hospital, Taipei, Taiwan.*

### **Background**

The CheckMate 577 trial demonstrated that adjuvant nivolumab improves disease-free survival in patients with resected esophageal cancer following neoadjuvant chemoradiotherapy. This study aimed to evaluate real-world outcomes associated with adjuvant immunotherapy.

### **Methods**

Patients with esophageal cancer and residual pathological disease who underwent neoadjuvant therapy followed by surgical resection between January 2019 and February 2024 were retrospectively analyzed. Participants were grouped by adjuvant treatment received: no adjuvant therapy, adjuvant immunotherapy (AI), or adjuvant chemotherapy (AC). Primary outcomes included overall survival (OS) and recurrence-free survival (RFS). Subgroup analyses were performed for patients meeting CheckMate 577 eligibility criteria and those with pathological node-positive (ypN+) status.

### **Results**

The study included 127 patients (mean age: 60 years; male: 86%): 23 received AI, 36 AC, and 68 received no adjuvant therapy. There were no significant differences in OS between AI and AC groups (median OS [mOS]: 34 months vs. 34 months;  $p=0.81$ ), nor in RFS (median RFS [mRFS]: 15 months vs. 16 months;  $p=0.94$ ). In the CheckMate 577-eligible subgroup ( $n=68$ ), OS and RFS were similar between AI and AC groups (mOS: 25 months vs. 47 months;  $p=0.16$ ; mRFS: 19 months vs. 20 months;  $p=0.74$ ). Likewise, among ypN+ patients ( $n=54$ ), no significant differences in OS or RFS were noted between AI and AC (mOS: 34 months vs. 31 months;  $p=0.74$ ; mRFS: 9.5 months vs. 14 months;  $p=0.89$ ).

### **Conclusions**

AI did not demonstrate a significant survival advantage compared to AC, even in patients meeting CheckMate 577 criteria or those with ypN+ status. Identifying the optimal adjuvant treatment for esophageal cancer remains a challenging and evolving issue.

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## **The current consensus on salvage surgery after targeted therapy for advanced EGFR-mutant non-small cell lung cancer**

**Yu-Wei Liu, MD, PhD, Shah-Hwa Chou, MD\***

*Division of Thoracic Surgery, Department of Surgery, Kaohsiung Medical University Hospital,  
Kaohsiung Medical University, Kaohsiung, Taiwan.*

Local consolidative therapy (including surgery) has emerged as a viable option for selected patients with advanced EGFR-mutant non-small cell lung cancer (NSCLC) who maintain disease control on tyrosine kinase inhibitors (TKIs). Across multiple retrospective series, median progression-free survival ranges from 14 to 52 months, with overall survival often exceeding three years—outcomes superior to TKI therapy alone. Surgery provides intact specimens for detailed pathologic and molecular assessment, enabling early detection of resistance mechanisms such as T790M mutation and histologic transformation. Despite feasibility and encouraging results in patients with oligoresidual disease and favorable biology, limitations include retrospective design, selection bias, and inconsistent oncologic benefit. Optimal timing, patient selection, and integration with next-generation targeted and immune therapies warrant validation in prospective trials.

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## Room 101C (English) | Saturday, July 11, 2026

### Lunch Symposium

**Time: 12:30-13:30 (GMT+8)**

|       |             |                                                                                                  |
|-------|-------------|--------------------------------------------------------------------------------------------------|
|       |             | Wen-Chien Huang (Taiwan)<br>Chair(s): Calvin S.H. Ng (Hong Kong)<br>Hui-Hsuan Shih (Taiwan)      |
| LS2-1 | 12:30-13:30 | <b>Polaris - Dual Correction Robotic-Assisted Bronchoscopy System</b><br>Chi-Kin Wan (Hong Kong) |

## **Polaris - Dual Correction Robotic-Assisted Bronchoscopy System**

**Chi-Kin Wan**

*Gleneagles Hong Kong Hospital*

Robotic-Assisted Bronchoscopy (RAB) is increasingly being explored as a platform for peripheral lung disease management, particularly for peripheral pulmonary nodule diagnosis. As clinical experience accumulates, RAB may also become an enabling platform for future bronchoscopic localization and selected local treatment approaches, including ablation. This session aims to provide a practical forum for discussion among clinicians on how RAB platforms can address real procedural challenges.

Using Polaris as one illustrative platform, the talk will frame the discussion around common questions asked by experienced bronchoscopists: how lesion access is confirmed, how anatomy shift and CT-to-body divergence may be managed, how lesion anatomy influences workflow selection, how procedural complexity and occupational radiation exposure can be reduced, and how a platform may evolve from diagnosis toward future intervention.

The presentation will use a pathway-based clinical framework to discuss airway-accessible lesions, distal or subpleural lesions, and selected no-bronchus-sign lesions. Rather than focusing on detailed engineering descriptions, the discussion will emphasize clinical decision-making, workflow design, confirmation strategy, imaging compatibility, procedural safety, and the practical needs of physicians considering RAB in different hospital environments.

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## Room 101C (English) | Saturday, July 11, 2026

### Industry Sponsored Keynote Session (Boehringer Ingelheim Taiwan Ltd.)

**Time: 14:00-15:00 (GMT+8)**

|                                                                                                                            |             |
|----------------------------------------------------------------------------------------------------------------------------|-------------|
| Chair(s): Tsai-Wang Huang (Taiwan)                                                                                         |             |
| K1-1                                                                                                                       | 14:00-15:00 |
| <b>Metastatic Trajectories in Non-Small Cell Lung Cancer Guide Local and Systemic Therapies</b><br>Pei-Hsing Chen (Taiwan) |             |

### Industry Sponsored Keynote Session (BeOne Medicines Ltd.)

**Time: 15:30-16:30 (GMT+8)**

|                                                                                        |             |
|----------------------------------------------------------------------------------------|-------------|
| Chair(s): Mong-Wei Lin (Taiwan)<br>Jang-Ming Lee (Taiwan)                              |             |
| K2-1                                                                                   | 15:30-16:00 |
| <b>Optimizing Resectable NSCLC Outcomes</b><br>Dong-Sheng Yue (China)                  |             |
| K2-2                                                                                   | 16:00-16:30 |
| <b>Evolving Landscape of Immunotherapy in Esophageal Cancer</b><br>Zhi-gang Li (China) |             |

## **Metastatic Trajectories in Non–Small Cell Lung Cancer Guide Local and Systemic Therapies**

**Pei-Hsing Chen, Jin-Shing Chen\***

*Division of Thoracic Surgery, Department of surgery, National Taiwan University Hospital*

Metastatic non–small cell lung cancer (NSCLC) is an evolutionary disease in which the primary tumor and metastatic lesions may acquire distinct biological properties over time. Longitudinal genomic analyses have shown marked post-dissemination divergence, multiple primary-tumor subclones seeding separate lesions, and frequent metastasis-to-metastasis spread<sup>[1]</sup>. Therefore, the role of local therapy should be defined not by lesion number alone but by the trajectory of disease, including treatment response, residual tumor burden, anatomical pattern, molecular profile, and potential for further progression. Systemic therapy remains the foundation of treatment. However, local consolidative therapy can be integrated to control residual, dominant, or resistant lesions while maintaining effective systemic therapy. The randomized phase II Gomez study established the clinical rationale for local consolidative therapy after initial systemic control in selected oligometastatic NSCLC<sup>[2]</sup>. In EGFR-mutant disease, prospective evaluation of lazertinib plus stereotactic body radiotherapy<sup>[3]</sup> and primary tumor resection after EGFR-tyrosine kinase inhibitor therapy<sup>[4]</sup> illustrate complementary radiation- and surgery-based strategies. Multidisciplinary, trajectory-based selection may optimize the timing and modality of local treatment while limiting toxicity and preserving systemic disease control.

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## Optimizing Resectable NSCLC Outcomes

**Dongsheng Yue**

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Resectable stage II–III non–small cell lung cancer (NSCLC) carries a high risk of recurrence, with rates reaching 52–75% within five years after surgery.<sup>[1]</sup> Conventional perioperative chemotherapy has provided only modest survival benefit, highlighting the need for new strategies.<sup>[2]</sup> Recent phase III trials—including CheckMate 816, KEYNOTE-671, AEGEAN, and RATIONALE-315—demonstrate that perioperative immunotherapy combined with chemotherapy significantly improves event-free survival (EFS), pathological complete response (pCR), and overall survival (OS).<sup>[3–8]</sup> In RATIONALE-315, tislelizumab plus chemotherapy achieved a 4-year EFS rate of 61.2% compared with 41% for chemotherapy alone, reducing recurrence or death risk by 42%.<sup>[9]</sup> The unique Fc-engineering of tislelizumab, designed to prevent macrophage-mediated T-cell clearance, may contribute to its superior pCR and major pathologic response (MPR) rates.<sup>[10]</sup> These findings support a paradigm shift from surgery-centric management to integrated perioperative immunotherapy, refining the standard of care and offering greater curative potential for patients with resectable NSCLC.

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## **Evolving Landscape of Immunotherapy in Esophageal Cancer**

**Dr. Zhigang Li, M.D., Ph.D.,**

*Shanghai Chest Hospital*

The management of esophageal cancer has undergone a paradigm shift, driven by the evolving landscape of immunotherapy. Clinical progress has been defined by redefining the first-line standard of care for metastatic esophageal squamous cell carcinoma (ESCC) and establishing comprehensive treatment approaches for locally advanced disease.

Dr. Li has pioneered these advancements, particularly through the NICE study, which initiated a wave of research into neoadjuvant immunotherapy plus chemotherapy. His practice has further optimized these strategies through real-world studies, precision immunotherapy utilizing molecular biomarkers—such as SPRY1+CD8+ T cells—and the exploration of minimal residual disease (MRD) detection to guide clinical decisions.

Beyond systemic therapy, Dr. Li's approach emphasizes organ-preserving strategies and the adoption of innovative surgical techniques, including robotic-assisted esophagectomy and extended free jejunal interposition, to maximize functional outcomes. By integrating these diverse clinical and translational insights, Dr. Li continues to strive toward establishing evidence-based treatment strategies that redefine the future of esophageal cancer care.

## Room 101C (English) | Sunday, July 12, 2026

### Young Investigator Award

**Time: 08:30-09:15 (GMT+8)**

|             |             |                                                                                                                                                                                |
|-------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             | Chair(s): Ching-Yuan Cheng (Taiwan)<br>Hsao-Hsun Hsu (Taiwan)<br>Seiichiro Sugimoto (Japan)                                                                                    |
| YIA-1       | 08:30-08:42 | <b>Evaluating the Effectiveness of Thoracoscopic Intervention for Pulmonary Abscess: Is Lobectomy the Optimal Solution after Medical Therapy Fails?</b><br>Po-Keng Su (Taiwan) |
| YIA-2       | 08:42-08:54 | <b>Effect of Mobile Augmented Reality Counseling on Improving Shared Decision-Making in Thoracic Surgery: Randomized Clinical Crossover Trial</b><br>Ying-Shian Chen (Taiwan)  |
| YIA-3       | 08:54-09:06 | <b>Enhancing Three-Dimensional Anatomical Understanding in Complex Thoracic Surgery: A Comparative Study of OpVerse and Synapse 3D</b><br>Yu-An Zheng (Taiwan)                 |
| 09:06-09:15 |             | <b>Award Presentation &amp; Group Photo</b>                                                                                                                                    |

RESEARCH

Open Access



# Evaluating the effectiveness of thoracoscopic intervention for pulmonary abscess: is lobectomy the optimal solution after medical therapy fails?

Po-Keng Su<sup>1,2,3</sup>, Shun-Mao Yang<sup>2,3\*</sup>, Cheng-Hung How<sup>1\*</sup>, Chao-Yu Liu<sup>1</sup>, Ka-I Leong<sup>1</sup>, Jei-Kuo Lin<sup>1</sup> and San-Fang Chou<sup>4</sup>

## Abstract

**Background** Lung abscess is typically managed by performing abscess drainage. While pulmonary resection effectively controls infection, its role in eliminating necrotic tissue remains debatable due to risks such as bleeding, desaturation, systemic inflammation, persistent air leakage, and bronchopleural fistula. In this study, we evaluated the outcomes of pulmonary resection for lung abscess refractory to medical therapy.

**Methods** We retrospectively analyzed 70 patients who underwent salvage thoracoscopic surgery for lung abscess, along with 60 days' follow-up, at a tertiary referral hospital between January 2016 and August 2022. Thirty-two patients underwent lobectomy, while 38 did not. The patients' demographics, comorbidities, disease progression, 30-day and 60-day mortality, and operative morbidity were compared between the lobectomy and non-lobectomy groups.

**Results** Necrotizing pneumonia was the leading cause of lung abscess ( $n = 53$ , 75.7%), with empyema being the most common sign of disease progression ( $n = 36$ , 51.4%). The lobectomy group had a lower mortality rate compared with the non-lobectomy group (15.6% vs. 36.8%,  $p = 0.047$ ). Multivariate analysis identified a higher Charlson Comorbidity Index (CCI) as a risk factor for 30-day mortality (HR = 1.286, 95% CI = 1.059–1.561;  $p = 0.011$ ), while lobectomy mitigated the 30-day mortality risk (HR = 0.255, 95% CI = 0.068–0.959;  $p = 0.043$ ). Similarly, a higher CCI augmented the 60-day mortality risk (HR = 1.317, 95% CI = 1.105–1.571;  $p = 0.002$ ), whereas lobectomy lowered it (HR = 0.319, 95% CI = 0.110–0.921;  $p = 0.035$ ).

**Conclusion** Lobectomy significantly improves the 30- and 60-day mortality outcomes compared to non-lobectomy surgery, making it a viable option for pharmacotherapy-refractory lung abscess.

**Keywords** Lobectomy, Lung abscess, Mortality, Pulmonary abscess drainage, Pulmonary resection

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## Background

Lung abscess, necrotizing pneumonia, and pulmonary gangrene are pulmonary infections that differ with respect to the degree of inflammation, necrosis, and parenchymal destruction [1]. Lung abscess is characterized by the formation of a cavity filled with necrotic debris, infectious and inflammatory tissues, and even pus within the lung parenchyma [2, 3]. Parenchymal consolidation containing air and fluid, surrounded by peripheral necrosis is a typical chest computed tomography (CT) finding of a lung abscess [4]. Etiologically, lung abscess can be classified as primary or secondary. Primary lung abscess occurs due to aspiration of oropharyngeal and gastrointestinal secretions, pneumonia, and immunodeficiency. Secondary lung abscesses arise from coexisting lung diseases (cystic fibrosis, bronchiectasis, bullous emphysema, or infected pulmonary infarcts), bronchial obstruction (related to tumor, foreign body, or mediastinal mass), spread of infection from direct and indirect sites (hematogenous, subphrenic abscess, or broncho-esophageal fistula), and congenital malformation [3, 5].

The clinical signs and treatment of lung abscess were first described by Hippocrates; however, an effective surgical intervention for lung abscesses was not clearly established at that time. In the pre-antibiotic era, approximately 100 years ago, lung abscess was often fatal, with mortality rates reportedly as high as 75% [6, 7]. In the early decades of the twentieth century, Neuhof and Hurwitt [8] pioneered a novel and reliable therapeutic concept for lung abscess: the one-stage open drainage operation. This procedure was performed in a series of 162 cases, reducing the mortality rate to 2.47%.

Between the 1940s and 1950s, several studies proposed the use of pulmonary resection, including lobectomy and pneumonectomy, to treat patients with lung abscess refractory to initial medical treatment [9–11]. Surgical interventions were administered to patients who experienced disease progression to empyema, hemoptysis, septic shock, or progressive respiratory distress despite initial therapy. Adding surgery to the treatment regimen aimed to remove permanently damaged lung parenchyma that could harbor recurrent infections and was considered in cases where conservative treatments alone were insufficient. Lung resection for lung abscess remains feasible in patients who do not respond to other treatments, and lobectomy or segmentectomy can be performed safely, with minimal morbidity and mortality [12, 13].

In our single-center, retrospective study, we analyzed patients with lung abscess who underwent thoracoscopic surgical treatment, with the aim of identifying predictors influencing treatment outcomes and mortality.

## Materials and methods

### Eligibility criteria

The data of 628 patients who underwent video-assisted thoracic surgery (VATS) for empyema and lung abscess at our institution between January 2016 to August 2022 were reviewed retrospectively. The eligibility criteria for patient selection are shown in Fig. 1. The inclusion criteria were patients: (1) aged  $\geq 18$  years; (2) diagnosed with lung abscess and empyema using the International Classification of Diseases-10 diagnostic codes under medical treatment but still progression; and (3) who underwent surgery including decortication, unroofing, wedge resection, segmentectomy, lobectomy, bilobectomy, and pneumonectomy. Patients were excluded if they had: (1) simple empyema without lung abscess (chest CT did not depict lung abscess or obvious cavity formation and fluid-filled central necrosis was absent); (2) no evidence of inflammation, necrosis, infection, abscess, or empyema on the pathological reports; (3) chest wall abscess; and (4) no surgical intervention (e.g., bronchoscopy). The study was approved by the Institutional Review Board (IRB) of Far Eastern Memorial Hospital (IRB approval no. 111279-E), which waived the need for informed consent.

### Preoperative assessment

All patients were treated by three attending thoracic surgeons at the Far Eastern Memorial Hospital, New Taipei City, Taiwan. Chest CT was performed for all patients to evaluate the extent of lung infection. We retrospectively reviewed the following clinical data: age, sex, comorbidity [Charlson Comorbidity Index (CCI)], smoking history, disease progression, etiology of lung abscess [3], and abscess location and size. In patients with comorbidity or disease progression, respiratory insufficiency referred to increased oxygen demand under initial treatment, respiratory failure was defined as ventilator use, and bilateral pneumonia implied that infection could not be controlled by medical treatment [12].

### Operative technique

All patients underwent VATS in the operating room under general anesthesia and lung isolation with a double-lumen or single-lumen endotracheal tube with blocker intubation. Patients were placed in the decubitus position during the procedure. Some patients underwent only decortication, whereas others underwent additional procedures such as wedge resection and lobectomy to eradicate the infectious foci. No patient underwent pneumonectomy and bilobectomy. If patients underwent lobectomy using another procedure, they were categorized into the lobectomy group. We also confirmed lung re-expansion during operation by using two-lung ventilation and inserting one or two chest tubes via the ports.

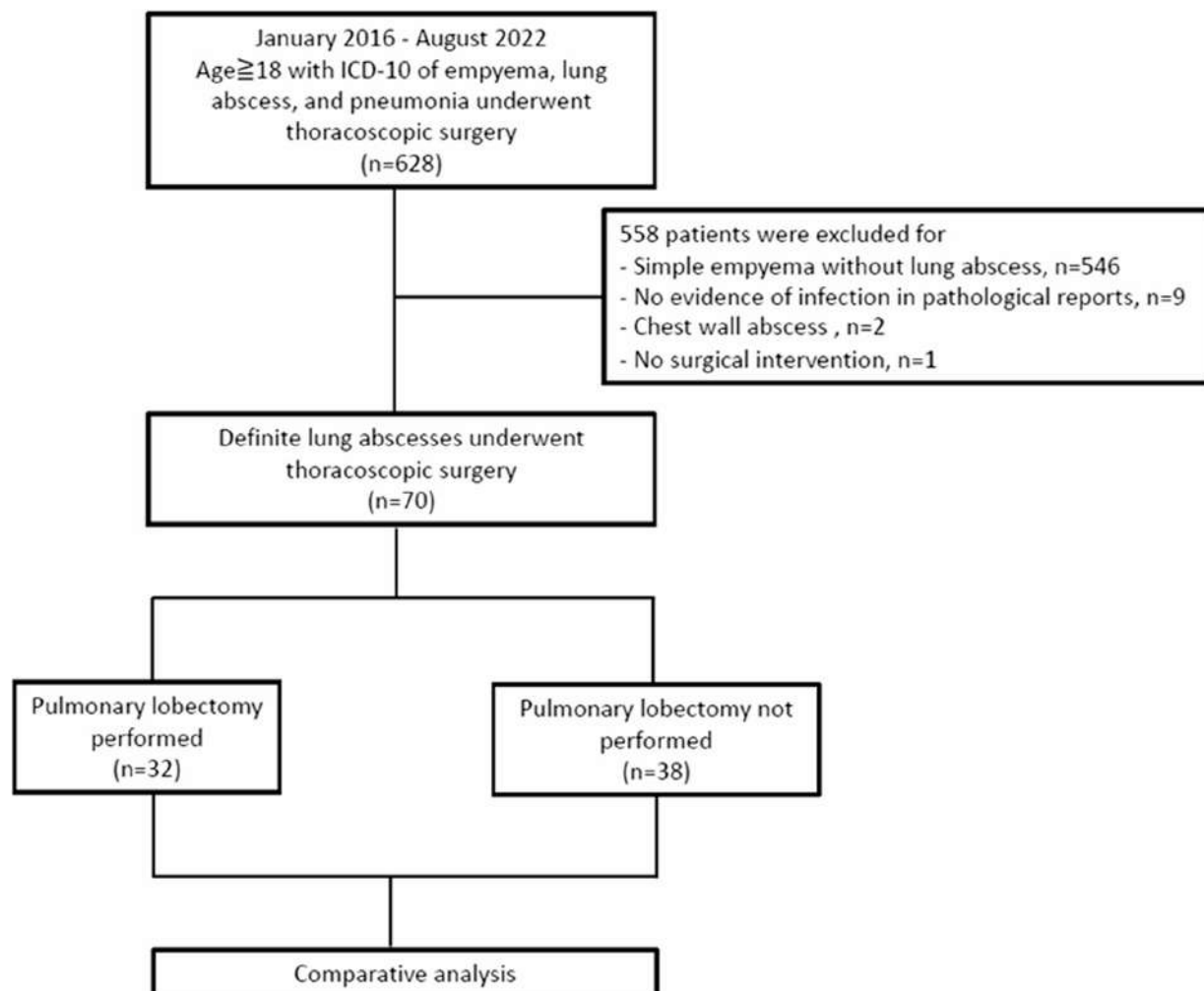


**Fig. 1** Patient allocation and exclusion

### Surgical outcomes

We obtained patients' basic data from their electronic medical records. After surgery, we analyzed their morbidity (Clavien-Dindo classification and the number of patients with grade  $\geq 3$ B), length of intensive care unit (ICU) stay (days), and 30-day and 60-day mortality. We used univariate and multivariate Cox proportional modeling to analyze the outcomes to determine the predictive factors associated with 30-day and 60-day mortality.

### Statistical analysis

The normality of numerical data was assessed using the Shapiro-Wilk test. Normally distributed numerical data were expressed as means  $\pm$  standard deviations, whereas non-normally distributed data were presented as medians (Q1, Q3). Categorical data were presented as frequencies and percentages. Statistical differences between groups were examined using the independent

t-test/Mann-Whitney U test or chi-squared/Fisher's exact test, as appropriate, depending on the characteristics of the data. The 30-day mortality and 60-day mortality were estimated using Kaplan-Meier analysis, and the differences between the lobectomy and non-lobectomy groups were analyzed using the log-rank test. The effect of lobectomy on mortality was analyzed using univariate and multivariate Cox proportional hazard regression. All statistical analyses were performed using IBM SPSS Statistics software version 22.0, with statistical significance between/among groups set at  $p < 0.05$ .

### Results

We divided 70 patients who underwent surgical intervention for lung abscesses into two groups based on the operative procedures. Thirty-two underwent lobectomy (lobectomy group) and the remaining 38 patients underwent surgery without lobectomy (non-lobectomy group).

**Table 1** Demographic data and characteristics of patients who underwent operation for lung abscess

|                                          | Lobectomy<br>(n = 32)   | Non-lobec-<br>tomy<br>(n = 38) | p<br>value |
|------------------------------------------|-------------------------|--------------------------------|------------|
| Age<br>(min-max)                         | 58.06 ± 15.9<br>(29–85) | 61.21 ± 11.3<br>(40–89)        | 0.352      |
| Sex (M: F)                               | 24:8                    | 32:6                           | 0.337      |
| Smoking                                  | 14 (43.8)               | 26 (68.4)                      | 0.038      |
| Comorbidity                              |                         |                                |            |
| None                                     | 11 (34.4)               | 9 (23.7)                       | 0.324      |
| Hypertension                             | 12 (37.5)               | 13 (34.2)                      | 0.775      |
| Diabetes mellitus                        | 8 (25)                  | 12 (31.6)                      | 0.544      |
| Chronic obstructive pulmonary<br>disease | 4 (12.5)                | 2 (5.3)                        | 0.402      |
| Lung cancer                              | 1 (3.1)                 | 1 (2.6)                        | 1.000      |
| Other malignancies                       | 6 (18.8)                | 7 (18.4)                       | 0.972      |
| Coronary artery disease                  | 4 (12.5)                | 8 (21.1)                       | 0.526      |
| Cerebrovascular accident                 | 3 (9.4)                 | 9 (23.7)                       | 0.202      |
| Lung disease                             | 4 (12.5)                | 2 (5.3)                        | 0.402      |
| Chronic kidney disease                   | 2 (6.3)                 | 3 (7.9)                        | 1.000      |
| Charlson Comorbidity Index <sup>a</sup>  | 2.0 (1.0, 5.0)          | 3.5 (2.0, 5.0)                 | 0.329      |
| Etiology                                 |                         |                                |            |
| Primary                                  |                         |                                |            |
| Necrotizing pneumonia                    | 21 (65.6)               | 32 (84.2)                      | 0.071      |
| Aspiration                               | 0 (0)                   | 2 (5.3)                        | 0.496      |
| immunodeficiency                         | 1 (3.1)                 | 2 (5.3)                        | 1.000      |
| Secondary                                |                         |                                |            |
| Tumor obstruction                        | 3 (9.4)                 | 1 (2.6)                        | 0.325      |
| Foreign body obstruction                 | 2 (6.3)                 | 0 (0)                          | 0.205      |
| Bronchiectasis                           | 1 (3.1)                 | 0 (0)                          | 0.457      |
| Cystic fibrosis                          | 1 (3.1)                 | 0 (0)                          | 0.457      |
| Bullous emphysema                        | 1 (3.1)                 | 0 (0)                          | 0.457      |
| Subphrenic infection                     | 0 (0)                   | 1 (2.6)                        | 1.000      |
| Pulmonary infarct                        | 1 (3.1)                 | 0 (0)                          | 0.457      |
| Congenital malformation                  | 1 (3.1)                 | 0 (0)                          | 0.457      |
| Comorbidity or progression of<br>disease |                         |                                |            |
| Empyema                                  | 11 (34.4)               | 25 (65.8)                      | 0.009      |
| Respiratory insufficiency                | 11 (34.4)               | 9 (23.7)                       | 0.324      |
| Bilateral pneumonia                      | 8 (25)                  | 10 (26.3)                      | 0.9        |
| Hemoptysis                               | 7 (21.9)                | 1 (2.6)                        | 0.02       |
| Septic shock                             | 2 (6.3)                 | 5 (13.2)                       | 0.442      |
| Respiratory failure                      | 1 (3.1)                 | 7 (18.4)                       | 0.063      |
| Air leakage                              | 1 (3.1)                 | 2 (5.3)                        | 1.000      |
| Location                                 |                         |                                | 0.906      |
| Right upper lobe                         | 5 (15.6)                | 5 (13.2)                       |            |
| Right middle lobe                        | 2 (6.3)                 | 1 (2.6)                        |            |
| Right lower lobe                         | 10 (31.3)               | 15 (39.5)                      |            |
| Left upper lobe                          | 6 (18.8)                | 6 (15.8)                       |            |
| LLL                                      | 9 (28.1)                | 11 (28.9)                      |            |
| Size                                     | 7.1 ± 2.8               | 5.98 ± 2.3                     | 0.07       |
| (min-max)                                | (2.5–12.5)              | (2.7–9.3)                      |            |

<sup>a</sup>The difference in the Charlson Comorbidity Index between the lobectomy and non-lobectomy groups was analyzed using the Mann–Whitney test

The patients' demographic features are summarized in Table 1. Fifty-six (80%) patients were men. The average age was 58.06 (± 15.9) years in the lobectomy group and 61.21 (± 11.3) years in the non-lobectomy group. Fourteen (43.8%) and 26 (68.4%) patients in the lobectomy and non-lobectomy groups reported a history of smoking, respectively ( $p < 0.05$ ). The Mann–Whitney U test did not reveal significant differences in the comorbidities and CCI between the two groups [lobectomy: 2.0 (1.0, 5.0); non-lobectomy: 3.5 (2.0, 5.0);  $p = 0.329$ ]. We also divided lung abscess into primary and secondary based on etiology. Necrotizing pneumonia was the most common etiology of primary lung abscess, while tumor obstruction was the most common etiology of secondary lung abscess. Empyema was the most common progressive sign in both groups, whose frequency was significantly greater in the non-lobectomy group than in the lobectomy group (65.8% vs. 34.4%;  $p = 0.009$ ). Respiratory insufficiency and bilateral pneumonia were the second and third most common signs of disease progression in both groups, respectively. Lung abscess occurred most commonly in the right lower lobe, and the location did not differ between the two groups. The size of the lung abscess did not differ significantly between the lobectomy ( $7.1 \pm 2.8$  cm) and non-lobectomy groups ( $5.98 \pm 2.3$  cm).

The 30-day mortality and 60-day mortality of the two groups are presented in Fig. 2. The 30-day survival and 60-day survival were plotted as Kaplan–Meier curves, which revealed that survival was longer in the lobectomy group (30-day mortality:  $p = 0.044$  and 60-day mortality:  $p = 0.048$ , respectively). Table 2 describes the postoperative outcomes in this study. The rate of morbidity did not differ significantly between the two groups [16 (50%) vs. 23 (60.5%);  $p = 0.377$ ]. Pneumonia was the most common morbidity in both groups. Atrial fibrillation occurred only in the lobectomy group, but the difference with the non-lobectomy group lacked statistical significance. We used the Clavien–Dindo classification to grade the severity of surgical complications and found that the frequency of severe complications (Clavien–Dindo grade  $\geq 3B$ ) was greater in the non-lobectomy group than in the lobectomy group (25% vs. 50%;  $p = 0.032$ ). The length of ICU stay did not differ significantly between the two groups. We also compared the number of days on postoperative ventilation, and excluded (i) initial ventilation before surgery, (ii) transfer to the respiratory care ward for further care, and (iii) death after surgery. Extended use of ventilation was not required in the lobectomy group.

In our study, the Cox proportional hazard model (Table 3) was used to analyze the outcomes in all patients. Multivariate analyses of 30- and 60-day mortality revealed that surgery with lobectomy was an independent factor that enhanced survival and that a higher

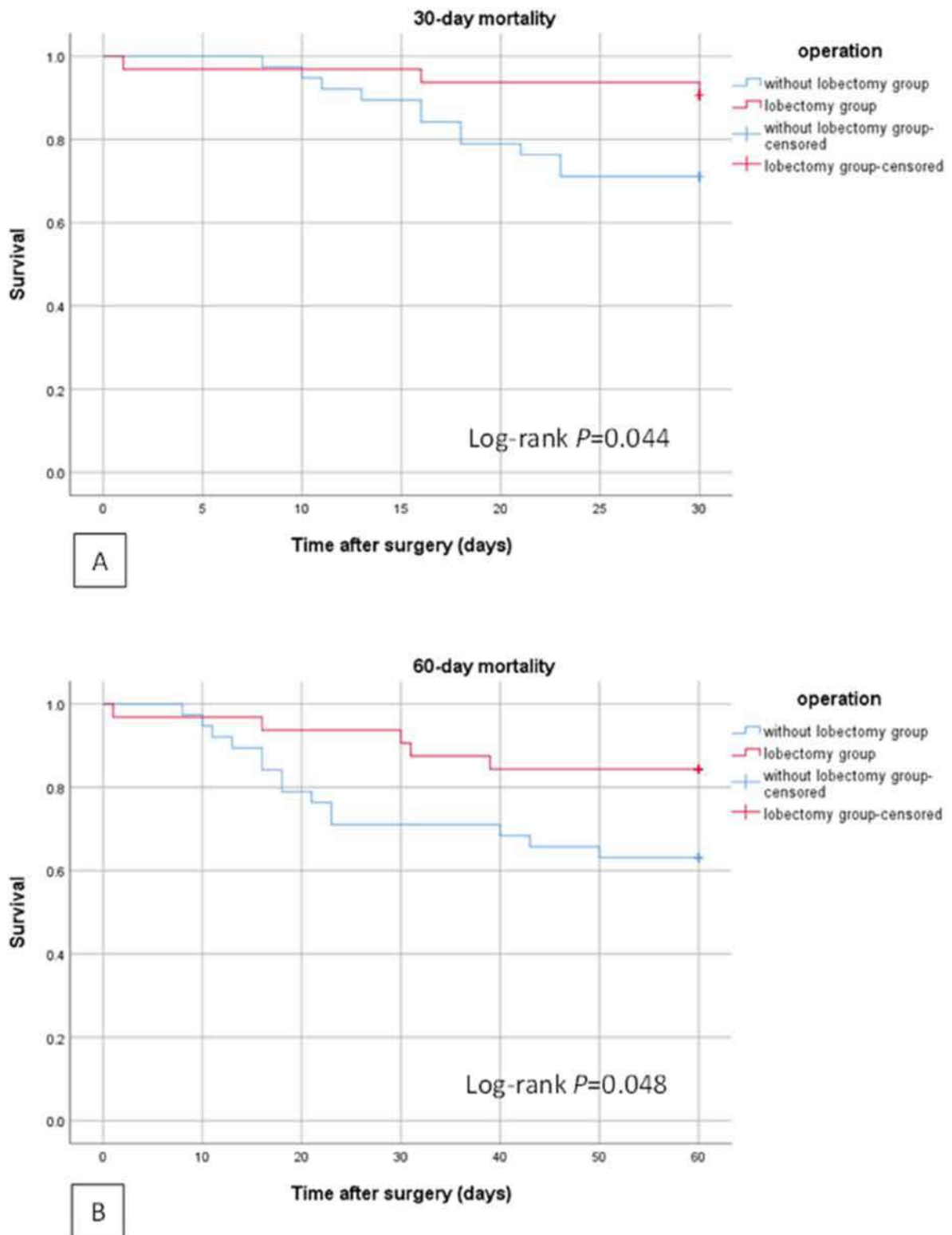


**Fig. 2** Kaplan–Meier analysis and log-rank test for 30-day and 60-day mortality stratified by surgery with lobectomy and without lobectomy. **A** 30-day mortality, **B** 60-day mortality



**Table 2** Postoperative morbidity and outcomes

|                                                                     | <b>Lobectomy<br/>(n = 32)</b> | <b>Non-lobectomy<br/>(n = 38)</b> | <b>p value</b> |
|---------------------------------------------------------------------|-------------------------------|-----------------------------------|----------------|
| Mortality (%)                                                       | 5 (15.6)                      | 14 (36.8)                         | 0.047          |
| Morbidity (%)                                                       | 16 (50)                       | 23 (60.5)                         | 0.377          |
| Atelectasis                                                         | 7 (21.9)                      | 11 (28.9)                         | 0.5            |
| Pneumonia                                                           | 9 (28.1)                      | 15 (39.5)                         | 0.319          |
| Pleural effusion                                                    | 5 (15.6)                      | 9 (23.7)                          | 0.401          |
| Prolonged air leakage                                               | 4 (12.5)                      | 5 (13.2)                          | 1.000          |
| Atrial fibrillation                                                 | 5 (15.6)                      | 0 (0)                             | 0.017          |
| Bronchial injury                                                    | 1 (3.1)                       | 0 (0)                             | 0.457          |
| Wound infection                                                     | 0 (0)                         | 1 (2.6)                           | 1.000          |
| Fungemia                                                            | 0 (0)                         | 1 (2.6)                           | 1.000          |
| Ventricular tachycardia                                             | 1 (3.1)                       | 0 (0)                             | 0.457          |
| Clavien-Dindo classification ≥ 3B (%)                               | 8 (25)                        | 19 (50)                           | 0.032          |
| Length of ICU stay (days) [median (Q1, Q3)] <sup>a</sup>            | 5.0 (3.00, 13.75)             | 6.0 (3.00, 16.25)                 | 0.741          |
| Days of postoperative ventilation <sup>b</sup><br>[median (Q1, Q3)] | (n = 22)<br>1.0 (1.0, 6.5)    | (n = 23)<br>1.0 (1.0, 4.0)        | 0.913          |

ICU Intensive Care Unit

<sup>a</sup>The differences in the length of ICU stay and days on postoperative ventilation between the lobectomy and non-lobectomy groups were analyzed using the Mann–Whitney test

<sup>b</sup>The data regarding days on postoperative ventilation exclude (i) initial ventilation before surgery, (ii) transfer to the respiratory care ward for further care, and (iii) death after surgery

CCI was a risk factor for higher mortality in patients with lung abscess.

## Discussion

In the current era, mortality due to lung abscess has declined substantially because of the advent of potent antibiotic therapy and the concept of drainage and intervention [6, 8]. However, despite this decline, the mortality rate remains unsatisfactory, ranging between 15% and 20% in recent years [14–16]. Lung abscess is often accompanied by other complications, and disease progression not only prolongs hospitalization but also encumbers treatment. Zhang et al. suggested the following indications for surgical intervention for lung abscess: treatment failure after intensive medical management, broncho-pleural fistula, lung abscess > 6 cm in diameter, and severe or life-threatening hemoptysis [2]. Diffuse destruction of the lung parenchyma may cause vascular insufficiency, limiting the delivery of antibiotics, and obstruction of the bronchus make hinder expectoration of the necrotic material [17, 18]. Hence, complete eradication of the focus of infection may be a feasible choice in the event of failure of medical treatment for lung abscess.

Lung abscess is highly concomitant with empyema. Cai et al. [19] indicated that the risk of empyema was significantly higher for patients with pulmonary abscess measuring ≥ 5 cm than for patients with smaller abscesses.

**Table 3** Cox proportional hazard model of 30-day and 60-day mortality for patients undergoing surgery for lung abscess

| Variable                   | Univariate             |         | Multivariate           |         |
|----------------------------|------------------------|---------|------------------------|---------|
|                            | HR (95% CI)            | p value | HR (95% CI)            | p value |
| 30-day mortality           |                        |         |                        |         |
| Surgery with lobectomy     | 0.293<br>(0.082–1.053) | 0.06    | 0.255<br>(0.068–0.959) | 0.043   |
| Age                        | 1.024<br>(0.985–1.064) | 0.237   | 0.985<br>(0.931–1.043) | 0.603   |
| Sex                        | 0.897<br>(0.250–3.215) | 0.867   |                        |         |
| Smoking                    | 1.319<br>(0.442–3.936) | 0.620   |                        |         |
| Size ≥ 5 cm                | 0.512<br>(0.177–1.477) | 0.216   | 0.640<br>(0.202–2.027) | 0.448   |
| Charlson Comorbidity Index | 1.268<br>(1.080–1.488) | 0.004   | 1.286<br>(1.059–1.561) | 0.011   |
| Empyema                    | 0.931<br>(0.326–2.654) | 0.893   | 0.663<br>(0.224–1.964) | 0.458   |
| 60-day mortality           |                        |         |                        |         |
| Surgery with lobectomy     | 0.372<br>(0.134–1.035) | 0.058   | 0.319<br>(0.110–0.921) | 0.035   |
| Age                        | 1.027<br>(0.993–1.062) | 0.120   | 0.992<br>(0.945–1.041) | 0.734   |
| Sex                        | 0.905<br>(0.300–2.729) | 0.860   |                        |         |
| Smoking                    | 1.632<br>(0.620–4.295) | 0.321   |                        |         |
| Size ≥ 5 cm                | 0.633<br>(0.249–1.610) | 0.337   | 0.867<br>(0.306–2.462) | 0.789   |
| Charlson Comorbidity Index | 1.294<br>(1.120–1.496) | < 0.001 | 1.317<br>(1.105–1.571) | 0.002   |
| Empyema                    | 0.831<br>(0.337–2.044) | 0.686   | 0.622<br>(0.245–1.580) | 0.318   |

Surgical intervention is often indicated in symptomatic patients with empyema, for which previous studies have reported satisfactory outcomes [20, 21]. However, if the empyema is related to lung abscess, the ICU admission and mortality rates are higher, with a trend toward second surgical intervention [22]. In these cases, decortication or partial lung resection may afford insufficient infection control.

In our study, age did not differ significantly between the two groups, while male preponderance was observed in the entire lung abscess cohort. We used the CCI to measure patients' comorbidities [23], and analyzed the etiology of lung abscess [3, 12]. Previous studies indicated that pulmonary malignancy was a poor predictor for lung abscess, and excluded it from the prognostication process [21, 24]. However, in the acute phase, the

**Table 4** Details of past studies on surgery for lung abscess

| Authors/<br>years<br>(country)         | Study type    | Sam-<br>ple<br>size | Indications for surgery                                                                                                                                                            | Surgical procedures                                                                                                         | Morbidity                                                                                                                          | Mortality  | Risk<br>factors                                                                 |
|----------------------------------------|---------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|------------|---------------------------------------------------------------------------------|
| Reimel et al., 2006 (USA) [1]          | Retrospective | 35                  | Empyema, $n = 17$<br>Hemoptysis, $n = 5$<br>Air leakage, $n = 7$<br>Septic shock, $n = 8$<br>Respiratory distress, $n = 7$                                                         | Pneumonectomy, $n = 4$<br>Lobectomy, $n = 18$<br>Segmentectomy, $n = 2$<br>Wedge resection, $n = 4$<br>Debridement, $n = 7$ | Wound infection, $n = 1$<br>Bronchial stump leak, $n = 1$<br>Postoperative empyema, $n = 4$<br>Cardiovascular instability, $n = 1$ | 3 (8.5%)   | Ventilator use (-)                                                              |
| Krishnadasan et al., 2000 (USA) [4]    | Retrospective | 5                   | Bronchopleural fistula, $n = 2$<br>Empyema, $n = 3$<br>Hemoptysis, $n = 1$                                                                                                         | Pneumonectomy, $n = 1$<br>Bilobectomy, $n = 1$<br>Lobectomy, $n = 2$<br>Wedge resection, $n = 1$                            | Postoperative empyema, $n = 2$                                                                                                     | N/A        | N/A                                                                             |
| Tsai et al., 2011 (Taiwan) [12]        | Retrospective | 26                  | Progressive respiratory distress, $n = 17$<br>Empyema, $n = 12$<br>Bronchopleural fistula, $n = 5$<br>Septic shock, $n = 4$<br>Hemoptysis, $n = 3$<br>Bilateral pneumonia, $n = 2$ | Wedge resection, $n = 1$<br>Lobectomy, $n = 19$<br>Bilobectomy, $n = 6$                                                     | Progressing pulmonary infection, $n = 3$<br>Postoperative empyema, $n = 3$                                                         | 4 (15.4%)  | Underlying diseases (-)                                                         |
| Schweigert et al., 2017 (Germany) [26] | Retrospective | 91                  | Pulmonary sepsis, $n = 48$<br>Empyema, $n = 43$<br>Persistent air leakage, $n = 25$<br>Acute renal failure, $n = 12$<br>Respiratory failure, $n = 25$                              | Segmentectomy, $n = 18$<br>Lobectomy, $n = 58$<br>Pneumonectomy, $n = 15$                                                   | N/A                                                                                                                                | 13 (14.3%) | Pulmonary sepsis (-)<br>Septic organ failure (-)<br>Preexisting comorbidity (-) |
| Our study                              | Retrospective | 70                  | Same as Table 1                                                                                                                                                                    | Lobectomy, $n = 32$<br>Non-lobectomy, $n = 38$                                                                              | Same as Table 2.                                                                                                                   | 19 (27.1%) | Lobectomy (+)<br>Preexisting comorbidity (-)                                    |

primary aim is to keep patients alive before further treatment; thus, we included these patients to analyze the short-term outcomes. Empyema was the most common sign of disease progression in our study, and a previous study also indicated poor outcomes for concomitant lung abscess and empyema [22]. In the current study, we performed decortication to excise “the peel” to facilitate sufficient lung expansion and evaluated the possibility of lobectomy in patients with empyema. However, since empyema hindered the approach to the bronchus and vessels, the number of patients with empyema was higher in the non-lobectomy group. Hemoptysis and air leakage often necessitate surgical treatment. We tended to perform lobectomy in patients with massive hemoptysis to remove the affected lobe and potentially eliminate the source of bleeding ( $p = 0.02$ ). In this study, the right lower lobe was the most common site of lung abscess, although the location of the lung abscess did not differ significantly between the two groups. We acquired chest CT in all patients before surgery and recorded the maximum diameter of the abscess cavity to determine its size. The lung abscess cavity size in the lobectomy group was

larger than in the non-lobectomy group, albeit without statistical significance.

The mortality rate for lung abscess accompanied by empyema exceeds 20% [22]. The mortality rate in our series was higher than that of previous studies, which could hypothetically be attributed to the larger abscess size and severe comorbidities in our patients. All patients underwent follow-up chest X-rays regularly after surgery. Persistent or progressive pneumonia was the most common post-surgical morbidity. We used the Clavien-Dindo classification to assess the surgical complications [25]. Although the morbidity rate did not differ significantly between the two groups in our study, the rate of Clavien-Dindo grade 3B was greater in the non-lobectomy group. Since we performed decortication or partial lung resection in the non-lobectomy group, the infectious source could not be eliminated completely. Damaged residual lung parenchyma could be a nidus for persistent or recurrent infections, necessitating further operation to control infection. No significant difference was noted with respect to the ICU stay and days on postoperative ventilation between the two groups. We analyzed the 30-day

and 60-day mortality using Kaplan–Meier analysis, which revealed that the lobectomy group had a significantly better survival rate. Previous studies have reported that ventilator use, concomitant empyema, septic shock, and preexisting comorbidity are among the risk factors for lung abscess [1, 12, 22, 26]. Our study showed that the outcomes are affected by the underlying comorbidity and operation method. We hypothesized that lobectomy could eliminate the damaged lung parenchyma completely in cases that are refractory to antibiotic treatment and can also avert empyema development. The underlying comorbidity is an obvious risk factor for lung abscess, consistent with previous studies.

We have summarized the details of past studies on surgery for lung abscess in Table 4. All these studies were retrospective in design and described the indications for surgery and the surgical procedure. Empyema was the most common progressive symptom in two cohorts [1, 4], and the second most common symptom in other two cohorts [12, 26]. According to those studies, empyema in patients with lung abscess often required surgical intervention, and lobectomy was the most common surgical strategy. The mortality rate ranged from 8.5 to 15.4%, and the predictive factors included ventilator use, underlying disease, sepsis, and organ failure. In our study population, we recorded the size of the abscess, and our data illustrated that lobectomy could improve the outcome. However, the mortality rate was higher than that reported by previous studies.

The limitations of our study should be acknowledged. First, the study was retrospective in design. Second, lung function testing should have been performed before and after lobectomy to evaluate the change in lung volume. However, since all of our patients underwent emergency operations, data on lung function were insufficient for analysis. Third, we did not perform long-term follow-up after the surgical procedures. This was a single-center experience, and we endeavor to accrue more comprehensive data in the future. To date, surgical intervention for lung abscesses lacks unanimous consensus, and we hope that future studies can establish categorical and clear criteria.

## Conclusions

Surgical intervention for lung abscess refractory to pharmacotherapy remains controversial. We analyzed the predictive factors for mortality in patients who underwent surgical interventions and found that thoracoscopic lobectomy could significantly improve mortality compared to other interventions. Hence, thoracoscopic lobectomy may be an effective and feasible treatment option for lung abscess recalcitrant to medical treatment.

## Abbreviations

|      |                                      |
|------|--------------------------------------|
| CCI  | Charlson Comorbidity Index           |
| CT   | computed tomography                  |
| ICU  | intensive care unit                  |
| VATS | video-assisted thoracoscopic surgery |

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Not applicable.

## Authors' contributions

Po-Keng Su: Conception and design of the study; Acquisition of data (laboratory or clinical); Data analysis and/or interpretation; Drafting of manuscript and/or critical revision; Approval of the final version of the manuscript. Shun-Mao Yang: Conception and design of the study; Data analysis and/or interpretation; Drafting of manuscript and/or critical revision; Approval of the final version of the manuscript. Cheng-Hung How: Conception and design of study; Acquisition of data (laboratory or clinical); Data analysis and/or interpretation; Drafting of manuscript and/or critical revision; Approval of the final version of the manuscript. Chao-Yu Liu: Acquisition of data (laboratory or clinical); Approval of the final version of the manuscript. Ka-I Leong: Acquisition of data (laboratory or clinical); Approval of the final version of the manuscript. Jei-Kuo Lin: Acquisition of data (laboratory or clinical); Approval of the final version of the manuscript. San-Fang Chou: Conception and design of study; Data analysis and/or interpretation.

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## Data availability

The datasets generated during this study will be available from the corresponding author on reasonable request after the publication of the main findings.

## Declarations

### Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. This study was initiated by the Far Eastern Memorial Hospital. The study was approved by the Institutional Review Board (IRB) of Far Eastern Memorial Hospital (IRB approval no. 111279-E), which waived the need for informed consent.

### Consent for publication

All authors in our study group agreed on the order of authorship and publication.

### Competing interests

The authors declare no competing interests.

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Original Paper

# Effect of Mobile Augmented Reality Counseling on Improving Shared Decision-Making in Thoracic Surgery: Randomized Clinical Crossover Trial

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## Abstract

**Background:** Augmented reality (AR) superimposes virtual objects onto a real-world environment, allowing users to interact in real time. As AR has become widely used, its integration into smartphones or tablets has enabled mobile augmented reality (MAR) experiences. AR has been adopted in many industries, and the literature has highlighted its applications in academic and clinical settings, particularly in enhancing visualization, communication, and learning.

**Objective:** This study investigated the potential of MAR as a mobile health tool to enhance shared decision-making (SDM) in thoracic surgery by increasing patient understanding and engagement during medical consultations.

**Methods:** A randomized crossover clinical trial was conducted at the Tri-Service General Hospital in Taiwan. Participants scheduled for thoracic surgery were enrolled and randomized in a crossover design. The MAR intervention incorporated patient-specific 3D anatomical models that were reconstructed from computed tomography imaging to facilitate understanding and support SDM. The impact of each counseling approach on SDM was evaluated using postintervention questionnaires.

**Results:** A total of 47 participants were enrolled in this study. After analyzing the data, we found that patients in the MAR group showed significantly higher scores compared to those in the traditional counseling group ( $P < .001$ ) during the SDM process. Moreover, patients reported higher satisfaction levels and found the visual objects helpful for understanding tumor location and surgical procedures.

**Conclusions:** This study demonstrated that MAR counseling significantly enhanced patients' comprehension of thoracic conditions and increased their active engagement in the SDM process ( $P < .001$ ). The integration of patient-specific 3D anatomical models into MAR technology provided an intuitive method for critical medical information. This digital approach not only enhanced personalization in medical communication but also reinforced patient education about their health care conditions. These findings suggest that MAR counseling represents a promising approach for promoting patient-centered care in thoracic surgery and has potential applications across various clinical domains.

**Trial Registration:** ClinicalTrials.gov NCT07062393; <https://clinicaltrials.gov/study/NCT07062393>



## KEYWORDS

mobile augmented reality; shared decision-making; patient education; thoracic surgery; 3D models

## Introduction

### Role of Mobile Augmented Reality in Clinical Counseling and Mobile Health

Augmented reality (AR) allows the seamless integration of virtual elements with real-world environments, including the superimposition of digital files, such as 3D models, animations, and videos. This enhances interactive learning, visualization, and communication in medical contexts [1]. A more accessible and scalable evolution of AR is mobile AR (MAR), which operates via smartphones and tablets [2]. Unlike AR headsets or smart glasses, MAR leverages everyday mobile devices to deliver immersive experiences, making it a cost-effective and broadly deployable solution in both clinical and remote settings.

In the medical field, AR has been increasingly applied in thoracic surgery for training, preoperative planning, and intraoperative assistance [3]. However, a noticeable gap exists in the literature regarding the use of MAR as a patient-facing mobile health (mHealth) tool to improve communication and support shared decision-making (SDM). By enabling real-time 3D visualization of patient-specific anatomy through mobile devices, MAR represents a novel strategy within the mHealth paradigm to promote accessibility, patient engagement, and autonomy in surgical counseling.

### Surgical Counseling Challenges in Thoracic Surgery

Lung cancer is a global health challenge, as reflected in the 2020 world statistics. The incidence of lung and bronchus cancer was reported at 31.5 cases per 100,000 population for men and 14.6 cases per 100,000 population for women. The widespread prevalence of lung cancer continues to affect a significant portion of the global population [4].

In Taiwan, the situation is even more concerning. According to the latest report by Taiwan's Ministry of Health and Welfare in 2021, the rate of new cases of lung and bronchus cancer was alarmingly high, at 77.39 per 100,000 population for men and 67.13 per 100,000 population for women. Among the 16,880 newly diagnosed cases, a considerable portion (40.4%) received surgical treatment [5], which is one of the essential treatment options and the standard approach for early-stage disease.

The surgical approaches for lung resection could be divided into open thoracotomy and minimally invasive thoracic surgery (ie, video-assisted and robot-assisted thoracoscopic surgery). The various modes of lung resection, including anatomical (pneumonectomy, lobectomy, and segmentectomy) and nonanatomical (wedge resection) [6], pose a significant challenge to patient understanding. Traditional methods of patient counseling, relying on oral explanations, 2D computed tomography scans, and schematic diagrams, often fail to provide a comprehensive understanding. Although informative, these methods do not fully convey the intricacies of each surgical

option, leaving patients inadequately equipped to make informed decisions.

This gap in understanding is critical, as patients need to comprehend various aspects of their condition, such as tumor location, its proximity to vital structures, and the specifics of different surgical procedures, each with its unique risks and implications. The limitations of current counseling methods highlight the necessity for innovative approaches that can enhance physician-patient communication, provide better visual support, and enable patients to engage more effectively in their treatment planning.

### Communication and SDM

Several factors contribute to the quality of patient counseling and decision-making. These include patient anxiety, cultural background, insufficient medical knowledge, and awareness, all of which can significantly influence clinical decision outcomes [7,8]. Patients tend to participate more actively in treatment planning when they clearly understand their medical information [9]. Ineffective communication, especially when lacking meaningful patient engagement [10], may result in misunderstandings, dissatisfaction, disputes, and even violence against health care providers [11]. SDM has been increasingly promoted to emphasize patient preferences, values, and autonomy in the medical decision-making process [12]. It is now widely endorsed by academic and professional societies as a means to improve decision quality [13]. In addition, assistive tools—especially visual and interactive aids—have also been shown to support this process [14].

### Study Objective

To address this unmet need, we developed a MAR-based counseling system that integrates patient-specific 3D visualization into the SDM process for thoracic surgery. This study introduces a novel application of mHealth aimed at bridging the gap between complex surgical information and patient understanding.

## Methods

### Study Design

This study was a single-center, 2-arm, randomized crossover clinical trial conducted at Tri-Service General Hospital, Taipei, Taiwan, between July 2022 and June 2023. The study compared traditional image-based counseling with MAR-enhanced counseling for patients undergoing thoracic surgery. Participants were randomized to 1 of 2 counseling sequences: traditional followed by MAR (group A) or MAR followed by traditional (group B). Each participant received both formats of counseling during a single encounter. To evaluate the impact of each method, participants completed self-administered questionnaires after each session to assess SDM and counseling preferences. No formal washout period was implemented due to the educational and noninterventional nature of the study.

## Patient and Public Involvement

Patients or the public were not involved in the design, conduct, reporting, or dissemination of this study, as the research focused on the technical development and initial validation of a mobile-based counseling tool. Future iterations may incorporate patient feedback to optimize usability and relevance.

## Sample Size Calculation

Sample size was calculated using G\*Power (version 3.1.9.7; Heinrich Heine University Düsseldorf) to detect a significant difference between 2 independent groups using nonparametric analysis. The calculation was based on unpublished pilot data from our research team, involving 10 patients who received both MAR and traditional counseling. A large effect size (Cohen  $d=0.9$ ) was observed in SDM score differences. Based on a two-tailed test with an alpha level of .05 and statistical power of 0.80, the required sample size was calculated to be 44 participants (22 per group). To accommodate for potential dropouts, 47 patients were ultimately enrolled.

## Recruitment

Participants were recruited through outpatient and inpatient referrals from thoracic surgery clinics. Inclusion criteria were as follows: (1) scheduled for thoracic surgery (eg, lobectomy, segmentectomy, or wedge resection); (2) aged 20 to 65 years; (3) capable of using a smart device; (4) able to communicate in Mandarin or Taiwanese; (5) willing and able to provide informed consent; and (6) capable of completing questionnaires independently or with minimal assistance. Exclusion criteria were as follows: (1) emergency surgery, (2) severe cognitive impairment or psychiatric illness interfering with participation, (3) visual or hearing impairments interfering with mobile device interaction, (4) prior participation in similar counseling studies, and (5) inability to complete follow-up.

## Randomization

Consenting participants were randomly allocated to either group A (traditional counseling first) or group B (MAR counseling first) using a basic random number generator by a research assistant without allocation concealment or stratification. Due to the nature of the interventions, blinding was not feasible in this study.

## Interventions

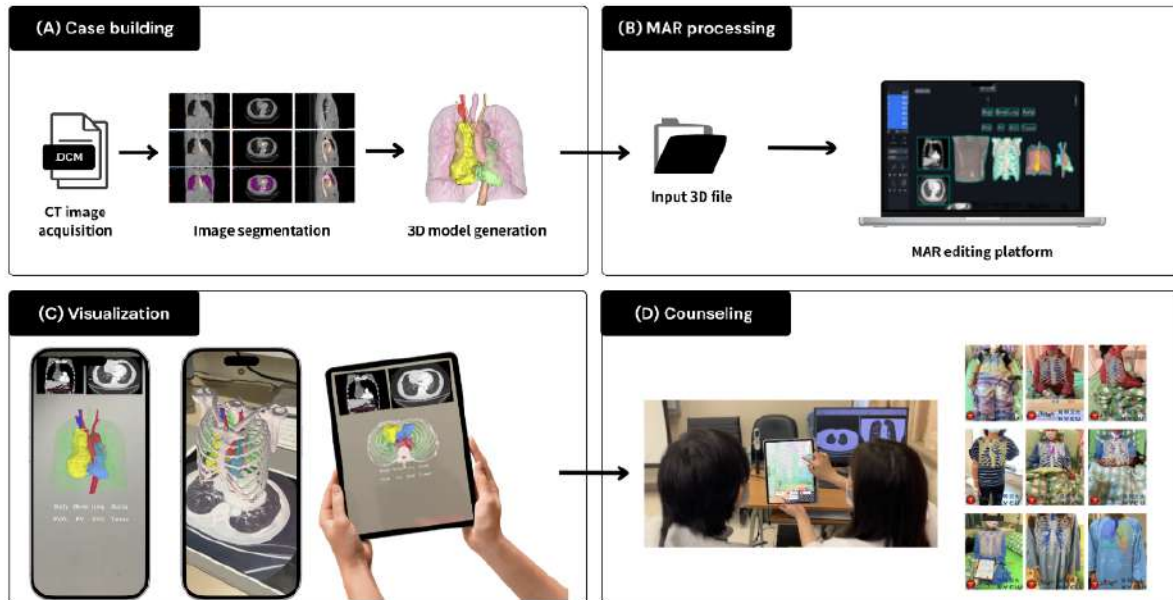
A standardized counseling protocol was developed to ensure consistency across both groups and was delivered by the same thoracic surgeon to minimize interoperator variability. During crossover sessions, surgeons maintained neutrality and avoided providing additional interpretation. Surgeons adhered to the protocol and followed a structured sequence to explain the tumor location, surgical options, and associated risks.

In group A, participants received traditional counseling first, which involved an explanation of their health condition using verbal explanations supported by axial, coronal, and sagittal CT images and a 10 to 15-minute discussion. They were asked to complete a questionnaire related to SDM (questionnaire 1), followed by MAR counseling with interactive, patient-specific 3D anatomical models presented through mobile devices, and then to fill out a second questionnaire (questionnaire 2). In contrast, participants in group B began with MAR counseling. This part included a 5-minute app introduction followed by a 10-to-15-minute personalized anatomical visualization and discussion using the MAR application. After participants (specifically to participants who are in group B) completed the questionnaire 1, they received traditional counseling and proceeded to complete questionnaire 2. All participants experienced both counseling approaches, and their overall preferences and perceptions were evaluated through a questionnaire 3. In [Multimedia Appendix 1](#), demonstration of both traditional and mobile augmented reality (MAR) counseling methods is shown in MP4 format.

## Patient-Specific 3D Models via MAR Application

CT images of 47 patients scheduled for thoracic surgery at the Tri-Service General Hospital were collected. Digital images in Digital Imaging and Communications in Medicine format were acquired and imported into Materialise Mimics software (version 22; Materialise NV) for anatomical segmentation and 3D reconstruction of the lung and tumor regions ([Figure 1A](#)). Subsequently, we meticulously crafted standard tessellation language 3D models and transformed these Standard Tessellation Language models into GLB format models in Blender software (version 3.6, Blender Foundation) to ensure accurate color representation. The finalized GLB files were then uploaded into the MAR Editor platform (version 3.4.2, Mifly). In the process of editing, we enhanced the visualization by assigning realistic colors, transparency settings, and interactive marks ([Figure 1B](#)). The editing platform allowed real-time interaction with the model on tablets or smartphones. Each model was fully interactive, allowing rotation, zooming, and exploration of the anatomical structures from multiple angles ([Figure 1C](#)). During counseling sessions, surgeons used these personalized models to explain the disease, treatment options, and the anticipated surgical procedures. ([Figure 1D](#)). For standardization, all participants interacted with the same mobile device, an iPad Pro (12.9 inch; fourth generation; Apple Inc), during MAR counseling sessions. In [Multimedia Appendix 2](#), step-by-step demonstration of the mobile augmented reality (MAR) 3D model creation and deployment is shown in MP4 format.

**Figure 1.** Preparation workflow for building a mobile augmented reality (MAR) system. (A) Acquiring patient-specific computer tomography (CT) data, performing anatomical segmentation, and generating models in a 3D format. (B) Models are optimized and uploaded to the editing platform to adjust settings. (C) Models are embedded into the application's interface, enabling interactive manipulation (zoom, rotation). (D) The finalized interactive model is deployed to the mobile device for physician-patient counseling.



## Measurement of Satisfaction Outcomes

To assess the impact of the different counseling methods on SDM and user preference, we designed the self-reported questionnaires for this study. Questionnaire 1 focused on SDM outcomes following the counseling session and included 10 items. Questionnaire 2 was the same as questionnaire 1, allowing the acquired preferences to be determined by comparing the results of questionnaire 2 with those of questionnaire 1. Questionnaire 3 specifically evaluated participants' overall preference for a traditional or an MAR counseling approach. All questionnaire items were rated on a 5-point Likert-type scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"). A higher score indicated a stronger impact of patient counseling on SDM. To ensure content validity, the questionnaires were reviewed and refined with input from an expert panel.

The primary outcome was the level of SDM assessed in each counseling session (questionnaire 1 and questionnaire 2). The secondary outcome was participant preference (questionnaire 3).

## Data Collection and Statistical Analysis

All 47 participants completed the questionnaires, and no one was excluded from the analysis. After the questionnaires were collected and anonymized in Microsoft Excel, relevant statistical analyses were performed using SPSS (version 24.0; IBM Corp). Descriptive statistics were used to summarize the baseline characteristics, demographic data, and outcome variables. Group differences were assessed using Fisher exact and the chi-square tests for categorical variables. To evaluate group comparisons and relationships among variables, independent 2-tailed *t* tests,

paired 2-tailed *t* tests, Pearson correlation analyses, and multiple linear regression models were conducted. We recognized that in a crossover study, participants receiving the experimental variable in the first period might continue to be affected in the second period. To minimize carryover effects, we applied a linear mixed model analysis, considering sequence and period effects to adjust the influencing factors.  $P < .05$  was considered statistically significant.

Given the noninterventonal and educational nature of this study, no interim analyses or stopping guidelines were planned.

## Ethical Considerations

The study was reviewed and approved by the institutional review board of Tri-Service General Hospital (A202205082) and was retrospectively registered on ClinicalTrials.gov (NCT07062393). Written informed consent was obtained from all participants before enrollment after being informed of the study purpose, procedures, and voluntary nature of participation. The study posed minimal risk, involved no invasive procedures, and used patients' own clinical data for educational counseling purposes. No additional imaging was required. No concomitant care or cointerventions were provided during the trial period. Participation was voluntary, with the right to withdraw at any time. All data were securely stored and anonymized before the analysis to ensure participant confidentiality. Access to identifiable information was restricted to authorized research personnel. No financial or material incentives were provided to participants.



## Results

### Participant Characteristics

A total of 47 participants fully completed questionnaires and were included in the final analysis, with 25 from counseling group A and 22 from counseling group B. A visual summary of the study flow is provided in [Figure 2](#). No adverse events or unintended effects were reported in either group during or after

the counseling sessions. The interventions involved no physical or psychological risks, and all participants completed the study without incident. Most participants in both groups were older than 30 years, held a university degree or higher, had been using smartphones for 10 to 20 years, and had no experience with AR or virtual reality (VR) technologies. No significant differences were observed in participant characteristics between the two groups, as summarized in [Table 1](#).

**Figure 2.** Study flowchart for participant enrollment, randomization, intervention, and analysis. MAR: mobile augmented reality.

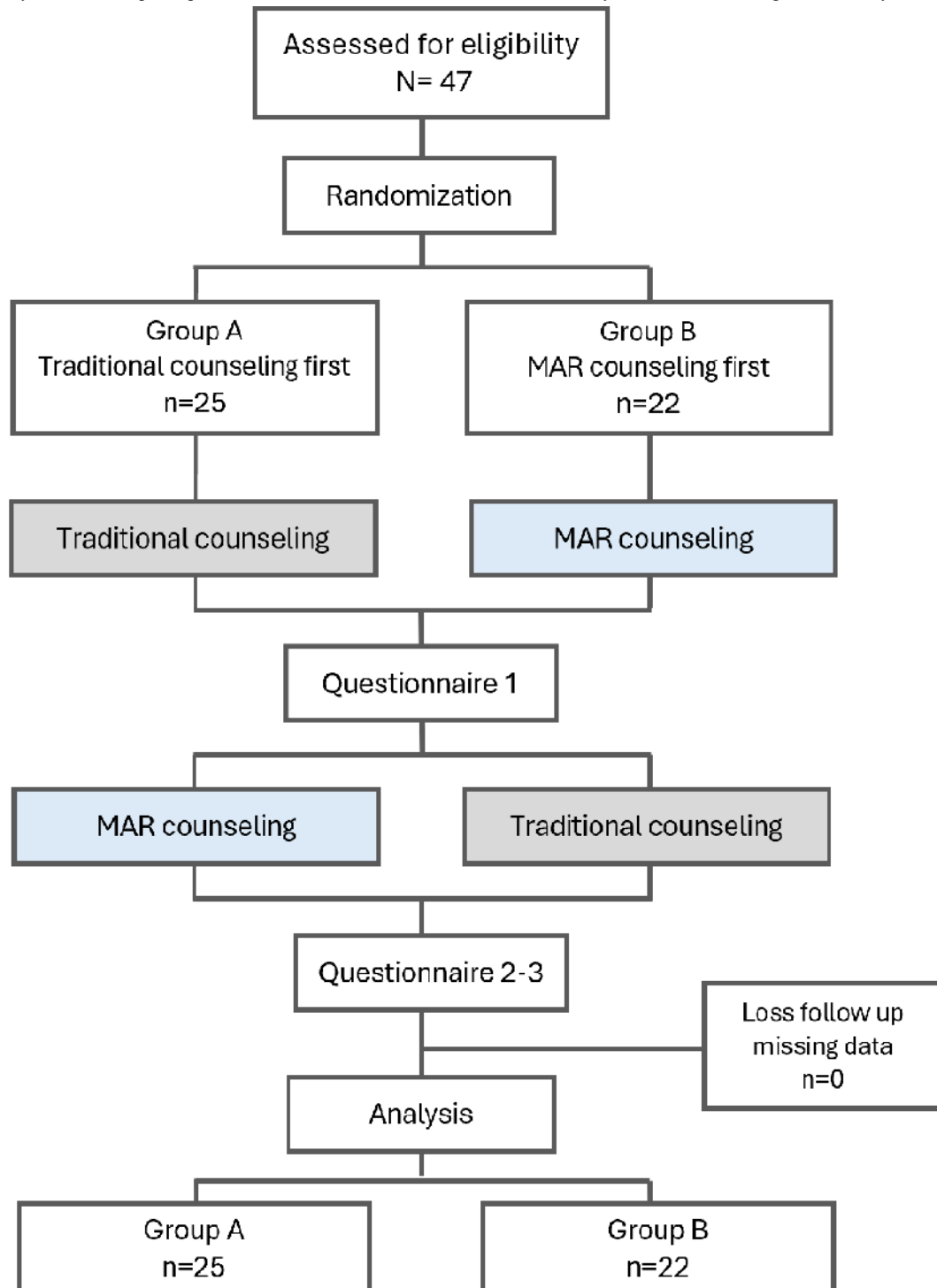


**Table 1.** Demographic characteristics of participants (N=47).

| Characteristics                                                     | Group A (n=25) | Group B (n=22) | P value           |
|---------------------------------------------------------------------|----------------|----------------|-------------------|
| <b>Sex n (%)</b>                                                    |                |                | .12 <sup>a</sup>  |
| Male                                                                | 8 (32%)        | 12 (54.6)      |                   |
| Female                                                              | 17 (68)        | 10 (45.4)      |                   |
| <b>Age (years), n (%)</b>                                           |                |                | .20 <sup>b</sup>  |
| <30                                                                 | 1 (4)          | 2 (9.1)        |                   |
| 30-59                                                               | 12 (48)        | 15 (68.2)      |                   |
| ≥60                                                                 | 12 (48)        | 5 (22.7)       |                   |
| <b>Education, n (%)</b>                                             |                |                | .35 <sup>a</sup>  |
| High school or lower                                                | 7 (28)         | 9 (40.9)       |                   |
| University or higher                                                | 18 (72)        | 13 (59.1)      |                   |
| <b>Duration of mobile phone use (years), n (%)</b>                  |                |                | >.99 <sup>b</sup> |
| ≤10                                                                 | 6 (24)         | 5 (22.7)       |                   |
| 10-20                                                               | 16 (64)        | 15 (68.2)      |                   |
| ≥20                                                                 | 3 (12)         | 2 (9.1)        |                   |
| <b>Average daily internet use (hours), n (%)</b>                    |                |                | .64 <sup>a</sup>  |
| <3                                                                  | 10 (40)        | 7 (31.8)       |                   |
| 3-5                                                                 | 10 (40)        | 8 (36.4)       |                   |
| ≥5                                                                  | 5 (20)         | 7 (31.8)       |                   |
| <b>Experience of using health care application, n (%)</b>           |                |                | .91 <sup>b</sup>  |
| Every day                                                           | 7 (28)         | 7 (31.8)       |                   |
| Every week                                                          | 5 (20)         | 4 (18.2)       |                   |
| Every month                                                         | 3 (12)         | 4 (18.2)       |                   |
| Less than once a month                                              | 4 (16)         | 4 (18.2)       |                   |
| Never                                                               | 6 (24)         | 3 (13.6)       |                   |
| <b>Experience of using AR<sup>c</sup> and VR<sup>d</sup>, n (%)</b> |                |                | .20 <sup>b</sup>  |
| Yes                                                                 | 4 (16)         | 7 (31.8)       |                   |
| No                                                                  | 21 (84)        | 15 (68.2)      |                   |

<sup>a</sup>Chi-square test.

<sup>b</sup>Fisher exact test.

<sup>c</sup>AR: augmented reality.

<sup>d</sup>VR: virtual reality.

## SDM Scores

**Table 2** presents the results of the questionnaire related to SDM. Before grouping, the overall mean score for traditional counseling was 37.40 (SD 5.83), and the overall mean score for MAR counseling was 47.98 (SD 2.92). The results related to patient SDM scores showed a significant difference ( $P \leq .001$ ). This finding indicates that MAR counseling was more effective in supporting patients' engagement in the decision-making process. In traditional counseling, the lowest-scoring topics were encouraging participation (mean 3.66, SD 0.70) and

enhancing communication (mean 3.66, SD 0.67). In contrast, MAR counseling achieved significantly higher scores in these 2 topics (mean 4.83, SD 0.38 and mean 4.87, SD 0.34;  $P < .001$ ), including thought organization (mean 4.83, SD 0.38) and trusting health care providers' treatment methods (mean 4.83, SD 0.38). MAR counseling also supported participants in understanding medical options (mean 4.74, SD 0.44) and provided more opportunities to ask questions to health care providers (mean 4.77, SD 0.43), thereby supporting decision-making (mean 4.79, SD 0.41).

**Table 2.** Results from the 10-item questionnaire assessing patients' perspectives on shared decision-making (SDM) after traditional versus mobile augmented reality (MAR) counseling.

| Questions                                                      | Traditional counseling, mean (SD) | MAR counseling, mean (SD) | <i>P</i> value <sup>a</sup> |
|----------------------------------------------------------------|-----------------------------------|---------------------------|-----------------------------|
| 1. Helps me feel more prepared to make decisions.              | 3.81(0.71)                        | 4.79 (0.41)               | ≤.001                       |
| 2. Helps me organize my thoughts about these decisions.        | 3.83 (0.64)                       | 4.83 (0.38)               | ≤.001                       |
| 3. Helps me consider the pros and cons of each option.         | 3.74 (0.68)                       | 4.77 (0.48)               | ≤.001                       |
| 4. Helps me compile the questions I want to ask.               | 3.69 (0.67)                       | 4.77 (0.43)               | ≤.001                       |
| 5. Clarifies and communicates what matters most to me.         | 3.72 (0.62)                       | 4.79 (0.41)               | ≤.001                       |
| 6. Helps me understand the available medical options.          | 3.81 (0.68)                       | 4.74 (0.44)               | ≤.001                       |
| 7. Provides me with the opportunity to ask questions.          | 3.68 (0.63)                       | 4.77 (0.43)               | ≤.001                       |
| 8. Encourages my participation in the health care process.     | 3.66 (0.70)                       | 4.83 (0.38)               | ≤.001                       |
| 9. Enhances communication between me and health care providers | 3.66 (0.67)                       | 4.87 (0.34)               | ≤.001                       |
| 10. Helps me trust health care providers' treatment methods    | 3.77 (0.73)                       | 4.83 (0.38)               | ≤.001                       |

<sup>a</sup>*P* values were obtained using the Wilcoxon rank-sum test. Higher scores indicate greater agreement with each statement (1-5 Likert scale).

Figures 3 and 4 illustrate the distribution of participant responses for each of the 10 questionnaire items following traditional and MAR counseling. In traditional counseling, most participants rated between “agree” and “neutral,” with a few selecting “strongly agree.” By contrast, the MAR counseling demonstrated higher agreement across all topics, with nearly all participants

selecting “agree or strongly agree.” The lowest-scoring item, considering the pros and cons of each treatment option (question 3), was rated at 95.46%. For all other topics, 100% of participants rated either agree or strongly agree, with virtually no neutral or negative responses.

**Figure 3.** Distribution of participant responses to each item of the 10-item Shared Decision-Making Questionnaire (SDM-Q-10) following traditional counseling. Responses were measured on a 5-point Likert scale ranging from “strongly disagree” to “strongly agree.” Item wording is provided in Table 2.

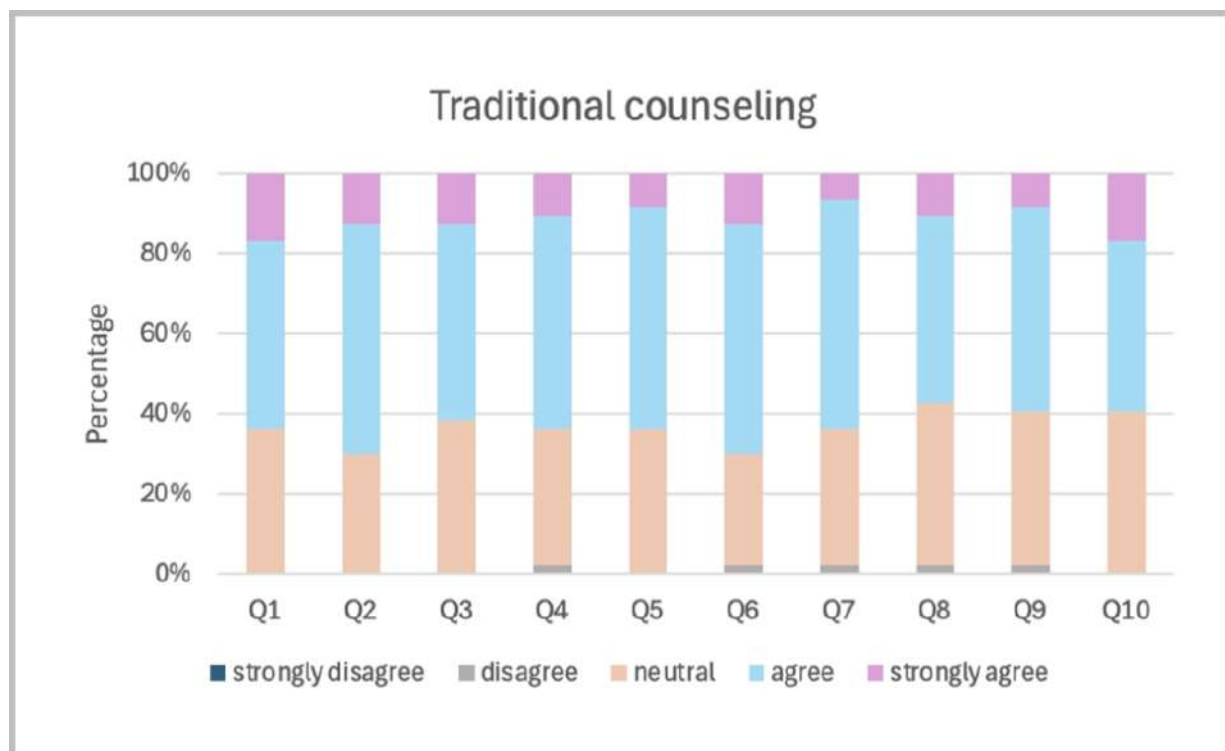
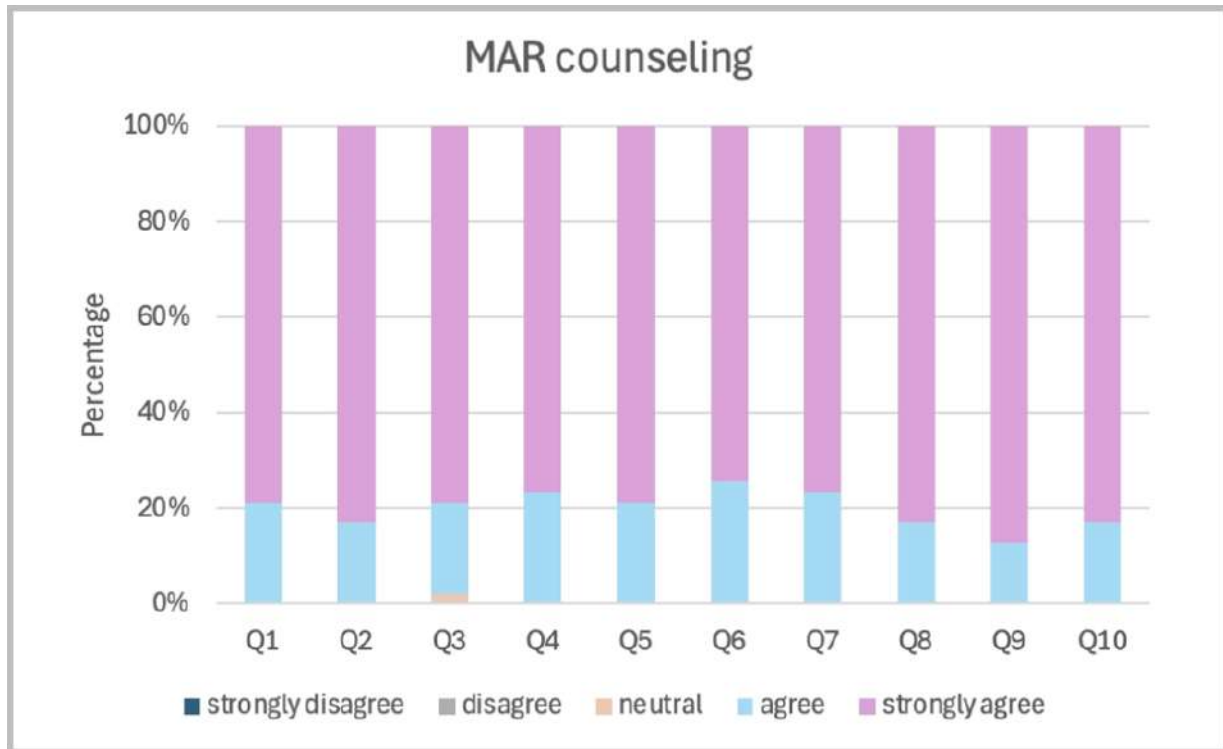


**Figure 4.** Distribution of participant responses to each item of the 10-item Shared Decision-Making Questionnaire (SDM-Q-10) following mobile augmented reality (MAR) counseling. Responses were measured on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree." Item wording is provided in Table 2.



### Interventions in Crossover Design

To evaluate the effect of counseling sequence on participant satisfaction, an independent sample *t* test was conducted to compare the differences between group A and group B in this crossover design. Participants were randomly assigned to either group A, which received traditional counseling followed by MAR counseling, or group B, which received MAR counseling first, followed by traditional counseling. The results showed no significant differences between the 2 sequences. The mean satisfaction score for traditional counseling was 36.92 (SD 6.07) in group A and 37.95 (SD 5.64) in group B ( $t=-0.60$ ,  $P=.55$ ), whereas MAR counseling scored 47.72 (SD 2.94) and 48.27 (SD 2.95) in group A and B, respectively ( $t=-0.64$ ,  $P=.52$ ). These findings indicated that the order in which traditional and MAR counseling methods were administered did not influence satisfaction outcomes.

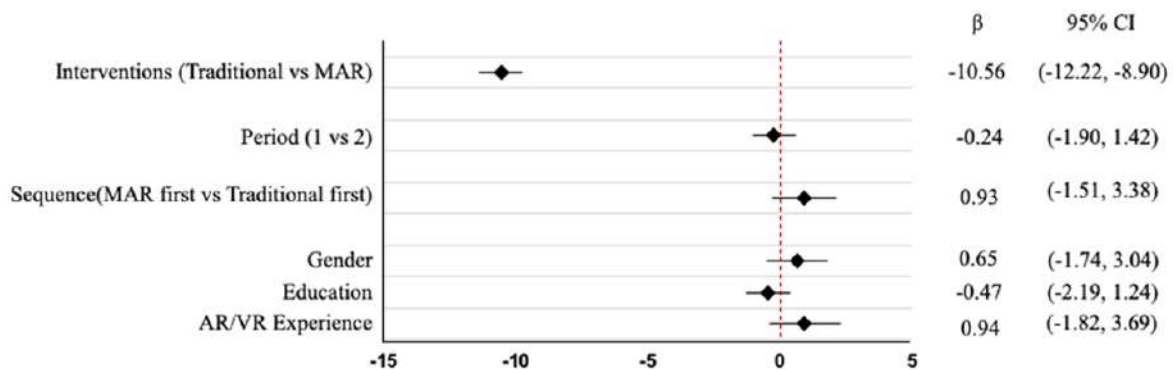
Further within-group analyses revealed that MAR counseling was consistently rated higher than traditional counseling across both sequences. In group A, the mean difference between traditional and MAR counseling was  $-10.80$  (SD 5.65,  $P<.001$ ,

Cohen  $d=-1.91$ ), and in group B, the difference between MAR and traditional counseling was  $10.32$  (SD 5.61,  $P<.001$ , Cohen  $d=1.84$ ).

### Adjusted Comparison Using Linear Mixed Model

Although the paired samples *t* test provided preliminary evidence that MAR counseling was rated higher than traditional counseling, additional analyses using a linear mixed model were conducted to examine any potential carryover effect. Considering both the sequence (traditional first or MAR first) and the period (first or second), neither the period nor the sequence effect reached statistical significance ( $P>.05$ ). Demographic variables, including gender, education level, and AR and VR experience, also did not significantly affect the outcomes. However, the analysis showed that the different interventions demonstrated a significant difference; MAR counseling scored 10.55 points higher than traditional counseling, reaching statistical significance ( $P\leq.001$ ). These findings indicate that the type of intervention was the primary factor influencing participants' perceptions; whereas period and sequence effects did not significantly impact counseling outcomes. The fixed-effect estimates are presented in Figure 5.

**Figure 5.** Fixed effects estimated from linear mixed model assessing the impact of treatment sequence, period, and demographic variables on shared decision-making (SDM) scores. AR: augmented reality; VR: virtual reality; MAR: mobile augmented reality.



### Participant Preferences

The participants' overall preferences were assessed with questionnaire 3 (I am willing to use this counseling method to communicate with health care providers; 1=traditional; 2=MAR). The analysis revealed that participants had a strong preference for the MAR counseling method. The mean score for MAR counseling (4.96, SD 0.20) was significantly higher than that for traditional counseling (mean 3.77, SD 0.70;  $P \leq .001$ ). Furthermore, 45 of 47 (96%) participants indicated a strong willingness to use MAR counseling as a communication method in the SDM process.

### Influence of Demographic Variables

To further investigate whether the participants' preferences were influenced by demographic variables, a multiple linear

regression analysis was conducted (Table 3). The results showed that none of the demographic variables, including gender, education level, duration of mobile phone use, average daily internet use, and AR and VR experience, reached statistical significance ( $P > .05$ ) in the MAR counseling group. Similarly, most of the demographic variables did not demonstrate a significant result in traditional counseling. However, without AR and VR experience showed a positive effect ( $B = 0.583$ ,  $\beta = .357$ ;  $P = .03$ ), indicating that the participants without AR and VR experience reported a higher preference for the traditional counseling approaches compared to those who had the experience in AR and VR technology. The adjusted  $R^2$  values for both models were low (MAR=0.12; traditional=0.19), indicating that demographic factors explained a small proportion of the results.

**Table 3.** Multiple linear regression predicting shared decision-making scores from demographic variables.

| Variable                                            | B (95% CI)               | $\beta$ | t test (df) | P value |
|-----------------------------------------------------|--------------------------|---------|-------------|---------|
| <b>MAR<sup>a</sup> counseling</b>                   |                          |         |             |         |
| Sex (female)                                        | 0.092 (-0.034 to 0.217)  | .224    | 1.476 (40)  | .15     |
| Education level (college)                           | -0.037 (-0.185 to 0.110) | -.092   | -0.51 (40)  | .61     |
| Education level (graduate)                          | -0.147 (-0.341 to 0.047) | -.259   | -1.532 (40) | .13     |
| Duration of mobile phone use                        | -0.003 (-0.121 to 0.116) | -.008   | -0.048 (40) | .96     |
| Average daily internet use                          | 0.026 (-0.056 to 0.109)  | .106    | 0.641 (40)  | .52     |
| AR <sup>b</sup> and VR <sup>c</sup> experience (no) | -0.013 (-0.173 to 0.148) | -.027   | -0.161 (40) | .87     |
| <b>Traditional counseling</b>                       |                          |         |             |         |
| Sex (female)                                        | 0.198 (-0.215 to 0.611)  | .142    | 0.969 (40)  | .34     |
| Education level (college)                           | 0.253 (-0.232 to 0.738)  | .183    | 1.054 (40)  | .30     |
| Education level (graduate)                          | 0.517 (-0.121 to 1.155)  | .266    | 1.637 (40)  | .11     |
| Duration of mobile phone use                        | -0.108 (-0.498 to 0.282) | -.089   | -0.561 (40) | .58     |
| Average daily internet use                          | 0.045 (-0.228 to 0.317)  | .053    | 0.332 (40)  | .74     |
| AR and VR experience (no)                           | 0.583 (0.055 to 1.111)   | .357    | 2.232 (40)  | .03     |

<sup>a</sup>MAR: mobile augmented reality.

<sup>b</sup>AR: augmented reality.

<sup>c</sup>VR: virtual reality.

## Discussion

### Principal Findings

The study results indicated that participants preferred MAR counseling more than traditional counseling approaches during SDM, particularly regarding trust and participant engagement. This effect may be attributed to participants gaining more disease-specific knowledge from MAR, which, in turn, led to increased engagement [9]. Paired samples *t* tests revealed significantly higher scores for MAR counseling, demonstrating that the digital approach had a positive impact in helping participants comprehend the risks and benefits associated with their treatment options. Furthermore, the findings were strengthened by the linear mixed model analysis, which considered sequence and period effects to adjust the impact factors. Neither the sequence nor the period effects reached statistical significance.

These findings are consistent with those of a previous study that used 3D models in patient counseling for renal masses [15]. Although it is possible that the visually rich nature of MAR contributed to patient engagement, the structured questionnaires assessed more than just visual appeal. Notably, items such as question 3 (“Helps me consider the pros and cons of each option”) and question 6 (“Helps me understand the available medical options”), which evaluated the understanding of pros and cons and treatment options, showed significant improvement in the MAR counseling. This suggests that MAR facilitated greater engagement and deeper cognitive processing of medical information. These findings indicate that the observed improvements in SDM were not limited to increased engagement or visual novelty but included measurable enhancement in understanding treatment risks and options. This supports the value of MAR not only as a communication aid but also as a decision-support tool grounded in cognitive comprehension that strengthens SDM processes in clinical practice.

### Implementation Considerations

However, several considerations should be noted. MAR counseling demanded more time and a more complex preparation process compared with traditional counseling. The cost-effectiveness of adopting this new counseling method should be explored thoroughly before full implementation.

MAR offers a powerful solution to enhance telemedicine and improve technological literacy. One key advantage is its ability to address the challenge of interpreting complex medical data, such as 2D DICOM images, which can be difficult for patients without specialized anatomical knowledge to understand. MAR overlays 3D visualizations onto the physical world, making it easier for patients and health care providers to comprehend medical images by offering an interactive, spatial representation of anatomy. This interactive experience enhances the clarity of diagnostic information, allowing for more informed SDM.

Moreover, unlike the use of AR smart glasses, which can sometimes cause discomfort such as dizziness or visual fatigue, patients using MAR on mobile devices did not report such issues. The display on a mobile device offers flexibility in positioning and control, reduces strain on the eyes, and prevents

the sensory overload that can occur with head-mounted displays. As a result, patients were more comfortable engaging with the technology for extended periods, facilitating a more seamless integration of MAR into telemedicine and clinical workflows. This ease of use further promotes patient empowerment, enabling them to take an active role in understanding their own health data.

Prior literature has reported that 3D models have made telemedicine visits as effective as in-person visits [15]. This finding could be applied to MAR counseling, as the counseling process can be conducted through smartphones or tablet devices. The integration of MAR into telemedicine can potentially enhance the quality of counseling in the future.

### Limitations

However, the implementation of MAR consultation also has hidden challenges. Compared with traditional methods, MAR counseling demands a longer preparation time, additional training for clinical staff, and reliance on stable hardware and network infrastructure. Although MAR technology offers the advantage of accessing virtual resources anytime and anywhere, whether in medical education or clinical settings, its effectiveness and usability remain closely tied to technical settings. When users operate MAR systems in environments with limited bandwidth or outdated hardware, they may experience delays, failed file loading, or degraded 3D rendering performance. These limitations may result in reduced acceptance or satisfaction, regardless of the perceived educational or clinical value of the MAR content.

Additionally, the questionnaires used in this study were developed to reflect the unique attributes of MAR, which may limit direct comparison with SDM outcome measures (eg, the 9-item Shared Decision Making Questionnaire or the OPTION [Observing Patient Involvement] scale). Future studies should incorporate validated tools alongside MAR-specific items to improve generalizability and construct validity. Finally, the study was conducted at a single institution with a modest sample size, which may limit the broader applicability of our findings. Although the sample size was statistically adequate based on pilot data, larger multicenter trials are warranted to improve generalizability and explore subgroup effects. Future multicenter studies with larger and more diverse populations, time-matched conditions, and validated instruments are warranted to confirm the impact and feasibility of MAR counseling in thoracic surgery and beyond.

### Conclusions

MAR counseling demonstrated a significantly higher impact on SDM compared with traditional counseling for patients undergoing thoracic surgery. This indicates that MAR consultation is effective in supporting patients' engagement in the decision-making process and enhancing their understanding, participation, and trust. Importantly, MAR counseling demonstrated statistically significant improvements in participants' perceptions compared to traditional counseling. In contrast, under traditional counseling, patients often find it difficult to effectively organize their questions. Insufficient interaction with physicians may limit patients' active



participation in the SDM process. MAR consultation scored significantly higher in the same topics, better supported patients, and promoted communication between physicians and patients. However, we recommend conducting a multicenter study with

a usability score assessment to validate the generalizability and feasibility of MAR counseling in future research. This will help ensure the widespread applicability and practicality of this approach in a broader context.

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### Data Availability

The datasets generated and analyzed during this study are not publicly available due to institutional restrictions but are available from the corresponding author upon reasonable request.

### Authors' Contributions

Conceptualization: KHL

Methodology: KHL, DHW, WR

Data curation: YSC

Formal analysis: YCH

Funding acquisition: KHL

Investigation: YSC

Project administration: KHL

Resources: TWH

Software: YCH, WR, DHW

Supervision: KHL, DHW

Validation: TWH

Visualization: YCH (lead), DHW (supporting)

Writing—original draft: YSC (lead), YCH (lead), JL (supporting)

Writing—review and editing: YSC (lead), YCH (lead), JL (supporting), KHL (supporting), TWH (supporting)

All authors have read and approved the final manuscript.

### Conflicts of Interest

None declared.

### Multimedia Appendix 1

Demonstration of both traditional and mobile augmented reality counseling methods (MP4 format).

[\[MP4 File \(MP4 Video\), 16670 KB-Multimedia Appendix 1\]](#)

### Multimedia Appendix 2

Step-by-step demonstration of the mobile augmented reality 3D model creation and deployment (MP4 format).

[\[MP4 File \(MP4 Video\), 88583 KB-Multimedia Appendix 2\]](#)

### Multimedia Appendix 3

CONSORT checklist.

[\[PDF File \(Adobe PDF File\), 246 KB-Multimedia Appendix 3\]](#)

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## Abbreviations

**AR:** augmented reality  
**VR:** virtual reality  
**MAR:** mobile augmented reality  
**SDM:** shared decision-making

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# Enhancing three-dimensional anatomical understanding in complex thoracic surgery: a comparative study of OpVerse and Synapse 3D

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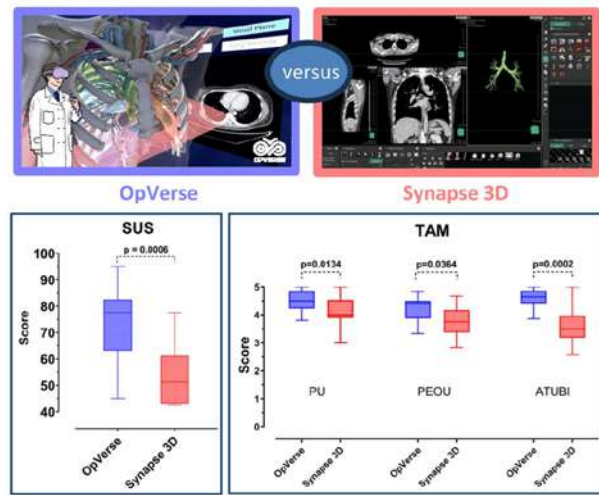
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## Enhancing Three-Dimensional Anatomical Understanding in Complex Thoracic Surgery: A Comparative Study of OpVerse and Synapse 3D

### Summary

The study evaluated the efficacy of OpVerse, a new VR platform, in enhancing 3D anatomical understanding during complex thoracic surgeries. The authors created patient-specific VR digital twin thoracic models from CT scans of 13 patients and had 12 system testers evaluate the usability and user acceptance of OpVerse and Synapse 3D.

**OpVerse exhibited enhanced capabilities for facilitating 3D anatomical comprehension**



Legend: VR, virtual reality; CT, computed tomography; SUS, system usability scale; TAM, technology acceptance model; PU, perceived usefulness; PEOU, perceived ease of use; ATUBI, attitude toward using and behavioral intention to use

### Abstract

**OBJECTIVES:** Virtual reality (VR) technology is increasingly employed in medical settings to provide innovative solutions for complex surgeries. In this study, we introduced and compared OpVerse, a multifunctional new VR platform developed for surgical simulations, with established software Synapse 3D to assess its efficacy in facilitating complex thoracic surgeries.

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**METHODS:** Patient-specific VR digital twin thoracic models were created based on computed tomography scans of 9 patients with large thoracic neoplasms and 4 requiring tracheobronchial reconstruction. Twelve doctors as system testers were enlisted to evaluate the usability and user acceptance of OpVerse and Synapse 3D using the System Usability Scale (SUS) and the Technology Acceptance Model; they provided qualitative feedback through interviews.

**RESULTS:** OpVerse achieved higher scores than Synapse 3D in SUS ( $73.3 \pm 14.6$  vs  $53.8 \pm 11.6$ ,  $P = 0.0006$ ), as well as perceived usefulness ( $4.5 \pm 0.4$  vs  $4.1 \pm 0.5$ ,  $P = 0.0134$ ), perceived ease of use ( $4.2 \pm 0.4$  vs  $3.8 \pm 0.6$ ,  $P = 0.0364$ ) and attitude towards using and behavioural intention to use ( $4.6 \pm 0.4$  vs  $3.6 \pm 0.7$ ,  $P = 0.0002$ ) in Technology Acceptance Model, compared to Synapse 3D, indicating enhanced efficiency and user engagement with the new system. Participants favoured OpVerse for its immersive qualities, intuitive interface (particularly rotation and enhanced visual transparency effects) and ability to enhance comprehension of complex 3D anatomical structures.

**CONCLUSIONS:** OpVerse, our streaming VR simulation platform, enables the manipulation and visualization of patient-specific digital twin thoracic models through features such as rotation, enhanced visual transparency effects and measurement. Preliminary results suggest that OpVerse may offer advantages in terms of immersion, ease of use and understanding of 3D anatomical structures compared to Synapse 3D.

**Keywords:** Complex thoracic surgery • Digital twin • Metaverse • Surgical simulation • Synapse 3D • Virtual reality

#### ABBREVIATIONS

|     |                                 |
|-----|---------------------------------|
| 2D  | Two-dimensional                 |
| 3D  | Three-dimensional               |
| CT  | Computed tomography             |
| STL | Stereolithography (file format) |
| SUS | System Usability Scale          |
| TAM | Technology Acceptance Model     |
| VR  | Virtual reality                 |

## INTRODUCTION

Thoracic surgery's intricate nature, due to the delicate organs involved, necessitates precise handling and avoidance of iatrogenic harm, particularly in complex cases [1]. While two-dimensional (2D) computed tomography (CT) scans have been crucial for surgical planning, their limitations in conveying spatial relationships can hinder comprehension for those with less medical training. Three-dimensional (3D) imaging overcomes this by providing a superior spatial representation of patient anatomy, facilitating clearer understanding and aiding both surgeons in preoperative planning and patients in making informed decisions.

Initially, the use of 3D reconstruction software, such as Synapse 3D (Fujifilm Medical Co., Ltd, Tokyo, Japan), was popular for this purpose. However, with the gradual rise of virtual reality (VR), this approach has begun to play an increasingly important role in the field of 3D surgical simulation associated with the planning of complex surgical procedures [1].

VR offers an immersive 3D environment for anatomical visualization, enhancing strategic planning and demonstrating clinical benefits like improved preoperative planning, enhanced decision-making and reduced operative time [2, 3]. Additionally, integrating communication technologies with VR facilitates real-time collaboration among multidisciplinary teams, improving patient outcomes and physician efficiency. However, the specific advancements gained by transitioning from 3D models on flat screens to VR experiences remain under-explored in the literature.

In this study, we developed a novel VR surgical simulation system named OpVerse. We conducted a comparative study with Synapse 3D, a commercial 3D reconstruction software package (Fujifilm), to evaluate the usability and effectiveness of both systems in facilitating anatomical understanding. This serves as an

initial report on OpVerse, highlighting its potential advantages in surgical planning and education.

## PATIENTS AND METHODS

### Patients

Thirteen individuals participated in this study. Among them, 9 had large thoracic neoplasms ( $>5$  cm) affecting vital organs such as great vessels, the heart and the airway, or causing nerve compression. The remaining 4 required tracheobronchial reconstruction due to deformative tracheobronchial trees. These patients were enrolled at a single institution between April 2021 and April 2024, with written informed consent obtained from all participants. The National Taiwan University Hospital Research Ethics Committee approved the study (project approval number 202305019RINC, approval date: 23 October 2023).

### Testers

Twelve doctors, comprising 3 attending surgeons, 4 senior residents of thoracic surgery and 5 junior residents of general surgery, evaluated the software to assess user experience. All testers provided written informed consent and confirmed no history of cybersickness associated with VR usage. All participants were first-time users of OpVerse and were not involved in any stage of its development process.

### Development of OpVerse

With patient consent, a preoperative thin-slice chest CT scan ( $\leq 1$  mm thickness) was performed without special protocol, which typically takes  $\sim 10$  min (Fig. 1A). A senior thoracic surgery resident used Synapse 3D for 3D reconstruction, a process that involves some built-in automation features but still requires significant manual verification and correction (Fig. 1B). This step generally takes  $\sim 1$ – $2$  h, depending on the complexity of the case. The accuracy of the final 3D models was verified by an attending thoracic surgeon. A digital twin model mirroring the specific anatomy, including tumour size and location, and vital structures of the patient, was obtained. We exported STL files, commonly used in 3D printing, which represent each organ or

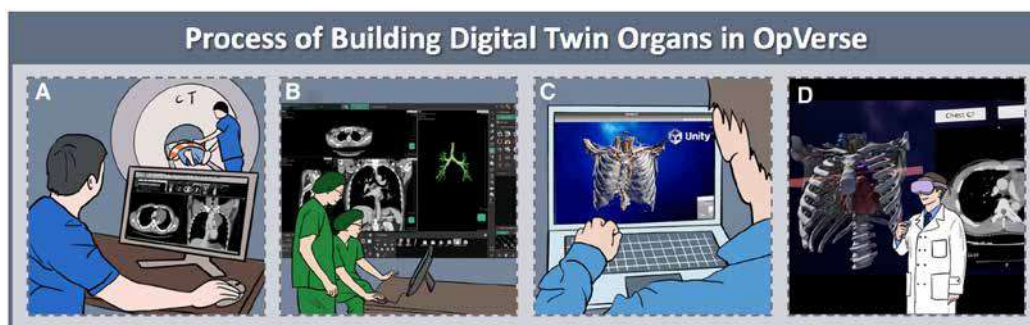


**Figure 1:** Process of building digital twin organs in OpVerse. (A) Acquisition of high-resolution patient CT data in DICOM format. (B) Reconstruction of a 3D digital model from the CT data using specialized software. (C) Creation of an immersive VR environment within the Unity platform. (D) Manipulation and observation of the patient's digital twin thoracic model in the VR world using a head-mounted display. 3D: three-dimensional; CT: computed tomography; DICOM: digital imaging and communications in medicine; VR: virtual reality.

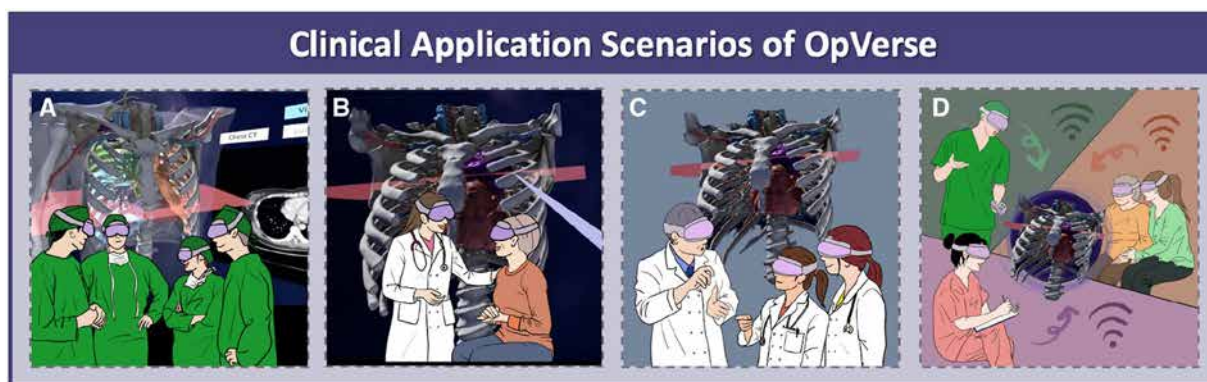


**Figure 2:** Clinical application scenarios of OpVerse. (A) Utilization of the system for preoperative multidisciplinary team discussions and surgical planning. (B) Employment of the system for patient education and disease explanation. (C) Integration of the system into medical education curricula. (D) Demonstration of the system's streaming capabilities, enabling real-time collaboration across different locations.

system of a patient. These files were subsequently imported into Unity 3D (version 2023.2.15; Unity Technologies, San Francisco, CA, USA), utilized as a game engine for our VR applications and converted into VR-compatible models scaled at a 1:1 ratio. This post-processing step, which applies optimized parameters refined through multiple trials, typically takes ~0.5–1 h (Fig. 1C). The detailed flowchart of the procedure can be found in [Supplementary Material, Fig. 1](#).

VR digital twin models were displayed within the metaverse, accessed using head-mounted displays (Meta Quest 3, Meta, Menlo Park, CA, USA), enabling users to freely interact with (Fig. 1D) and explore the models from different perspectives in various clinical scenarios (Fig. 2A–C).

We also developed a streaming feature for real-time collaboration and educational purposes, facilitating access through various devices, including mobile phones, personal computers and head-mounted displays. Utilizing web real-time communication, we established a cloud-streaming service, allowing for interactive updates on the server and multicasting to clients, with the audio of the primary user broadcast remotely (Fig. 2D).

## Features of OpVerse

Upon receiving the VR headset, users encounter bifurcated interactive content. The right segment displays CT imaging data, accessible through a handheld controller. In contrast, the left

presents a 3D thoracic model, using semitransparent and varying colour rendering to differentiate organs and tissues, with pivotal structures annotated. Additionally, we have designed a cross-sectional view of the 3D thoracic model to correlate with the CT images displayed on the right (Fig. 3A). Users can rotate their thoracic model in all directions using a handheld controller equipped with a laser pen to designate target locations. Users can also employ a toggle button to activate or deactivate the 3D model data of the corresponding organ and adjust their viewing angle to transition between transparent and opaque visual presentations.

Furthermore, the distance measurement feature of this system addresses the limitations of traditional 2D imaging modalities, such as CT or magnetic resonance imaging, which are restricted to measuring lengths along the 3 mutually perpendicular axes (X, Y, Z). This feature also facilitates the measurement of curved lengths.

Through these controls, users gain the ability to observe and analyse the anatomical structures of specific cases from every perspective within the VR environment.

## Study design

The user experience of OpVerse and Synapse 3D (version 6.7; Fujifilm Medical Co., Ltd) was compared through 3 tasks: counting ribs involved or abutted by the tumour (task 1, Fig. 3B); the maximum length of the thoracic tumour was measured thrice (task 2,



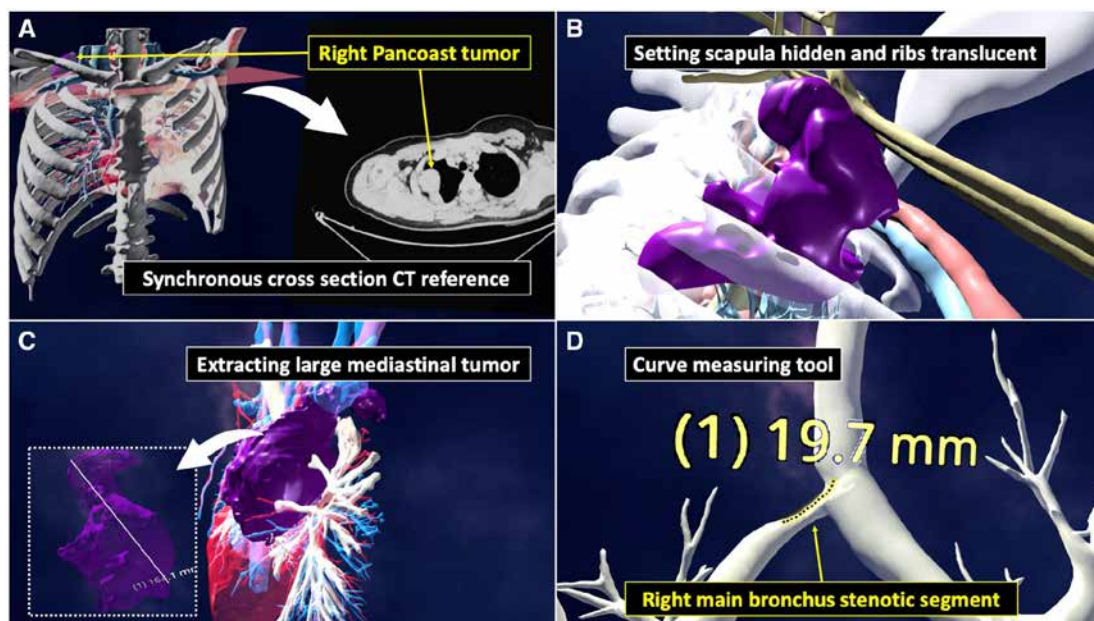


**Figure 3:** Features and functionalities within OpVerse that can be leveraged to address testing tasks. **(A)** A digital twin chest model of a 37-year-old female (case #1) with a right Pancoast tumour, displayed alongside the corresponding CT cross-section for reference. **(B)** Task 1: count the number of ribs affected by the tumour for case #1. **(C)** Task 2: measure the longest diameter of the anterior mediastinal pleomorphic lipoblastic sarcoma for a 28-year-old male (case #3). **(D)** Task 3: measure the curved length of the tuberculosis-related stenotic bronchus segment for a 38-year-old female (case #10). CT: computed tomography.

Fig. 3C) and measuring the stenotic length of the deformative tracheobronchial tree thrice (task 3, Fig. 3D). Participants performed these tasks using both systems, with the starting system randomly assigned to each participant to avoid bias. Following a 2-min tutorial, participants commenced their assigned 3 tasks. The 1st task, which involved counting the number of ribs abutted by the tumour, was performed once. The 2nd and 3rd tasks, which involved measuring lengths, were repeated 3 times. Participants then completed the System Usability Scale (SUS) and Technology Acceptance Model (TAM) questionnaires, based on a five-point Likert scale. SUS scores were calculated as  $(X + Y) \times 2.5$ , where  $X$  equals the sum of points from odd-numbered questions –5, and  $Y$  equals 25 minus the sum of points from even-numbered questions. Following task and questionnaire completion, interviews were conducted to gather subjective evaluations of both systems, guided by a pre-established outline. The study design algorithm is outlined in Fig. 4.

## Statistical analysis

The paired  $t$ -test was conducted for SUS and TAM score comparison. These analyses were performed using Statistical Analysis System version 9.4. (SAS Institute Inc., Cary, NC, USA). Statistical graphs were generated using GraphPad Prism version 10.0.0 for Windows (GraphPad Software, Boston, MA, USA). All tests were two-sided, and a  $P$ -value of  $<0.05$  was considered statistically significant.

## RESULTS

### Patients

Our study included 13 patients undergoing complex thoracic surgeries. Seven patients had large mediastinal tumours, 2 had

Pancoast tumours and 4 underwent tracheobronchial reconstruction using cryopreserved aortic allografts [4] (Table 1). Patients with mediastinal tumours underwent sternotomy with an average operative time of  $301.7 \pm 127.7$  min, experiencing no severe complications (Clavien-Dindo  $\leq$  II). Median intensive care unit and hospital stays were 4 and 10 days, respectively. One patient (case #8) had prolonged stays due to myasthenia gravis-related respiratory failure. For Pancoast tumours, a modified Masaoka incision enabled safe tumour resection, resulting in hospital stays under 10 days and unaffected postoperative activities for both patients. Tracheobronchial reconstruction cases typically exceeded 600 min, except for patient 11, where the operative time was significantly reduced due to localized damage.

### User experience

The 12 system testers comprised 4 women and 8 men, with an average age of  $33.0 \pm 8.2$  years (range: 23–55 years) (Supplementary Material, Table S1). Although the initial task completion time was comparable between Synapse 3D ( $53.8 \pm 27.6$  s) and OpVerse ( $52.3 \pm 29.1$  s), subsequent repetitions of tasks 2 and 3 were faster in OpVerse. Furthermore, OpVerse measurements exhibited less variation (Supplementary Material, Table S2), suggesting greater consistency.

The SUS test results indicate that the average usability score for OpVerse among the 12 doctors was  $73.3 \pm 14.6$ , whereas that for the Synapse 3D system averaged  $53.8 \pm 11.6$  ( $P = 0.0006$ , Supplementary Material, Table S3 and Fig. 5A).

The TAM assessment demonstrated that OpVerse was rated significantly higher than Synapse 3D in terms of perceived usefulness ( $4.5 \pm 0.4$  vs  $4.1 \pm 0.5$ ,  $P = 0.0134$ ), perceived ease of use ( $4.2 \pm 0.4$  vs  $3.8 \pm 0.6$ ,  $P = 0.0364$ ), and attitude towards using and behavioural intention to use ( $4.6 \pm 0.4$  vs  $3.6 \pm 0.7$ ,  $P = 0.0002$ )

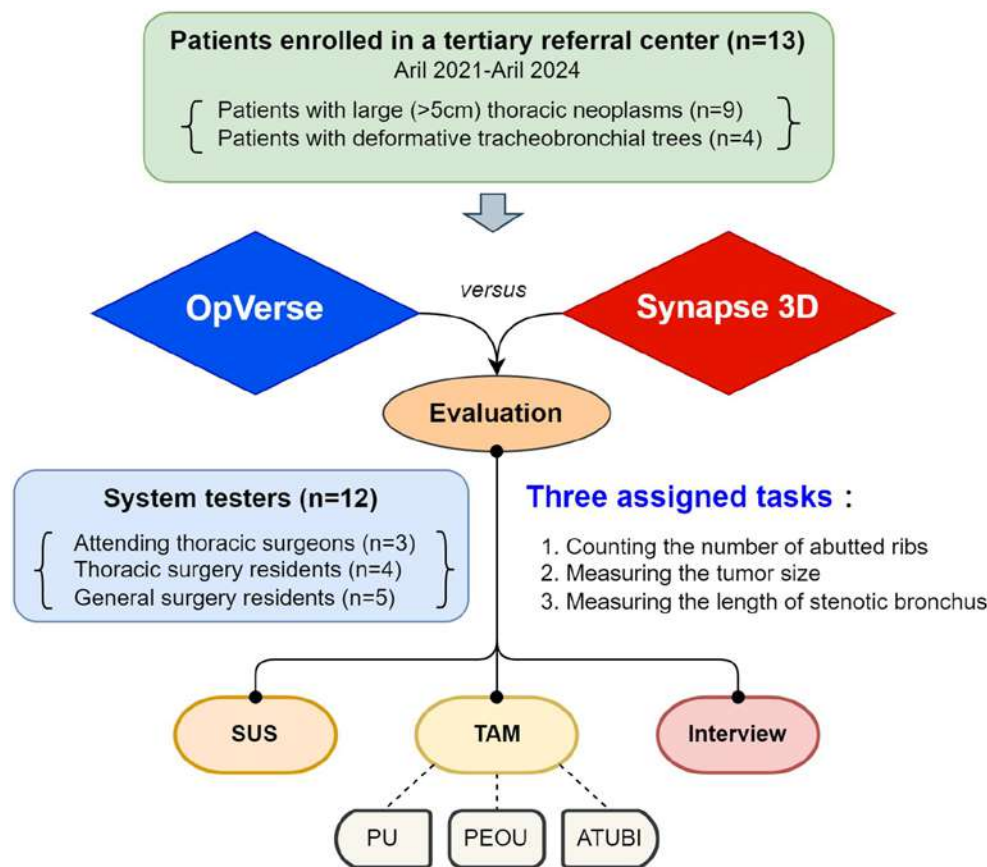


**Figure 4:** Algorithm of study design. 3D: three-dimensional; ATUBI: attitude towards using and behavioural intention to use; PEOU: perceived ease of use; PU: perceived usefulness; SUS: System Usability Scale; TAM: Technology Acceptance Model.

(Supplementary Material, Table S4, Fig. 5B). Detailed SUS and TAM scores for each participant are available in Supplementary Material, Fig. S2 and Supplementary Material, Tables S5 and S6.

Feedback from system testers strongly favoured OpVerse for enhancing 3D anatomical comprehension (Interview outline is provided in Supplementary Material, Table S7). A majority (10/12) found OpVerse superior to Synapse 3D in visuals, usability and immersion, particularly for 3D visualization and multi-angle observation. The enhanced visual transparency effects were most favoured (7/12), aiding understanding of spatial relationships. Additionally, 67% (8/12) emphasized the rotation function's value in enhancing 3D understanding through multi-angle observation. In terms of interactive features that enhanced engagement, 25% (3/12) appreciated the drag and zoom functions for their flexibility, responsiveness and ease of use, contributing to a more enjoyable user experience.

Most respondents (83%, 10/12) found operating 3D models in VR to be simpler and more intuitive than on a flat screen. Moreover, 75% (9/12) reported that OpVerse offered a stronger sense of immersion and 3D perception, facilitating a clearer understanding of spatial relationships.

However, 17% of respondents (2/12) pointed out some disadvantages of the VR system. Respondent 10 mentioned that the VR system has a high learning cost, requires time to adapt and the necessary equipment can be expensive. Respondent 12 noted that although the VR system provides a seamless interface

and model observation, the equipment requirements may limit its widespread adoption. Six respondents suggested improvements in the measurement function, noting that it lacks precision and makes grasping depth and position difficult.

We have provided a comprehensive introductory video about this OpVerse research, encompassing the system development process, functionalities, research design and outcomes. Please refer to the video for a more thorough understanding (Video 1).

## DISCUSSION

Three-dimensional imaging enhances understanding of surgical anatomy, particularly complex structures. Commercial software such as Synapse 3D and Mimics, along with open-source options including MITK, 3D Slicer and InVesalius, have minimized unexpected surgical errors in recent years by enabling preoperative simulation [5]. The application of VR for 3D anatomical visualization has been validated as an effective method for surgical planning. However, these 2 modalities—3D reconstruction software and VR simulation systems—have not been directly compared until now. Our newly developed VR system, OpVerse, generates digital twin organ models from specific patient images, offering high immersion. Observing, measuring and manipulating 3D models with this system is straightforward. Additionally, the remote streaming capability of the system,

**Table 1:** The basic information of enrolled patients undergoing complex thoracic surgery

|           | Age | Sex | Diagnosis                                                  | Critical point of surgery                                                                              | Treatment                                                                                                           | Hospital stay (days) | ICU stay (d) | Operative time (min) | Clavien-Dindo classification |
|-----------|-----|-----|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|----------------------|--------------|----------------------|------------------------------|
| <b>1</b>  | 37  | F   | Desmoid tumour                                             | Right Pancoast 6 cm tumour with abutment to right brachial plexus                                      | Modified right Masaoka incision for tumour excision + right 1st–3rd rib partial resections                          | 7                    | 2            | 347                  | II                           |
| <b>2</b>  | 48  | M   | Atypical carcinoid tumour                                  | Recurrent 14 cm mediastinal tumour with severe airway compression and great vessel encasement          | Sternotomy for tumour debulking surgery                                                                             | 18                   | 6            | 357                  | II                           |
| <b>3</b>  | 28  | M   | Pleomorphic lipoblastic sarcoma                            | Large 10 cm mediastinal tumour with severe adhesion to aorta, pulmonary artery and pericardium         | Neoadjuvant CCRT, followed by left thoracotomy for tumour excision                                                  | 10                   | 1            | 148                  | I                            |
| <b>4</b>  | 30  | M   | Undifferentiated liposarcoma                               | Large 12 cm mediastinal tumour with severe adhesion to great vessels                                   | Sternotomy for tumour excision, followed by adjuvant CCRT                                                           | 9                    | 4            | 244                  | I                            |
| <b>5</b>  | 31  | M   | Synovial sarcoma                                           | Left Pancoast 5 cm tumour with encasement of left subclavian vein and abutment to left brachial plexus | Modified left Masaoka incision for tumour excision + left clavicle ORIF, followed by adjuvant CCRT                  | 9                    | 2            | 225                  | I                            |
| <b>6</b>  | 24  | M   | Germ cell tumour                                           | Large 10 cm mediastinal tumour with abutment to aorta, pulmonary artery and pericardium                | Neoadjuvant chemotherapy, followed by sternotomy for tumour excision                                                | 7                    | 1            | 144                  | I                            |
| <b>7</b>  | 56  | F   | Desmoid tumour                                             | Large 8 cm mediastinal tumour with invasion to manubrium and abutment to innominate vein and SVC       | Sternotomy for tumour excision + sternoclavicular joint reconstruction                                              | 17                   | 9            | 449                  | II                           |
| <b>8</b>  | 58  | F   | Thymoma (type B2/B3) with myasthenia gravis                | Mediastinal 6 cm tumour with direct invasion to innominate vein and SVC                                | Neoadjuvant chemotherapy, followed by sternotomy for radical thymectomy + SVC reconstruction using artificial graft | 58                   | 33           | 446                  | II                           |
| <b>9</b>  | 58  | M   | Atypical carcinoid tumour                                  | Large 9 cm tumour with involvement of innominate vein and pericardium                                  | Sternotomy for tumour excision + innominate vein ligation + pericardium repair, followed by adjuvant chemotherapy   | 10                   | 1            | 324                  | II                           |
| <b>10</b> | 38  | F   | Tuberculosis-related right main bronchus stenosis          | Right main bronchus stenosis with RUL total collapse                                                   | RUL lobectomy + right main bronchus bronchoplasty using cryopreserved aortic allograft                              | 23                   | 7            | 617                  | I                            |
| <b>11</b> | 23  | M   | Traumatic trachea rupture                                  | 1st and 2nd trachea ring rupture with respiratory compromise                                           | Tracheal defect repair using cryopreserved aortic allograft                                                         | 52                   | 4            | 294                  | II                           |
| <b>12</b> | 6   | F   | Corrosive oesophageal injury, complicated with T-E fistula | T-E fistula ~2.5 cm in length                                                                          | Sternotomy for T-E fistula repair using cryopreserved aortic allograft under CPB support                            | 54                   | 19           | 605                  | IIla                         |
| <b>13</b> | 44  | M   | Tuberculosis-related lower trachea stenosis                | Segmental trachea stenosis in length                                                                   | Right thoracotomy for tracheal reconstruction using cryopreserved aortic allograft under VV-ECMO support            | 79                   | 42           | 699                  | II                           |

CCRT: concurrent chemoradiotherapy; CPB: cardiopulmonary bypass; ICU: intensive care unit; ORIF: open reduction and internal fixation; RUL: right upper lung; SVC: superior vena cava; T-E fistula: trachea-oesophageal fistula; VV-ECMO: venovenous extracorporeal membrane oxygenation.



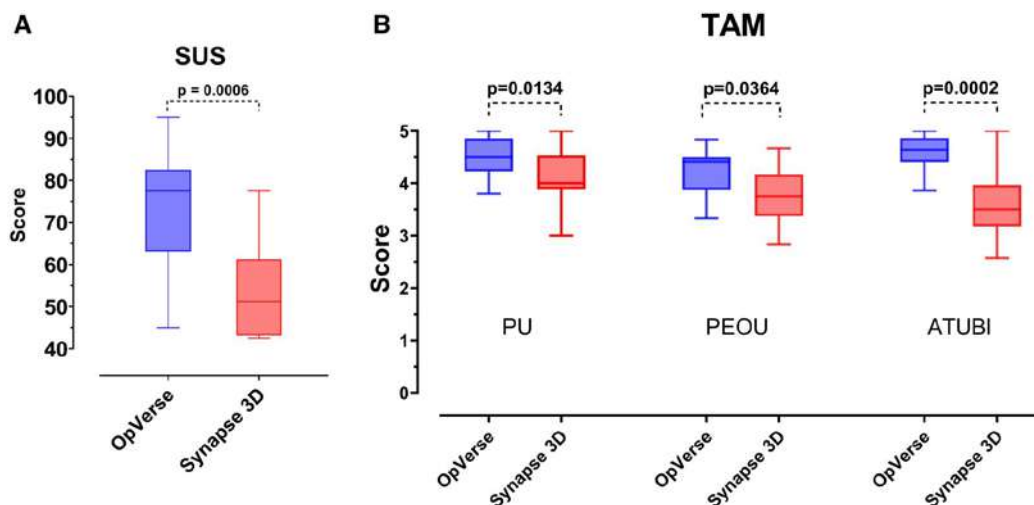
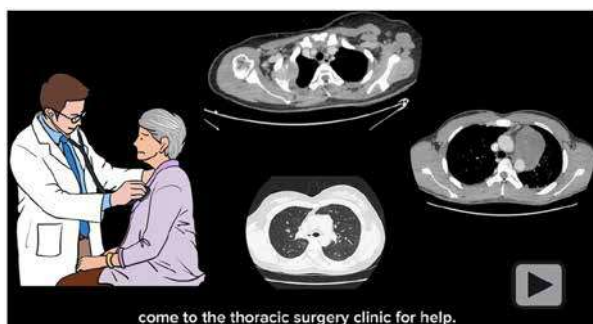
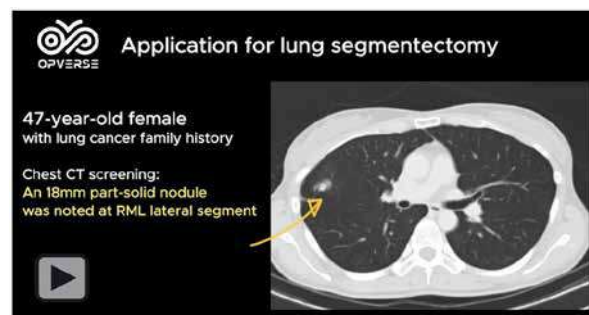


**Figure 5:** Comparison of OpVerse and Synapse 3D using (A) SUS and (B) TAM assessment questionnaires. 3D: three-dimensional; ATUBI: attitude towards using and behavioural intention to use; PEOU: perceived ease of use; PU: perceived usefulness; SUS: System Usability Scale; TAM: Technology Acceptance Model.



**Video 1:** This video demonstrates the workflow of creating patient-specific digital twin models in OpVerse, a novel VR platform for surgical simulation, and presents the results of comparing OpVerse with Synapse 3D in terms of usability and user experience.



**Video 2:** This video illustrates how the OpVerse system aids in the preoperative simulation and assessment for a patient scheduled for RML S4 segmentectomy, emphasizing its immersive experience, three-dimensional visualization, and user-friendly interface.

combined with the aforementioned features, allows for its use in medical explanations, multidisciplinary discussions, preoperative planning and education.

In our study, we selected complex mediastinal tumours and tracheal deformities for VR visualization due to their intricate anatomical relationships and critical structures. Mediastinum involves vital organs where any inadvertent injury can have severe consequences. VR models enhance anatomical understanding, increasing surgical confidence and reducing unexpected injuries. Tracheobronchial reconstruction was chosen for its complexity and limited global experience. Our VR system possibly improves understanding of deformed tracheal anatomy, minimizing failure risks. Surgeries with complex anatomy and low tolerance for error are well-suited for preoperative planning using such VR simulation systems. Although we selected these challenging cases as pilot test subjects for this study, the application scope of our system is not limited to these scenarios. For example, common segmentectomy procedures can also benefit from the enhanced stereoscopic depth and immersion provided by our VR system (Video 2).

Compared with 3D reconstruction software, such as Synapse 3D, in this study, respondents reported fewer difficulties using OpVerse. Although 3D reconstruction software offers advanced

functions like fusion, extraction and automatic image analyses, untrained operators may face challenges with these functions and interference during basic operations. Difficulties in operating 3D models, particularly in model rotation in Synapse 3D, were also corroborated by the perceived usefulness and perceived ease of use dimension of the TAM questionnaire. The rotation function of OpVerse was frequently cited as a significant advantage, with ~67% of respondents indicating greater flexibility than Synapse 3D, easing the achievement of desired view-points. Furthermore, the enhanced visual transparency effect is a vital design feature of the OpVerse system. Over half of the testers believed that enhanced visual transparency effects facilitated understanding the relative positions of anatomical structures. Owing to superior visual effects, enhanced transparency is another key reason why 80% of testers considered OpVerse superior to Synapse 3D. Additionally, based on scores for attitude towards using and behavioural intention to use in the TAM questionnaire, we believe that OpVerse captures user attention more effectively owing to its superior immersive experience and enjoyable use. The ease of use of OpVerse was also supported by interview results. Many interviewees noted that the OpVerse system is more user-friendly than Synapse 3D for beginners.

OpVerse's superior performance in SUS and TAM scores compared to Synapse 3D can be attributed to its enhanced immersive experience and user-friendly interface, which includes features such as intuitive controls, efficient model rotation and effective visual transparency. These scores are derived from well-validated and reliable assessment tools, signifying their credibility in evaluating technological usability and acceptance [6, 7]. While this study did not directly assess clinical outcomes, existing research suggests a potential correlation between improved SUS and TAM scores and positive clinical impacts in medical training and patient education. For instance, studies have shown that XR technologies potentially enhance anatomical understanding, improve efficiency in surgical procedures and facilitate surgical training and skill acquisition [8–10]. Given the reliance of surgical procedures on precise anatomical understanding and minimal error tolerance, the immersive nature of VR simulation systems like OpVerse may be particularly valuable in this context.

In our 1st task, using Synapse 3D, 5 out of 12 individuals reported that 4 ribs were in contact with or encased by the tumour. However, using OpVerse, testers reported a maximum of 3 ribs in contact with or encased in the tumour. This discrepancy may be attributed to the simplification of the 3D model during its creation to reduce hardware load. In actual surgery, although the 4th rib came into contact with the tumour, there was no adhesion or invasion. While 3D images or models may not be fully able to predict tumour invasiveness, particularly in borderline cases difficult to predict from original CT images, both OpVerse and Synapse 3D met the original design requirements for accuracy and precision in 3D model display.

VR presents promising opportunities for surgical simulation, yet several challenges persist. The high cost of advanced VR hardware can limit accessibility for some institutions and individuals. While our study did not report instances of cybersickness, its potential impact on users warrants consideration. The current limitations in haptic feedback realism and the steeper learning curve observed in older users represent further areas for improvement. Our research suggests a potential correlation between age and VR adaptation, emphasizing the need for tailored training approaches. Additionally, the physical design of VR headsets, particularly their weight, may pose challenges for patient use. Technical issues can also disrupt training sessions. These factors highlight the necessity for continuous refinement and user-centred design in the development of VR systems for surgical simulation to ensure their widespread adoption and effectiveness in improving surgical training and patient care.

The integration of VR technology into thoracic surgery has revolutionized preoperative planning and surgical training. It provides 3D, interactive and patient-specific anatomical representations that enhance surgical precision, decision-making and outcomes. This marks a significant shift from traditional 2D imaging techniques. Recently, an increasing number of research teams have successfully applied VR technology to thoracic surgeries. However, most of these advances have been published as case reports or case series, lacking comparative studies using existing imaging tools ([Supplementary Material, Table S8](#)) [2, 3, 11–18]. A few studies have compared VR with traditional CT imaging, but researchers may have overlooked the comparison between VR and 3D reconstruction software [17, 18]. Prior to the rise of VR, we heavily relied on 3D reconstruction software to aid our understanding of surgical anatomy and preoperative

planning [19]. Thus, comprehensive comparative studies are required.

The present study effectively filled this gap. To our knowledge, no previous study has directly compared VR with 3D reconstruction software for application in thoracic surgery. Additionally, this study provided questionnaire surveys and actual operation interviews with not only less experienced postgraduate year residents but also attending thoracic surgeons, contributing to the current literature.

## Limitations

Our study has several limitations. First, the lack of multicentre involvement and blinding may introduce bias, as testers were from the same institution where the tool was developed. Although we randomized the order of system usage and included participants from different levels of medical training, the perception of bias remains. Second, while the pilot nature of this study limited the number of testers, we conducted structured interviews to elicit insightful and rich qualitative data, offering valuable insights despite the smaller sample size [20]. Future studies should include testers from different institutions for a more neutral evaluation. Additionally, our data focused on user-based assessments of VR and 3D software usability rather than their direct application in surgical procedures. A prospective, large-numbered, multi-institutional study on perioperative outcomes in real-world settings is needed to establish clinical efficacy.

## CONCLUSION

In conclusion, we developed a streaming VR simulation platform, OpVerse, which allows users to manipulate and view patient-specific digital twin thoracic models using functions such as rotation, enhanced visual transparency effects and measurement. Preliminary results suggest that OpVerse may offer advantages in terms of immersion, ease of use and understanding of 3D anatomical structures compared to existing reconstruction software like Synapse 3D. However, further validation is needed. We anticipate that, with additional independent testing, the OpVerse system could be effectively applied to preoperative simulations, multidisciplinary discussions, disease explanations and medical education.

## SUPPLEMENTARY MATERIAL

[Supplementary material](#) is available at *EJCTS* online.

## FUNDING

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**Conflict of interest:** none declared.

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The authors confirm that OpVerse, the software described in this manuscript, is not currently commercialized or available for sale in any form.



## DATA AVAILABILITY

The data underlying this article cannot be shared publicly due to the privacy of individuals that participated in the study. The data will be shared on reasonable request to the corresponding author.

## ETHICS APPROVAL

The National Taiwan University Hospital Research Ethics Committee approved the study (project approval number 202305019RINC, approval date: 23 October 2023).

## Author contributions

**Yu-An Zheng:** Data curation; Investigation; Writing—original draft. **Yi-Ching Lee:** Investigation; Writing—original draft. **Jing-Yuan Huang:** Data curation; Formal analysis; Investigation. **Hsien-Yuan Hsieh:** Data curation; Investigation. **Yang-Sheng Chen:** Investigation; Methodology; Software. **Xu-Heng Chiang:** Conceptualization; Formal analysis; Project administration; Writing—review & editing. **Ping-Hsuan Han:** Supervision; Validation. **Mong-Wei Lin:** Supervision; Validation. **Haso-Hsun Hsu:** Supervision; Validation. **Yi-Ping Hung:** Funding acquisition; Methodology; Resources; Software; Supervision. **Jin-Shing Chen:** Conceptualization; Funding acquisition; Supervision.

## Reviewer information

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## Room 101C (English) | Sunday, July 12, 2026

### President's Paper Award

**Time: 09:15-10:00 (GMT+8)**

|             |             |                                                                                                                                                                                                                      |
|-------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             | Jin-Shing Chen (Taiwan)<br>Chair(s): Chung-Ping Hsu (Taiwan)<br>Yukio Sato (Japan)                                                                                                                                   |
| PPA-1       | 09:15-09:27 | <b>Effect of Environmental Factors on Postoperative Recurrent Primary Spontaneous Pneumothorax: A Case-crossover Study</b><br>Yu-Wei Liu (Taiwan)                                                                    |
| PPA-2       | 09:27-09:39 | <b>Sublobar Resection Versus Lobectomy for Small (<math>\leq 3</math> cm) NSCLC with Visceral Pleural Invasion: A Propensity-Score-Matched Survival Analysis from a Nationwide Cohort</b><br>Xu-Heng Chiang (Taiwan) |
| PPA-3       | 09:39-09:51 | <b>Clinical Stage-Specific Prognostic Impact of Adequate Lymphadenectomy in Early-Stage Lung Cancer</b><br>Chia Liu (Taiwan)                                                                                         |
| 09:51-10:00 |             | <b>Award Presentation &amp; Group Photo</b>                                                                                                                                                                          |

RESEARCH

Open Access



# Effect of environmental factors on postoperative recurrent primary spontaneous pneumothorax: a case-crossover study

Yu-Wei Liu<sup>1,2,3</sup>, Chieh-Ni Kao<sup>2</sup>, Chi-Chang Ho<sup>4</sup>, Shah-Hwa Chou<sup>2</sup>, Pau-Chung Chen<sup>4,5,6,7,10\*</sup> and Shu-Hung Huang<sup>3,8,9,10\*</sup>

## Abstract

**Objective** Surgery is one of the preferred primary treatments for primary spontaneous pneumothorax (PSP); however, postoperative recurrent pneumothorax (PORP), defined as recurrence on the same side, occurs in 3–13% of cases. While environmental factors have been implicated in PSP occurrence, their role in PORP remains unclear. This study aimed to investigate the impact of environmental factors on the onset of PSP and PORP in the same patient population.

**Methods** Between 2009 and 2019, a total of 442 patients (aged ≤ 40 years) underwent 486 surgeries for PSP, with 43 patients (8.8%) experiencing a first PORP. Management of PORP included reoperation (29 patients), pleural drainage with chemical pleurodesis (4 patients), and conservative observation (10 patients). In this case-crossover study, the day of symptom onset for PSP and PORP was designated as the “case day.” To evaluate potential lag effects, the days leading up to symptom onset, ranging from 1 day prior (lag day 1) to 7 days prior (lag day 7), were also analyzed as “case days.” Unidirectional matched control days were selected 14–21 days before the case day (lag day 0).

**Results** Elevated PM<sub>2.5</sub> levels were significantly associated with PSP onset at lag day 0 and lag day 1, with increased odds observed at these time points ( $p = 0.04$  and  $p = 0.02$ , respectively). No such association was found for PORP patients. Meteorological factors did not appear to influence PSP or PORP risk. Seasonally, both the PSP incidence and the PORP incidence were significantly greater in autumn and spring than in summer and winter ( $p < 0.001$ ).

**Conclusion** PSP and PORP demonstrate seasonal clustering, with higher incidences in autumn and spring. Elevated PM<sub>2.5</sub> levels appear to contribute to PSP onset but not PORP, suggesting that air pollution may be a potential trigger for PSP. Further research is needed to clarify environmental influences and optimize tailored management strategies.

**Clinical trial number** Not applicable.

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**Keywords** Primary spontaneous pneumothorax (PSP), Postoperative recurrent pneumothorax (PORP), Environmental factors, Meteorology, Air pollution, Seasonal variations

## Introduction

Primary spontaneous pneumothorax (PSP) is a benign condition that predominantly affects young, tall, and thin males. Despite well-established management strategies, the high recurrence rate remains a significant challenge. Recurrence rates for PSP are typically reported to range from 16 to 52%, complicating counseling about future risk and creating uncertainty regarding optimal management [1]. More recent studies indicate that recurrence occurs in 21–32% of cases after the first episode, with 4–21% involving the contralateral side [2, 3]. Our previous research demonstrated that preemptive contralateral blebectomy during initial PSP surgery significantly reduces the risk of future contralateral recurrence [4, 5]. Currently, conservative management is recommended for initial PSP treatment, with early surgical intervention reserved for patients who prioritize recurrence prevention—such as those with a history of tension pneumothorax, persistent air leak, or high-risk occupations [6, 7]. However, postoperative recurrent pneumothorax (PORP), defined as recurrence on the same side, still occurs in 3–13% of patients following surgery [8–10].

The triggers for PSP episodes remain largely undefined, contributing to anxiety and psychological burdens among affected young individuals. Over the last few decades, studies have proposed potential associations between PSP incidence and meteorological or environmental factors, but findings have been inconsistent across different geographic regions [11–17]. A recent systematic review and meta-analysis [18] echoed these inconsistencies, attributing them to variations in study designs, measurement methods, and statistical analyses. While some studies reported higher temperatures on days with spontaneous pneumothorax (SP) than on control days, research on the influence of air pollution on PSP has been limited, resulting in inconclusive evidence.

PSP and its recurrence present considerable clinical and public health concerns in young adults, and the optimal strategies for prevention remain uncertain. In particular, efforts to predict and reduce the occurrence of PORP are areas with significant room for improvement.

This study seeks to address these gaps by conducting a longitudinal analysis of a well-characterized PSP cohort with documented postoperative recurrence. The primary objective of this study was to investigate the associations between meteorological and air pollution factors and the occurrence of PSP and PORP episodes in the same patient population.

## Methods

### Study design and patient enrollment

This retrospective cohort study reviewed 673 primary spontaneous pneumothorax (PSP) cases treated between January 2009 and December 2019 at a tertiary center in southern Taiwan. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Kaohsiung Medical University Hospital (Approval no. KMHIRB-E(1)-20240197), with a waiver of written informed consent. Of these cases, 442 patients who underwent 486 video-assisted thoracoscopic surgeries (VATS) for PSP were included. To exclude secondary spontaneous pneumothorax cases, patients older than 40 years, those with preexisting pulmonary diseases, and those with prior ipsilateral thoracic surgeries were excluded.

The 3-port needlescopic VATS technique, as described by Chou et al. [19], was employed. The visceral pleura was thoroughly inspected, followed by blebectomy via an endoscopic stapler (Echelon 60; Ethicon, USA, or Autosuture GIA Universal; Covidien, USA) on the basis of the surgeon's preference. For pleurodesis, our standard practice primarily involved mechanical pleural abrasion using Marlex mesh (Bard Limited, UK) or gauze until uniform blood oozing was achieved. Talc pleurodesis and apical pleurectomy were reserved specifically for managing PORP. Postoperative recurrent pneumothorax (PORP) was defined as a recurrence confirmed by chest X-ray or computed tomography (CT) scan occurring > 7 days after chest tube removal following initial VATS [20].

### Exposure measurement

The environmental data were sourced from the Taiwan Climate Change Projection Information and Adaptation Knowledge Platform (TCCIP) [21], while the air pollution data were provided by the Environmental Protection Administration. Daily air pollutant concentrations were estimated via hybrid spatial prediction models on the basis of measurements from Taiwan Air Quality Monitoring (TAQM) stations. Data on meteorological and air pollution factors were collected for patients' residential areas and regular activity regions, with simulated data estimated to the township level.

The key pollutants analyzed included NO<sub>2</sub>, O<sub>3</sub>, and PM<sub>2.5</sub>, alongside meteorological factors such as atmospheric pressure, temperature, rainfall, and relative humidity. The time intervals for these factors were extracted to explore associations with PSP and PORP onset in the same patients. Detailed methodologies for

air pollutant data collection, geospatial datasets, and prediction models have been published previously [22].

A case-crossover design was employed, leveraging its similarity to traditional matched-pair case-control designs, with patients serving as their own controls. This design utilizes data from the same participant at different time points for self-comparison, effectively controlling for time-invariant confounders such as genetic factors, sex, and chronic diseases. By minimizing inter-individual variability, the design reduces the potential influence of confounders on study outcomes (i.e., case and control groups share identical confounder profiles). While this approach is robust in controlling for certain biases, the use of retrospective observational data may overlook some time-varying confounders, such as acute disease onset. However, such “unexpected events” are generally infrequent across the study population and are unlikely to significantly bias the causal inference between the variables of interest (e.g., air pollution) and health outcomes.

This design is particularly effective for investigating short-term associations but is inherently limited by exposure measurement heterogeneity. Meteorological factors and air pollutants were assessed using daily mean, maximum, and minimum values for the case day (day of symptom onset) and lag days (1–7 days prior). Parameters analyzed included  $\text{NO}_2$ ,  $\text{O}_3$ , and  $\text{PM}_{2.5}$ , alongside meteorological factors such as atmospheric pressure, temperature, rainfall, and relative humidity, consistent with previous studies [14, 15, 23, 24].

#### PORP management and follow-up

Primary treatment options for PORP include observation, pleural drainage with sclerosing agents, or reoperation, with decisions made through doctor-patient counseling. Pneumothorax size was calculated using the formula by Collins et al. PORP with <20% lung collapse

was managed with oxygen therapy, while pleural drainage was applied for 20–30% collapse. Chemical pleurodesis with OK432 was used when no air leaks were present, and full lung re-expansion was confirmed. Reoperation was indicated for >30% lung collapse, visible blebs or bullae (>1 cm) on CT, air leaks lasting >3–5 days post-drainage, or unresolved collapse after conservative treatment.

All patients underwent reoperation under general anesthesia with double-lumen intubation in the lateral decubitus position via VATS. A 10-mm camera port was placed in the sixth or seventh intercostal space, avoiding previous port sites. Two additional ports were created under direct vision. Adhesiolysis was performed as needed using electrocautery. Blebs/bullae were resected with an endostapler. Pleurectomy, Talc pleurodesis, or additional coverage methods were applied at the surgeon’s discretion (see *Additional Fig. 1*).

In terms of posttreatment follow-up, patients attended outpatient clinics one week post-discharge and continued regular visits for six months. They were instructed to seek medical attention if they experienced symptoms suggestive of pneumothorax recurrence, such as chest pain, cough, or dyspnea.

#### Statistical analysis

Statistical analyses were conducted via STATA software version 14.0 for Windows. The case-crossover design utilized patients as their own controls. Continuous variables are expressed as the means ± standard deviations (SDs) or medians (ranges), and categorical variables are expressed as percentages. Comparisons between categorical variables were made via the chi-square test or Fisher’s exact test. Spearman’s rank correlation coefficient was used to evaluate the relationships between meteorological factors and air pollutants.

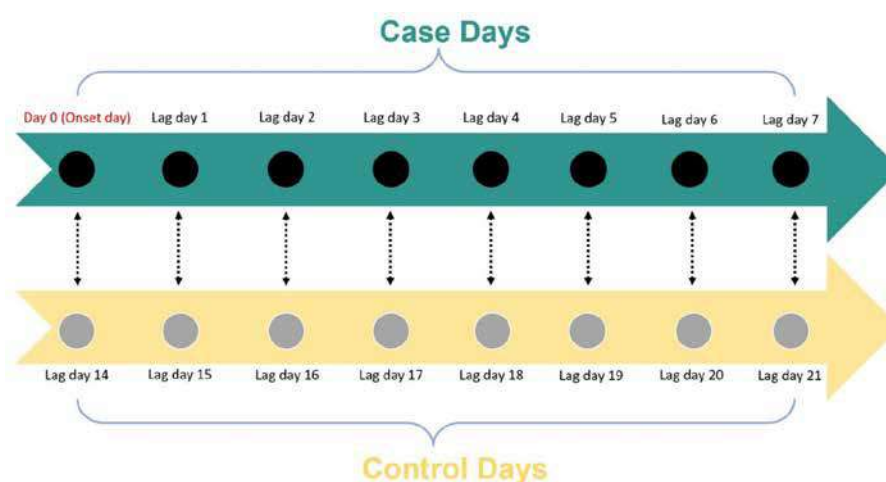


**Fig. 1** A scheme showing case days and control days related to case-control design

The case day was defined as the day of PSP symptom onset (day 0). Lag days 1–7 (preceding symptom onset) were also analyzed, with unidirectional matched control days selected 14–21 days prior to the case day to evaluate lag effects (Fig. 1). Conditional logistic regression was employed for unidirectionally matched data, with odds ratios (ORs) reported per standard deviation increase in daily mean or maximum values. The results are presented with 95% confidence intervals (CIs), and statistical significance was set at  $p < 0.05$ .

## Results

### Clinical characteristics

Between January 2009 and December 2019, a total of 442 patients (aged  $\leq 40$  years) underwent 486 surgeries for PSP. In total, 79 cases of postoperative recurrence were identified. Patients with contralateral recurrence ( $n = 21$ ), non-first ipsilateral recurrence ( $n = 14$ ), or simultaneous bilateral recurrence ( $n = 1$ ) were excluded, leaving 43 patients with a first ipsilateral PORP. These patients were categorized into three treatment groups: conservative observation with simple oxygen therapy ( $n = 10$ ), reoperation ( $n = 29$ ), and pleural drainage with chemical pleurodesis ( $n = 4$ ) (Fig. 2).

Within the entire PSP cohort, our surgical indications for PSP primarily included recurrence, evident blebs or bullae on chest CT ( $> 1$  cm), persistent air leakage, and other relevant factors during the first episode. Over a median interval of 13.5 months (range: 1.1–68.9 months), 43 cases of first ipsilateral postoperative recurrent

pneumothorax (PORP) were identified, corresponding to a recurrence rate of 8.8% (43/486). Additionally, we included data from 399 patients without PORP for comparison. As shown in Table 1, a comparison between PORP and non-PORP patients revealed no significant differences in clinical characteristics. However, PORP patients exhibited numerically higher complication rates (18.5% vs. 13%) compared to non-PORP patients, although the difference was not statistically significant.

### Environmental factors associated with initial PSP and PORP onset

The daily mean levels of  $PM_{2.5}$ ,  $NO_2$ , and  $O_3$  on the day of initial PSP onset were  $37.55 \mu g/m^3$ , 20.4 ppb, and 35.3 ppb, respectively. For PORP onset, these values were  $34.1 \mu g/m^3$ , 19.6 ppb, and 37.4 ppb. The meteorological parameters on the day of initial PSP onset included a daily mean surface atmospheric pressure of 1009.7 hPa, rainfall of 7.39 mm, relative humidity of 70.2%, and temperature of  $25.3^\circ C$ . The corresponding values at PORP onset were 1010.4 hPa, 3.8 mm, 68.1%, and  $25.1^\circ C$ , respectively.

The distributions of daily average air pollutant levels and meteorological factors for PSP and PORP are shown with visual representations provided in Fig. 3 and Fig. 4.

Significant correlations were observed between air pollutants and meteorological factors, except for ozone ( $O_3$ ), which was not significantly associated with most weather parameters (see *Additional Tables 1 and 2*).

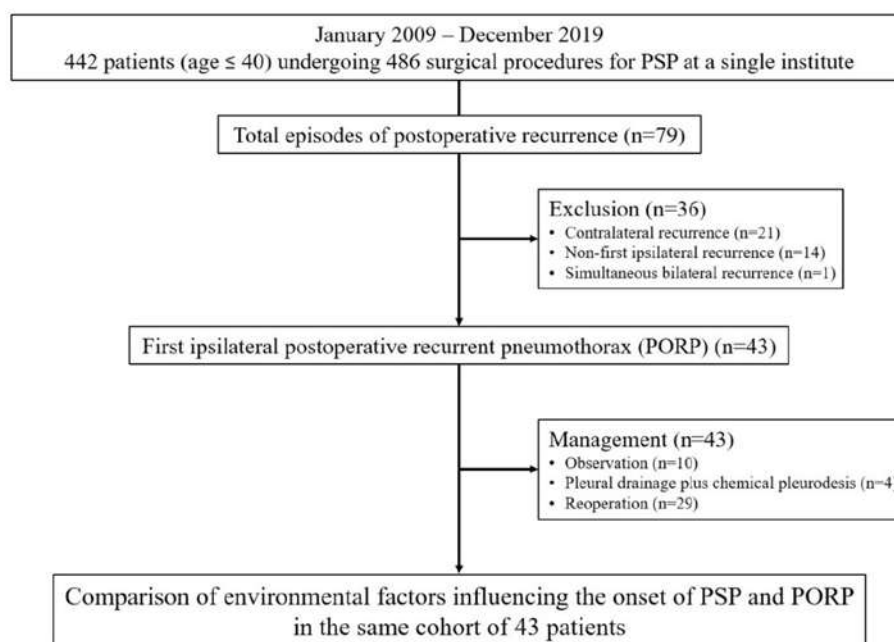


**Fig. 2** Flow diagram of patient recruitment. PSP, *primary spontaneous pneumothorax*; PORP, *postoperative recurrent pneumothorax*



**Table 1** Demographic and clinical features of PSP patients according to PORP

| Variables                                                    | Non-PORP patients (n = 399) | PORP patients (n = 43) | p-value |
|--------------------------------------------------------------|-----------------------------|------------------------|---------|
| Age, yr (median, range)                                      | 19 (15–40)                  | 18 (14–40)             | 0.52    |
| Male, N (%)                                                  | 351 (88%)                   | 39 (91%)               | 0.89    |
| Smoking, N (%)                                               | 72 (18%)                    | 6 (14%)                | 0.57    |
| Body mass index, Kg/m <sup>2</sup> (median, range)           | 19.2 (14.6–25.7)            | 18.7 (12.8–26.8)       | 0.64    |
| Family history of PSP, N (%)                                 | 6 (1.5%)                    | 1 (2.3%)               | 0.68    |
| Laterality of surgical approach for first operation, N (%)   |                             |                        |         |
| Right                                                        | 165 (41%)                   | 16 (37%)               | 0.87    |
| Left                                                         | 155 (39%)                   | 18 (42%)               |         |
| Bilateral*                                                   | 79 (20%)                    | 9 (21%)                |         |
| Indication for first operation                               |                             |                        |         |
| Recurrence                                                   | 187 (47%)                   | 23 (53%)               | 0.47    |
| Evident blebs/bullae detected on CT (> 1 cm)                 | 128 (32%)                   | 8 (19%)                |         |
| Persistent air leakage (> 5 days)                            | 61 (15%)                    | 6 (14%)                |         |
| Simultaneous bilateral PSP                                   | 6 (2%)                      | 3 (7%)                 |         |
| Tension pneumothorax                                         | 17 (4%)                     | 3 (7%)                 |         |
| First operation time, minutes (median, range)                | 70 (45–245)                 | 75 (50–220)            | 0.72    |
| Postoperative hospital stay, days (median, range)            | 6 (2–21)                    | 6 (3–25)               | 0.65    |
| Blood loss, ml (median, range)                               | 10 (0–180)                  | 10 (0–200)             | 0.82    |
| Complications of first operation (Yes), N (%)                | 52 (13%)                    | 8 (18.5%)              | 0.31    |
| Persistent air leakage (> 5 days)                            | 28 (7%)                     | 5 (11.6%)              |         |
| Atelectasis                                                  | 17 (4.3%)                   | 2 (4.6%)               |         |
| Fever                                                        | 5 (1.3%)                    | 1 (2.3%)               |         |
| Wound dehiscence/poor healing                                | 2 (0.5%)                    | 0                      |         |
| Management of first ipsilateral PORP, N (%)                  |                             |                        |         |
| Reoperation                                                  | N/A                         | 29 (67.4%)             |         |
| Observation                                                  | N/A                         | 10 (23.3%)             |         |
| Pleural drainage plus chemical pleurodesis                   | N/A                         | 4 (9.3%)               |         |
| Time interval between first operation and first PORP (month) |                             |                        |         |
| Median (range)                                               | N/A                         | 13.5 (1.1–68.9)        |         |
| Mean ± SD                                                    | N/A                         | 18.4 ± 17.3            |         |

Footnote: \*bilateral VATS for ipsilateral PSP and contralateral blebectomy; CT, computed tomography; PSP, primary spontaneous pneumothorax; PORP, postoperative recurrent pneumothorax; N/A, not available

Table 2 highlights the relationships between air pollutant levels and initial PSP onset. A one-standard-deviation (SD) increase in daily mean PM<sub>2.5</sub> levels on the case day (lag day 0) and lag day 1 was significantly associated with a higher risk of PSP (OR [95% CI] = 1.12 [1.04–1.18],  $p = 0.04$ ; and OR = 1.09 [1.03–1.16],  $p = 0.02$ , respectively). In contrast, no significant associations were found

between air pollutant levels and PORP onset at various lag days (Table 3).

Additionally, meteorological factors did not demonstrate significant associations with the onset of either initial PSP or PORP across all lag days (see Tables 4 and 5).

#### Seasonal variations in initial PSP and PORP onset

The incidence of initial PSP was significantly greater during autumn and spring than during summer and winter ( $p < 0.001$ ). Similarly, PORP incidence followed a seasonal pattern, with the highest rate occurring in spring, whereas the initial PSP peak occurred in autumn. Initial PSP was more prevalent in September, November, and August, whereas the incidence of PORP was significantly greater from March to May ( $p < 0.001$ ) (Fig. 5).

#### Discussion

In this 11-year retrospective cohort study, we analyzed 43 cases of ipsilateral postoperative recurrent pneumothorax (PORP) following initial surgery for primary spontaneous pneumothorax (PSP). Acknowledging the global variability in risk factors for PORP, we chose to focus on environmental factors associated with the incidence of initial primary spontaneous pneumothorax (PSP) and PORP, rather than revisiting commonly explored risk factors. To our knowledge, this is the first study to examine the impact of environmental factors on the occurrence of both initial PSP and PORP in the same patients. Several key findings have emerged.

#### Environmental factors and PSP/PORP

Air pollutants are known to irritate airway epithelial cells, leading to airway inflammation, dysfunction, and obstruction. Oxidative stress induced by NO<sub>2</sub>, O<sub>3</sub>, and PM<sub>2.5</sub> is a key driver of inflammation in lung epithelial cells [25, 26]. These air pollutants, along with meteorological factors, can impact the lung parenchyma and help explain the pathophysiology underlying PSP occurrence [12, 27, 28]. When communication with the lower airway is disrupted—either temporarily due to bronchospasm and airway inflammation or permanently due to structural changes—air becomes trapped inside blebs or bullae. In such cases, a drop in atmospheric pressure can increase the transpulmonary pressure gradient, causing rapid distension of weakened bleb or bullae walls, ultimately leading to rupture and the onset of PSP. Our study revealed a significant association between elevated PM<sub>2.5</sub> concentrations on the day of PSP symptom onset (lag day 0) and the preceding day (lag day 1) and an increased risk of PSP. However, no such association was observed for PORP. We hypothesize that the pleural symphysis resulting from surgical pleurodesis may obscure the onset of PORP symptoms, masking the timing and severity of recurrence as reported by patients. For future research

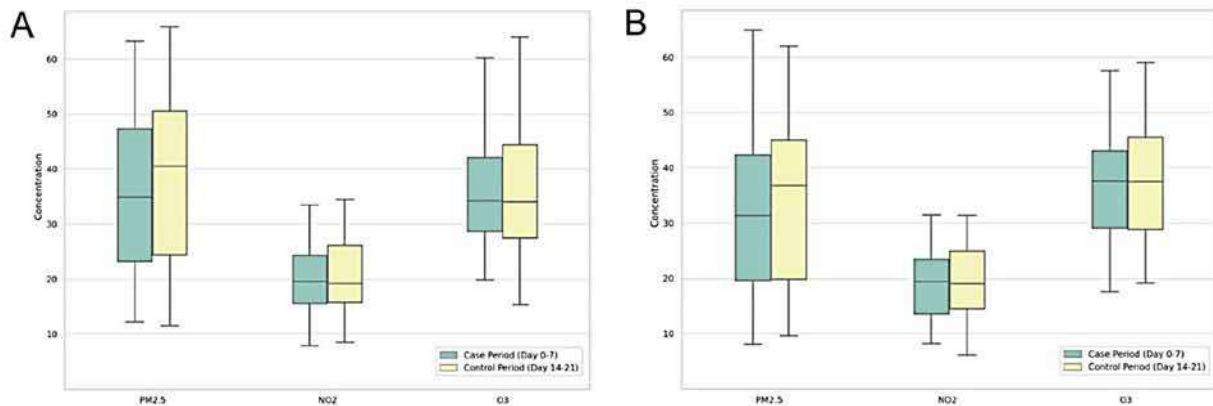


**Fig. 3** The distributions of daily average air pollutant levels for PSP and PORP occurrence. **(A)** Distribution of air pollutants levels for first PSP occurrence. **(B)** Distribution of air pollutants levels for PORP occurrence. PSP, *primary spontaneous pneumothorax*; PORP, *postoperative recurrent pneumothorax*

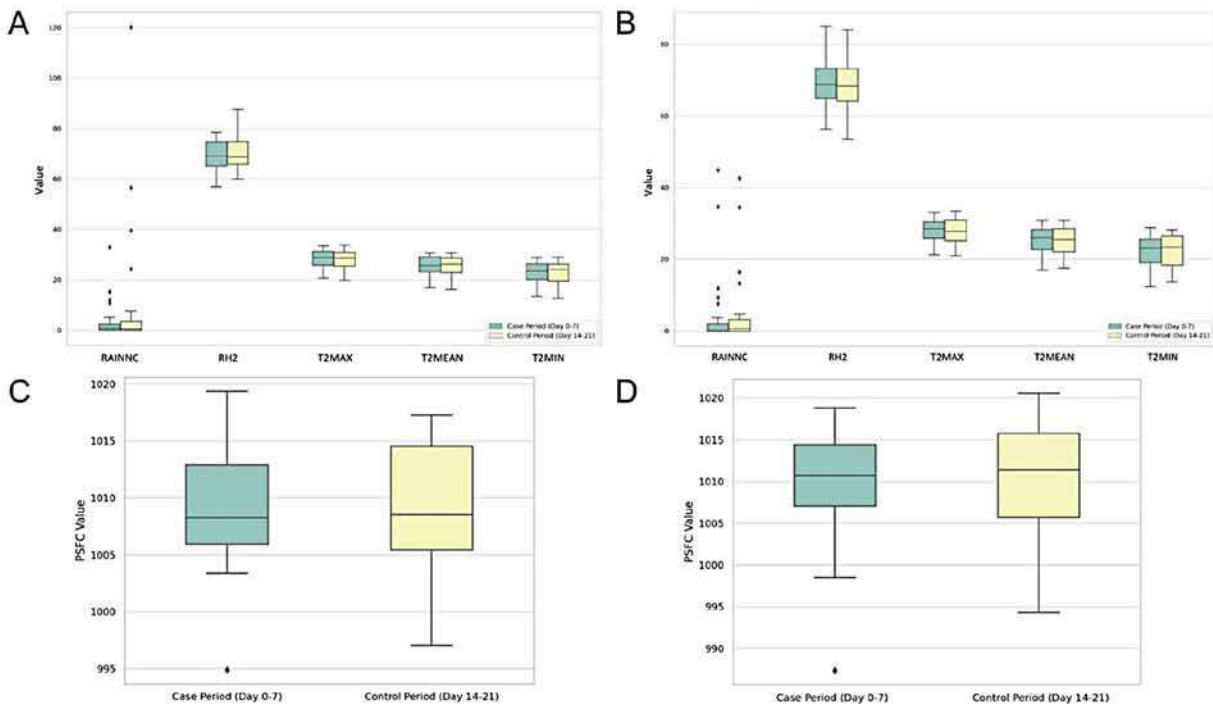


**Fig. 4** The distributions of daily average meteorological factors for PSP and PORP occurrence. **(A)** Distribution of daily average weather data for first PSP occurrence. **(B)** Distribution of daily average weather data for PORP occurrence. **(C)** Distribution of daily mean surface pressure for first PSP occurrence. **(D)** Distribution of daily mean surface pressure for PORP occurrence. PSP, *primary spontaneous pneumothorax*; PORP, *postoperative recurrent pneumothorax*; RAINNC, *accumulated non-convective precipitation*; RH2, *relative humidity at 2 m above ground*; T2MAX, *maximum temperature at 2 m above ground*; T2MEAN, *mean temperature at 2 m above ground*; T2MIN, *minimum temperature at 2 m above ground*; PSFC, *surface pressure*

investigating the role of environmental factors in PSP, excluding patients who have undergone surgery may yield more consistent and homogenous results.

The associations between meteorological factors and PSP have been explored in previous studies, with higher daily temperatures and lower atmospheric pressure identified as potential triggers [27, 28]. Theoretically, changes in atmospheric pressure can cause trapped

air within blebs or bullae to expand, leading to rupture. Similarly, Gay-Lussac's law suggests that increased temperatures increase gas pressure, contributing to PSP occurrence. While our study did not find statistically significant meteorological factors, both PSP and PORP cases occurred during periods of higher daily temperatures and lower mean atmospheric pressure, which aligns with the literature.



**Table 2** Univariate regression analysis of air pollutant levels for first PSP occurrence

| Factors               | PM <sub>2.5</sub> (μg/m <sup>3</sup> ) |             | NO <sub>2</sub> (ppb) |      | O <sub>3</sub> (ppb) |      |
|-----------------------|----------------------------------------|-------------|-----------------------|------|----------------------|------|
|                       | OR (95% CI)                            | P           | OR (95% CI)           | P    | OR (95% CI)          | P    |
| Case period (0–7 Day) | 1.05 (0.97–1.15)                       | 0.19        | 0.93 (0.78–1.11)      | 0.42 | 1.01 (0.94–1.08)     | 0.82 |
| Lag 0                 | 1.12 (1.04–1.18)                       | <b>0.04</b> | 0.91 (0.78–1.1)       | 0.22 | 0.98 (0.93–1.03)     | 0.53 |
| Lag 1                 | 1.09 (1.03–1.16)                       | <b>0.02</b> | 0.92 (0.78–1.1)       | 0.31 | 0.98 (0.93–1.02)     | 0.42 |
| Lag 2                 | 1.03 (0.91–1.08)                       | 0.96        | 0.92 (0.79–1.1)       | 0.27 | 1.01 (0.97–1.1)      | 0.56 |
| Lag 3                 | 1.00 (0.91–1.06)                       | 0.95        | 1.03 (0.92–1.2)       | 0.61 | 1.03 (0.98–1.1)      | 0.25 |
| Lag 4                 | 1.01 (0.96–1.08)                       | 0.66        | 0.99 (0.87–1.13)      | 0.96 | 1.04 (0.99–1.1)      | 0.12 |
| Lag 5                 | 1.05 (0.99–1.12)                       | 0.12        | 0.95 (0.84–1.1)       | 0.38 | 0.98 (0.93–1.02)     | 0.31 |
| Lag 6                 | 1.03 (0.97–1.10)                       | 0.33        | 0.86 (0.72–1.0)       | 0.06 | 1.01 (0.96–1.1)      | 0.83 |
| Lag 7                 | 1.00 (0.91–1.05)                       | 0.84        | 1.02 (0.91–1.2)       | 0.68 | 0.99 (0.95–1.04)     | 0.86 |

**Table 3** Univariate regression analysis of air pollutant levels for postoperative recurrent pneumothorax

| Factors               | PM <sub>2.5</sub> (μg/m <sup>3</sup> ) |      | NO <sub>2</sub> (ppb) |      | O <sub>3</sub> (ppb) |      |
|-----------------------|----------------------------------------|------|-----------------------|------|----------------------|------|
|                       | OR (95% CI)                            | P    | OR (95% CI)           | P    | OR (95% CI)          | P    |
| Case period (0–7 Day) | 1.01 (0.95–1.08)                       | 0.81 | 0.95 (0.81–1.12)      | 0.52 | 0.98 (0.91–1.04)     | 0.47 |
| Lag 0                 | 1.02 (0.96–1.09)                       | 0.55 | 0.98 (0.86–1.13)      | 0.81 | 0.98 (0.93–1.04)     | 0.36 |
| Lag 1                 | 1.01 (0.94–1.06)                       | 0.95 | 1.01 (0.87–1.12)      | 0.87 | 0.99 (0.94–1.05)     | 0.78 |
| Lag 2                 | 1.01 (0.96–1.05)                       | 0.82 | 1.02 (0.92–1.13)      | 0.74 | 0.98 (0.94–1.02)     | 0.34 |
| Lag 3                 | 1.01 (0.96–1.04)                       | 0.98 | 1.0 (0.91–1.11)       | 0.96 | 0.97 (0.92–1.02)     | 0.29 |
| Lag 4                 | 1.01 (0.97–1.05)                       | 0.64 | 0.94 (0.83–1.06)      | 0.29 | 0.98 (0.94–1.03)     | 0.42 |
| Lag 5                 | 1.02 (0.97–1.08)                       | 0.45 | 0.89 (0.67–1.04)      | 0.18 | 0.99 (0.96–1.04)     | 0.96 |
| Lag 6                 | 1.02 (0.96–1.06)                       | 0.69 | 0.93 (0.79–1.09)      | 0.37 | 1.01 (0.96–1.06)     | 0.77 |
| Lag 7                 | 0.98 (0.93–1.03)                       | 0.38 | 0.99 (0.88–1.13)      | 0.93 | 0.99 (0.94–1.04)     | 0.71 |

Despite limited research on the role of air pollution in PSP, our findings contribute to a growing body of evidence suggesting its importance. Notably, studies addressing both meteorological and air pollution factors in PSP from Italy [14, 15], South Korea [23, 24], and Turkey [29] have yielded varying results. For example, Park et al. [23] reported associations between PSP and several air pollutants, including O<sub>3</sub>, NO<sub>2</sub>, PM<sub>10</sub>, and PM<sub>2.5</sub>, whereas Kim et al. [24] reported a link between CO levels and PSP risk. The interplay between meteorological factors and air pollution remains complex and warrants careful interpretation to avoid bias.

#### Seasonal variations in PSP and PORP

Our study revealed distinct seasonal patterns in PSP and PORP incidence, with higher occurrences during autumn and spring. This finding aligns with previous hypotheses suggesting the influence of infectious, chronobiological, or meteorological factors [14, 30]. The concept of clustering was first defined by Smit et al. [31], who described it as when two patients are admitted to the hospital within three days of each other. For instance, studies in Japan and China have reported PSP peaks in autumn [16, 32], whereas spring and summer peaks have been observed in Turkey, Tunisia, and Saudi Arabia [13, 28, 33, 34]. The inconsistency in PSP seasonality across studies may result from variations in meteorological, environmental, and geographic conditions. These regional differences

underscore the role of weather changes in triggering PSP and highlight the need for localized studies to provide robust evidence.

#### Implications and limitations

This study contributes valuable data from southern Taiwan, a region with significant air pollution, to the limited body of research on environmental factors and PSP. While previous Taiwanese studies have focused on meteorological factors [35], our inclusion of air pollution data provides a more comprehensive analysis. Previous studies have highlighted the difficulty of accurately predicting the time and location of PSP onset due to potential recall bias from patients [11, 28, 29]. While most research has utilized national meteorological observatory station data or nearest city observatory station records for retrospective analyses, our use of township-level administrative units further enhances the accuracy of environmental exposure assessments, particularly in young patients whose regular activities are concentrated in urban areas.

Several limitations of this study should be acknowledged. The retrospective design and relatively small sample size limit the statistical power of our analysis, particularly for PORP cases. Additionally, the relatively low incidence of PORP in our study may have introduced selection bias. Despite this, our findings provide a foundation for future research on PSP and environmental factors, with an emphasis on simple PSP patients who have

**Table 4** Univariate regression analysis of meteorological factors for first PSP occurrence

| Factors               | Daily mean surface pressure (hPa) |       | Daily average rainfall (mm) |      | Daily average relative humidity (%) |       | Daily maximum temperature (°C) |      | Daily average temperature (°C) |      | Daily minimum temperature (°C) |      |
|-----------------------|-----------------------------------|-------|-----------------------------|------|-------------------------------------|-------|--------------------------------|------|--------------------------------|------|--------------------------------|------|
|                       | OR (95% CI)                       | P     | OR (95% CI)                 | P    | OR (95% CI)                         | P     | OR (95% CI)                    | P    | OR (95% CI)                    | P    | OR (95% CI)                    | P    |
| Case period (0–7 Day) | 0.88 (0.69–1.14)                  | 0.34  | 0.97 (0.91–1.03)            | 0.33 | 0.94 (0.83–1.1)                     | 0.38  | 1.33 (0.86–2.1)                | 0.21 | 1.26 (0.83–1.9)                | 0.28 | 1.22 (0.84–1.77)               | 0.29 |
| Lag 0                 | 0.94 (0.77–1.14)                  | 0.53  | 0.99 (0.96–1.01)            | 0.43 | 0.99 (0.9–1.1)                      | 0.85  | 1.04 (0.8–1.4)                 | 0.74 | 1.04 (0.79–1.4)                | 0.77 | 1.1 (0.83–1.4)                 | 0.58 |
| Lag 1                 | 0.9 (0.74–1.1)                    | 0.304 | 0.99 (0.96–1.03)            | 0.57 | 0.99 (0.90–1.1)                     | 0.81  | 1.2 (0.87–1.7)                 | 0.26 | 1.1 (0.79–1.5)                 | 0.61 | 1.1 (0.79–1.4)                 | 0.74 |
| Lag 2                 | 0.89 (0.73–1.1)                   | 0.28  | 1.0 (0.98–1.01)             | 0.79 | 0.98 (0.88–1.1)                     | 0.76  | 1.2 (0.87–1.5)                 | 0.31 | 1.2 (0.85–1.6)                 | 0.36 | 1.2 (0.8–1.6)                  | 0.31 |
| Lag 3                 | 0.94 (0.75–1.2)                   | 0.6   | 0.92 (0.81–1.04)            | 0.21 | 0.88 (0.75–1.02)                    | 0.102 | 1.2 (0.86–1.6)                 | 0.31 | 1.2 (0.86–1.7)                 | 0.27 | 1.2 (0.89–1.8)                 | 0.2  |
| Lag 4                 | 0.91 (0.72–1.14)                  | 0.41  | 0.97 (0.92–1.02)            | 0.24 | 0.97 (0.88–1.1)                     | 0.57  | 1.1 (0.76–1.6)                 | 0.62 | 1.2 (0.78–1.8)                 | 0.41 | 1.13 (0.79–1.6)                | 0.5  |
| Lag 5                 | 0.93 (0.76–1.14)                  | 0.49  | 0.98 (0.93–1.02)            | 0.29 | 0.97 (0.89–1.1)                     | 0.47  | 1.2 (0.81–1.7)                 | 0.42 | 1.25 (0.81–1.9)                | 0.31 | 1.4 (0.92–2.02)                | 0.12 |
| Lag 6                 | 0.94 (0.79–1.1)                   | 0.45  | 0.92 (0.80–1.1)             | 0.24 | 0.97 (0.88–1.1)                     | 0.46  | 1.4 (0.97–2.1)                 | 0.07 | 1.4 (0.92–2.11)                | 0.12 | 1.2 (0.84–1.6)                 | 0.38 |
| Lag 7                 | 0.96 (0.83–1.12)                  | 0.63  | 0.97 (0.93–1.01)            | 0.24 | 0.96 (0.88–1.04)                    | 0.29  | 1.2 (0.89–1.6)                 | 0.22 | 1.2 (0.88–1.67)                | 0.23 | 1.2 (0.88–1.5)                 | 0.28 |

**Table 5** Univariate regression analysis of meteorological factors for postoperative recurrent pneumothorax

| Factors               | Daily mean surface pressure (hPa) |      | Daily average rainfall (mm) |       | Daily average relative humidity (%) |      | Daily maximum temperature (°C) |      | Daily average temperature (°C) |      | Daily minimum temperature (°C) |      |
|-----------------------|-----------------------------------|------|-----------------------------|-------|-------------------------------------|------|--------------------------------|------|--------------------------------|------|--------------------------------|------|
|                       | OR (95% CI)                       | P    | OR (95% CI)                 | P     | OR (95% CI)                         | P    | OR (95% CI)                    | P    | OR (95% CI)                    | P    | OR (95% CI)                    | P    |
| Case period (0–7 Day) | 0.89 (0.72–1.09)                  | 0.24 | 0.99 (0.94–1.05)            | 0.79  | 1.05 (0.94–1.2)                     | 0.39 | 1.12 (0.79–1.58)               | 0.51 | 1.1 (0.79–1.54)                | 0.54 | 1.22 (0.84–1.49)               | 0.43 |
| Lag 0                 | 0.91 (0.77–1.08)                  | 0.25 | 1.0 (0.96–1.05)             | 0.26  | 1.03 (0.95–1.12)                    | 0.44 | 1.16 (0.87–1.52)               | 0.3  | 1.2 (0.9–1.6)                  | 0.21 | 1.14 (0.89–1.46)               | 0.27 |
| Lag 1                 | 0.89 (0.75–1.06)                  | 0.19 | 0.96 (0.89–1.03)            | 0.3   | 1.02 (0.92–1.1)                     | 0.94 | 1.16 (0.86–1.57)               | 0.34 | 1.1 (0.83–1.45)                | 0.51 | 1.1 (0.88–1.39)                | 0.39 |
| Lag 2                 | 0.9 (0.75–1.07)                   | 0.23 | 1.0 (0.95–1.06)             | 0.87  | 1.03 (0.92–1.1)                     | 0.89 | 1.13 (0.87–1.5)                | 0.37 | 1.1 (0.84–1.45)                | 0.48 | 1.1 (0.86–1.38)                | 0.46 |
| Lag 3                 | 0.93 (0.77–1.13)                  | 0.47 | 1.0 (0.99–1.02)             | 0.59  | 1.04 (0.96–1.12)                    | 0.34 | 1.01 (0.75–1.4)                | 0.94 | 1.02 (0.75–1.39)               | 0.87 | 1.05 (0.81–1.36)               | 0.71 |
| Lag 4                 | 0.91 (0.75–1.1)                   | 0.31 | 0.61 (0.36–1.0)             | 0.053 | 1.02 (0.94–1.12)                    | 0.59 | 1.2 (0.85–1.69)                | 0.29 | 1.13 (0.82–1.55)               | 0.46 | 1.11 (0.85–1.46)               | 0.43 |
| Lag 5                 | 0.91 (0.77–1.1)                   | 0.29 | 0.85 (0.67–1.1)             | 0.16  | 1.02 (0.92–1.13)                    | 0.71 | 1.08 (0.81–1.4)                | 0.62 | 1.1 (0.81–1.47)                | 0.57 | 1.13 (0.87–1.48)               | 0.34 |
| Lag 6                 | 0.94 (0.81–1.1)                   | 0.38 | 0.99 (0.94–1.04)            | 0.68  | 1.03 (0.94–1.13)                    | 0.53 | 1.08 (0.83–1.4)                | 0.56 | 1.1 (0.82–1.4)                 | 0.63 | 1.1 (0.83–1.37)                | 0.62 |
| Lag 7                 | 0.97 (0.84–1.12)                  | 0.64 | 1.0 (0.96–1.05)             | 0.15  | 1.11 (1–1.23)                       | 0.05 | 0.96 (0.79–1.2)                | 0.64 | 0.97 (0.79–1.19)               | 0.79 | 1.01 (0.81–1.28)               | 0.90 |

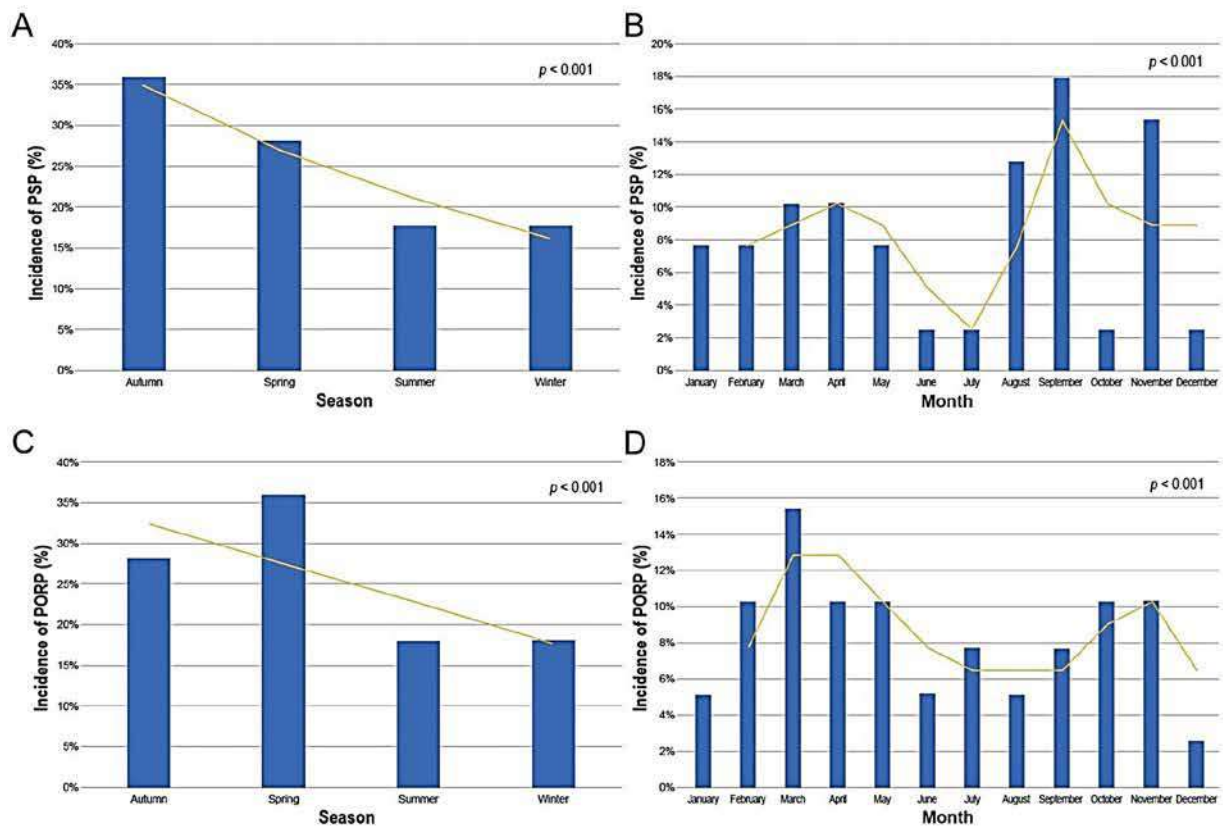


**Fig. 5** Incidence of PSP and PORP by seasonal variation. **(A)** Incidence of PSP by season. **(B)** Incidence of PSP by month. **(C)** Incidence of PORP by season. **(D)** Incidence of PORP by month. PSP, primary spontaneous pneumothorax; PORP, postoperative recurrent pneumothorax

not undergone surgery. Additionally, the exclusion of PSP cases during the COVID-19 pandemic (2020–2023) may have introduced selection bias, as patients were less likely to seek medical care during this period [36]. Furthermore, COVID-19 has been associated with worse outcomes in PSP patients [37], potentially complicating comparisons between pandemic and nonpandemic periods.

## Conclusion

PSP and PORP exhibit seasonal clustering, with higher incidences in autumn and spring. Elevated PM<sub>2.5</sub> levels were associated with PSP onset but not PORP, suggesting a potential link between air pollution and PSP. Future large-scale, prospective studies are warranted to further elucidate the environmental and clinical factors contributing to PSP and PORP occurrence individually and to refine tailored management strategies.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12931-025-03254-1>.

Supplementary Material 1

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None.

## Author contributions

The authors confirm their contributions to the paper as follows: study conception and design: YL, PC, SH; data collection: YL, CK, CH, SC; analysis and interpretation of results: YL, PC, SH; draft manuscript preparation: YL, PC, SH. All the authors reviewed the results and approved the final version of the manuscript.

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## Data availability

No datasets were generated or analysed during the current study.

## Declarations

### Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Kaohsiung Medical University Hospital (Approval no. KMHIRB-E(I)-20240197).

### Consent for publication

The need for informed consent for publication was waived according to the policy of our IRB.

## Competing interests

The authors declare no competing interests.

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## Article

# Sublobar Resection Versus Lobectomy for Small ( $\leq 3$ cm) NSCLC with Visceral Pleural Invasion: A Propensity-Score-Matched Survival Analysis from a Nationwide Cohort

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**Simple Summary:** For clinicians treating small-sized non-small-cell lung cancers with visceral pleural invasion, choosing the best surgical approach—either less-extensive sublobar resection or standard lobectomy—has been challenging due to mixed evidence. This study investigated this issue using a large patient database and found that lung-cancer-specific survival rates were comparable between both surgical methods for these specific tumors ( $\leq 3$  cm without lymph node spread). This suggests sublobar resection can be an equally effective, potentially less invasive, treatment option for appropriately selected patients, offering valuable guidance for surgical decision-making, though further confirmation from future studies is encouraged.

**Abstract: Background/Objectives:** While sublobar resection (SLR) is accepted for selected small, early non-small-cell lung cancers (NSCLCs), its efficacy for tumors with visceral pleural invasion (VPI) remains debated. This study aimed to compare lung-cancer-specific survival (LCSS) between SLR and lobectomy in pT2a (tumor  $\leq 3$  cm with VPI) N0M0 NSCLCs from a nationwide population-based database. **Methods:** This retrospective study utilized Taiwan Cancer Registry data from 2011 to 2018, selecting patients with pT2a (tumor  $\leq 3$  cm with VPI) N0M0 NSCLC that underwent SLR or lobectomy, with specific exclusion criteria. Propensity score matching (1:1) was performed using a greedy algorithm with a 0.01 caliper width. LCSS was compared using Kaplan–Meier analysis with log-rank tests and Cox proportional hazards models before and after matching. **Results:** In the 2460-patient cohort (624 SLR, 1836 lobectomy) before matching, lobectomy was associated with significantly better overall ( $p = 0.01$ ) and PL1 VPI subgroup ( $p = 0.009$ ) LCSS. In the matched cohort (523 pairs), no significant difference in LCSS was observed between SLR



and lobectomy, either overall ( $p = 0.21$ ) or when stratified by PL1 ( $p = 0.11$ ) or PL2 ( $p = 0.94$ ) status. Multivariate Cox analysis in the matched cohort confirmed no significant association between surgery type and LCSS (adjusted HR 0.75, 95% CI 0.52–1.08,  $p = 0.124$ ), but older age ( $>75$  years), PL2 VPI, and lymphovascular invasion were independent predictors of worse LCSS (all  $p < 0.001$ ). **Conclusions:** This large population-based study, after rigorous adjustment for confounders, found that SLR and lobectomy provided comparable LCSS. SLR may be an alternative for selected patients, but prospective validation is recommended.

**Keywords:** non-small-cell lung cancer (NSCLC); visceral pleural invasion (VPI); sublobar resection; lobectomy; propensity score matching; early lung cancer

## 1. Introduction

Lobectomy has long been considered the standard surgical approach for curative-intent resection of early-stage non-small-cell lung cancer (NSCLC) [1]. However, this paradigm has been increasingly challenged over the past decade. Several landmark randomized controlled trials, notably the JCOG0802/WJOG4607L study and the CALGB 140503 trial, have provided robust evidence that sublobar resection (SLR), encompassing segmentectomy and wedge resection, can achieve non-inferior or equivalent oncological outcomes compared to lobectomy for select patients with small (typically defined as  $\leq 2$  cm), peripheral NSCLCs [2,3]. These findings have ushered in an era where SLR is a valid alternative for appropriately selected early-stage lung cancers.

Nevertheless, surgical decision-making in NSCLC is complex and extends beyond tumor size alone. A multitude of clinicopathological factors significantly influence patient prognosis and guide the selection of the optimal surgical strategy [4]. For instance, the radiological appearance of a tumor, such as the proportions of the ground-glass opacity and solid components, is often considered; tumors with a predominant ground-glass opacity component might be deemed suitable for SLR, whereas highly solid tumors, even if small, may prompt consideration for lobectomy due to potentially more aggressive biology [5,6]. Among these prognostic factors, visceral pleural invasion (VPI) is well-established as an indicator of adverse outcomes in NSCLC [7]. The presence of VPI, defined as tumor extension beyond the elastic layer of the visceral pleura, is associated with a higher risk of recurrence and poorer survival, often leading to an upstaging of the pathological tumor classification, e.g., a T2a designation even for tumors  $\leq 3$  cm according to the 8th edition AJCC staging manual [8,9].

This creates a critical clinical conflict. Whereas recent trials endorse SLR for selected small NSCLCs [2,3], the inherent biological aggressiveness signified by VPI raises the question of whether lobectomy is necessary for adequate oncological control. The central issue is whether the negative impact of VPI overrides the potential sufficiency of SLR in the context of small tumor size. Retrospective studies comparing lobectomy and SLR specifically for small (e.g.,  $\leq 2$  cm or  $\leq 3$  cm), VPI-positive NSCLCs have yielded conflicting results. Some large database analyses suggest superior survival outcomes with lobectomy [10], whereas others, including meta-analyses or different database studies, indicate that SLR—particularly segmentectomy or when used for tumors  $\leq 2$  cm—may achieve comparable survival rates [11,12]. Consequently, owing to these inconsistent findings, often derived from retrospective data with inherent limitations, a definitive consensus on the optimal surgical extent is lacking. This represents a significant knowledge gap regarding the appropriate management strategy for patients presenting with small-sized, VPI-positive NSCLCs [10,13].

To address this knowledge gap, the present study leveraged the comprehensive data resources of the Taiwan Cancer Registry (TCR). The TCR is a rigorously maintained, nationwide, population-based database known for its high quality and completeness, providing a valuable platform for real-world evidence generation [14,15]. By analyzing survival outcomes in a large representative cohort of patients from the TCR diagnosed with small-sized NSCLC and confirmed VPI, we aimed to compare the effectiveness of lobectomy and SLR. This study seeks to provide crucial evidence to inform surgical decision-making for this challenging patient population.

## 2. Materials and Methods

### 2.1. Study Population

Data for this retrospective cohort study were retrieved from the TCR, a validated nationwide population-based database [14,15]. We initially identified 36,560 patients diagnosed with NSCLC from 1 January 2011 to 31 December 2018. Patients were selected according to a sequential algorithm, which is depicted in Figure 1. The exclusion criteria included a lack of surgical intervention, pathologically confirmed tumor size greater than 3 cm, absence of visceral pleural invasion (PL0) or presence of extensive pleural involvement classified as PL3 (T3 disease), pathologically confirmed nodal or distant metastasis (N+ or M1), involved surgical margins, and duplicate or incomplete records unsuitable for analysis. The final analytic cohort comprised 2460 patients with pathologically staged T2aN0M0 NSCLC, characterized by tumors  $\leq 3$  cm in size with VPI (corresponding to PL1 or PL2). These patients were then categorized according to the surgical procedure performed: SLR (n = 624) or lobectomy (n = 1836).

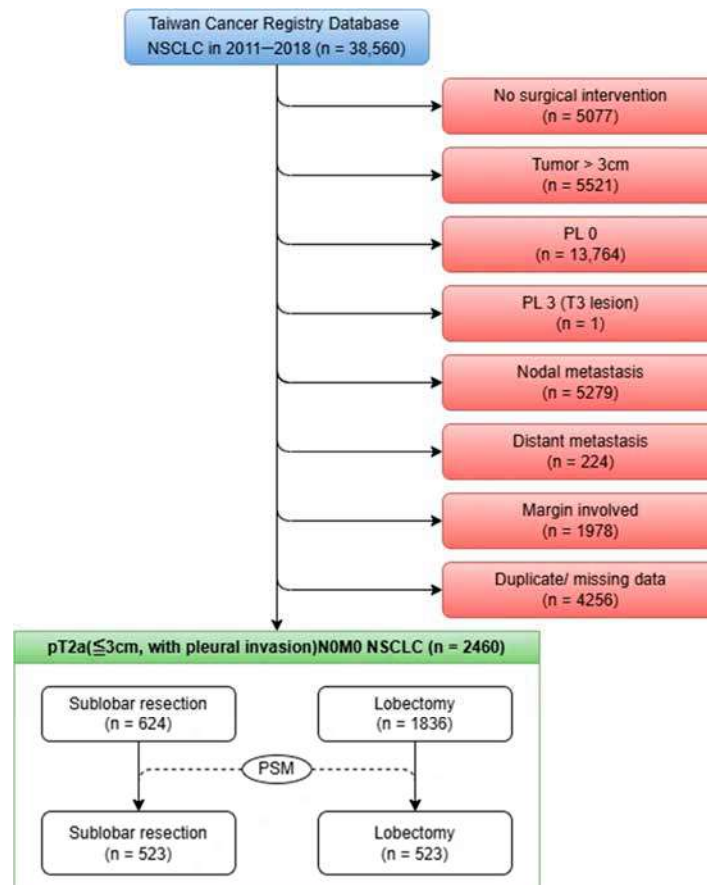


**Figure 1.** Selection algorithm.



## 2.2. Propensity Score Matching

To minimize potential selection bias and confounding effects due to differences in baseline characteristics between the SLR and lobectomy groups, we performed propensity score matching (PSM). Propensity scores, representing the estimated probability of receiving SLR or lobectomy given the observed covariates, were calculated using a multivariable logistic regression model. Based on clinical relevance and previous literature [1,5,8], the covariates included in the model were as follows: patient age, sex, self-reported smoking history, tumor size, pathological T stage (pT), histological type, tumor differentiation grade, lymphovascular invasion (LVI), and VPI. Patients who underwent SLR were matched 1:1 to those who underwent lobectomy using a greedy nearest-neighbor matching algorithm without replacement. A caliper width of 0.01 standard deviations of the logit of the propensity score was applied during matching. Exact matching was not enforced for any covariate. The goodness-of-fit and discriminative ability of the logistic regression model were evaluated using the Hosmer–Lemeshow test and the c-statistic. Furthermore, the distribution of propensity scores before and after matching was visually inspected to assess the balance achieved (Supplementary Figure S1).

## 2.3. Surgical Modalities and Main Outcomes

The primary exposure variable in this study was the type of curative-intent pulmonary resection performed. Patients included in the final cohort, all having undergone complete (margin-negative) resection, were categorized into two groups based on the surgical procedure documented in the TCR: lobectomy or SLR. The primary endpoint for evaluating treatment effectiveness was lung-cancer-specific survival (LCSS). The use of LCSS as the primary endpoint allowed for a focused assessment of surgical efficacy against cancer-related death, mitigating confounding from mortality due to other causes (competing risks), which is particularly relevant in population-based studies [16]. LCSS was defined as the time from definitive surgical resection to death attributed to lung cancer, censoring for death from other causes [17]. Survival status, date of death, and cause of death information were ascertained by linking the TCR records with data obtained from the official Taiwanese national death registry database.

## 2.4. Statistics

All statistical analyses were performed using R version 4.5.0 (R Foundation for Statistical Computing, Vienna, Austria) and SAS 9.4 (SAS Institute, Cary, NC, USA). A two-sided  $p$ -value  $< 0.05$  was considered statistically significant.

Descriptive statistics were generated to summarize patient demographics and baseline clinicopathological characteristics for the study population prior to matching and the propensity-score-matched cohort. Continuous variables are presented as mean  $\pm$  standard deviation (SD). Categorical variables are presented as frequencies (n) and percentages (%). Baseline characteristics between the lobectomy and SLR groups were compared using Student's  $t$ -tests or Mann–Whitney U tests for continuous variables, and chi-squared tests for categorical variables.

LCSS probabilities were estimated using the Kaplan–Meier method, and survival curves were generated for the lobectomy and SLR groups, before and after matching. Differences between the Kaplan–Meier survival curves were compared using the log-rank test.

To evaluate the independent association between the type of surgical procedure (SLR versus lobectomy) and LCSS, Cox proportional hazards regression models were utilized. Hazard ratios (HRs) and their corresponding 95% confidence intervals (CIs) were estimated. Both unadjusted (crude) and multivariable-adjusted Cox models were developed.

### 3. Results

#### 3.1. Baseline Characteristics

A total of 2460 patients with surgically resected pT2a ( $\leq 3$  cm with VPI) N0M0 NSCLC met the inclusion criteria and constituted the initial cohort for analysis before PSM (Table 1). Of these, 624 (25.4%) underwent SLR and 1836 (74.6%) underwent lobectomy. The mean age of this overall cohort was  $63.7 \pm 10.4$  years. Most patients were female (1415 patients, 57.5%). Most patients were never smokers (1791 patients, 72.8%). Histologically, adenocarcinoma was overwhelmingly the most common subtype, identified in approximately 90% of cases (2204 patients, 89.6%). Regarding the extent of VPI, 1873 patients (76.1%) were classified as PL1, and 587 (23.9%) as PL2. During the follow-up period documented in the registry for this cohort (2011–2024), disease recurrence was observed in 439 patients, comprising 73 (3.0%) cases of locoregional recurrence and 366 (14.9%) cases of distant recurrence.

**Table 1.** Demographic and clinical features of patients with pT2a ( $\leq 3$  cm, with pleural invasion) N0M0 NSCLC that underwent sublobar resection or lobectomy.

|                             | Before Matching |                    |               |         | After Matching |                    |               |         |
|-----------------------------|-----------------|--------------------|---------------|---------|----------------|--------------------|---------------|---------|
|                             | Total           | Sublobar Resection | Lobectomy     | p Value | Total          | Sublobar Resection | Lobectomy     | p Value |
|                             | (n = 2460)      | (n = 624)          | (n = 1836)    |         | (n = 1046)     | (n = 523)          | (n = 523)     |         |
| Age, yrs                    | 63.7 (10.4)     | 68.0 (10.6)        | 62.3 (9.9)    | <0.001  | 66.86 (9.85)   | 66.94 (9.97)       | 66.77 (9.75)  | 0.775   |
| Female                      | 1415 (57.5%)    | 331 (53.0%)        | 1084 (59.0%)  | 0.010   | 573 (54.8%)    | 283 (54.1%)        | 290 (55.4%)   | 0.709   |
| BMI, kg/m <sup>2</sup>      | 24.3 (3.6)      | 24.6 (3.7)         | 24.2 (3.5)    | 0.034   | 24.41 (3.62)   | 24.59 (3.79)       | 24.23 (3.42)  | 0.113   |
| Smoking status              |                 |                    |               | 0.003   |                |                    |               | 0.893   |
| Never smoker                | 1791 (72.8%)    | 425 (68.1%)        | 1366 (74.4%)  |         | 727 (69.5%)    | 362 (69.2%)        | 365 (69.8%)   |         |
| Ever smoker                 | 669 (27.2%)     | 199 (31.9%)        | 470 (25.6%)   |         | 319 (30.5%)    | 161 (30.8%)        | 158 (30.2%)   |         |
| Laterality                  |                 |                    |               | <0.001  |                |                    |               | <0.001  |
| Right                       | 1525 (62.0%)    | 338 (54.2%)        | 1187 (64.7%)  |         | 621 (59.4%)    | 277 (53.0%)        | 344 (65.8%)   |         |
| Left                        | 935 (38.0%)     | 286 (45.8%)        | 649 (35.3%)   |         | 425 (40.6%)    | 246 (47.0%)        | 179 (34.2%)   |         |
| Tumor size, cm              |                 |                    |               | <0.001  |                |                    |               | 0.683   |
| 0–1                         | 124 (5.0%)      | 65 (10.4%)         | 59 (3.2%)     |         | 76 (7.3%)      | 37 (7.1%)          | 39 (7.5%)     |         |
| 1–2                         | 924 (37.6%)     | 305 (48.9%)        | 619 (33.7%)   |         | 516 (49.3%)    | 252 (48.2%)        | 264 (50.5%)   |         |
| 2–3                         | 1412 (57.4%)    | 254 (40.7%)        | 1158 (63.1%)  |         | 454 (43.4%)    | 234 (44.7%)        | 220 (42.1%)   |         |
| Differentiation *           |                 |                    |               | 0.217   |                |                    |               | 0.933   |
| Well                        | 240 (9.8%)      | 71 (11.4%)         | 169 (9.2%)    |         | 115 (11.0%)    | 57 (10.9%)         | 58 (11.1%)    |         |
| Moderate                    | 1572 (63.9%)    | 397 (63.6%)        | 1175 (64.0%)  |         | 664 (63.5%)    | 336 (64.2%)        | 328 (62.7%)   |         |
| Poor                        | 585 (23.8%)     | 145 (23.2%)        | 440 (24.0%)   |         | 254 (24.3%)    | 123 (23.5%)        | 131 (25.0%)   |         |
| N/A                         | 63 (2.6%)       | 11 (1.8%)          | 52 (2.8%)     |         | 13 (1.2%)      | 7 (1.3%)           | 6 (1.1%)      |         |
| Histology                   |                 |                    |               | 0.001   |                |                    |               | 0.615   |
| Adenocarcinoma              | 2204 (89.6%)    | 534 (85.6%)        | 1670 (91.0%)  |         | 906 (86.6%)    | 449 (85.9%)        | 457 (87.4%)   |         |
| SCC                         | 107 (4.3%)      | 40 (6.4%)          | 67 (3.6%)     |         | 55 (5.3%)      | 31 (5.9%)          | 24 (4.6%)     |         |
| Others                      | 149 (6.1%)      | 50 (8.0%)          | 99 (5.4%)     |         | 85 (8.1%)      | 43 (8.2%)          | 42 (8.0%)     |         |
| Lymphovascular invasion     | 94 (3.8%)       | 25 (4.0%)          | 69 (3.8%)     | 0.874   | 39 (3.7%)      | 19 (3.6%)          | 20 (3.8%)     | 1.000   |
| Visceral pleural invasion   |                 |                    |               | 0.011   |                |                    |               | 0.939   |
| PL1                         | 1873 (76.1%)    | 499 (80.0%)        | 1374 (74.8%)  |         | 830 (79.3%)    | 414 (79.2%)        | 416 (79.5%)   |         |
| PL2                         | 587 (23.9%)     | 125 (20.0%)        | 462 (25.2)    |         | 216 (20.7%)    | 109 (20.8%)        | 107 (20.5%)   |         |
| Lymph nodes examined number | 17.52 (11.30)   | 12.70 (10.20)      | 19.16 (11.19) | <0.001  | 16.14 (11.24)  | 12.99 (10.39)      | 19.29 (11.18) | <0.001  |
| Recurrence *                |                 |                    |               | 0.061   |                |                    |               | 0.249   |
| In situ                     | 0               |                    |               |         | 0              |                    |               |         |
| Locoregional                | 73 (3.0%)       | 23 (3.7%)          | 50 (2.7%)     |         | 38 (3.6%)      | 20 (3.8%)          | 18 (3.4%)     |         |
| Distant                     | 366 (14.9%)     | 80 (12.8%)         | 286 (15.6%)   |         | 141 (13.5%)    | 74 (14.1%)         | 67 (12.8%)    |         |
| N/A                         | 105 (4.3%)      | 35 (5.6%)          | 70 (3.8%)     |         | 46 (4.4%)      | 29 (5.5%)          | 17 (3.3%)     |         |

Table 1. Cont.

|                  | Before Matching |                    |             |         | After Matching |                    |             |         |
|------------------|-----------------|--------------------|-------------|---------|----------------|--------------------|-------------|---------|
|                  | Total           | Sublobar Resection | Lobectomy   | p Value | Total          | Sublobar Resection | Lobectomy   | p Value |
|                  | (n = 2460)      | (n = 624)          | (n = 1836)  |         | (n = 1046)     | (n = 523)          | (n = 523)   |         |
| Adjuvant therapy |                 |                    |             | <0.001  |                |                    |             | 0.408   |
| CCRT             | 4 (0.2%)        | 2 (0.3%)           | 2 (0.1%)    |         | 2 (0.2%)       | 2 (0.4%)           | 0 (0.0%)    |         |
| Chemotherapy     | 831 (33.8%)     | 164 (26.3%)        | 667 (36.3%) |         | 310 (29.6%)    | 146 (27.9%)        | 164 (31.4%) |         |
| Radiotherapy     | 5 (0.2%)        | 2 (0.3%)           | 3 (0.2%)    |         | 2 (0.2%)       | 1 (0.2%)           | 1 (0.2%)    |         |
| TKI              | 11 (0.4%)       | 4 (0.6%)           | 7 (0.4%)    |         | 6 (0.6%)       | 4 (0.8%)           | 2 (0.4%)    |         |

Data are presented as mean ± SD (range) or number (%). \* Missing data for differentiation and recurrence are indicated by N/A. BMI, body mass index; CCRT, concurrent chemoradiotherapy; NSCLC, non-small-cell lung cancer; SCC, squamous cell carcinoma; TKI, tyrosine kinase inhibitor.

### 3.2. PSM for LCSS Analysis

PSM successfully yielded 523 matched pairs of patients who underwent either SLR or lobectomy. As shown in Table 1, baseline demographics and clinicopathological characteristics were well-balanced between the SLR and lobectomy groups after matching. No statistically significant differences were observed for key variables including age, sex, body mass index, smoking status, tumor size categories, histological type, tumor differentiation grade, LVI, or VPI status (all  $p > 0.05$ , Table 1). Notably, tumor laterality was not included as a covariate in the PSM model due to its perceived lesser impact on prognosis and, consequently, remained significantly different between the groups after matching ( $p < 0.001$ , Table 1). The resulting matched cohort ( $n = 1046$ ) had a mean age of  $66.9 \pm 9.9$  years, and comprised 573 (54.8%) female patients (Table 1).

### 3.3. LCSS Before and After Matching

LCSS was first compared between the SLR and lobectomy groups in the initial cohort prior to matching (Figure 2). This analysis revealed that patients who underwent lobectomy had significantly better LCSS than those who received SLR (Figure 2A,  $p = 0.01$ ). When stratified by the extent of visceral pleural invasion, a similar significant survival advantage for lobectomy was observed among patients with PL1 invasion (Figure 2B,  $p = 0.009$ ). In contrast, within the subgroup of patients with PL2 invasion, no statistically significant difference in LCSS was detected between the two surgical approaches (Figure 2C,  $p = 0.14$ ).

Following PSM, which yielded 523 pairs of patients with balanced baseline characteristics, Kaplan–Meier survival analysis was repeated (Figure 3). In the overall matched cohort, the survival curves for SLR and lobectomy were closely aligned, and the previously observed significant difference was no longer present (Figure 3A,  $p = 0.21$ ). Stratified analyses within the matched cohort also showed no significant differences in LCSS between SLR and lobectomy, both for patients with PL1 invasion (Figure 3B,  $p = 0.11$ ) and for those with PL2 invasion (Figure 3C,  $p = 0.94$ ). Furthermore, an analysis comparing segmentectomy and wedge resection within this matched cohort revealed no significant difference in lung-cancer-specific survival between these two sublobar approaches (Supplementary Figure S2).

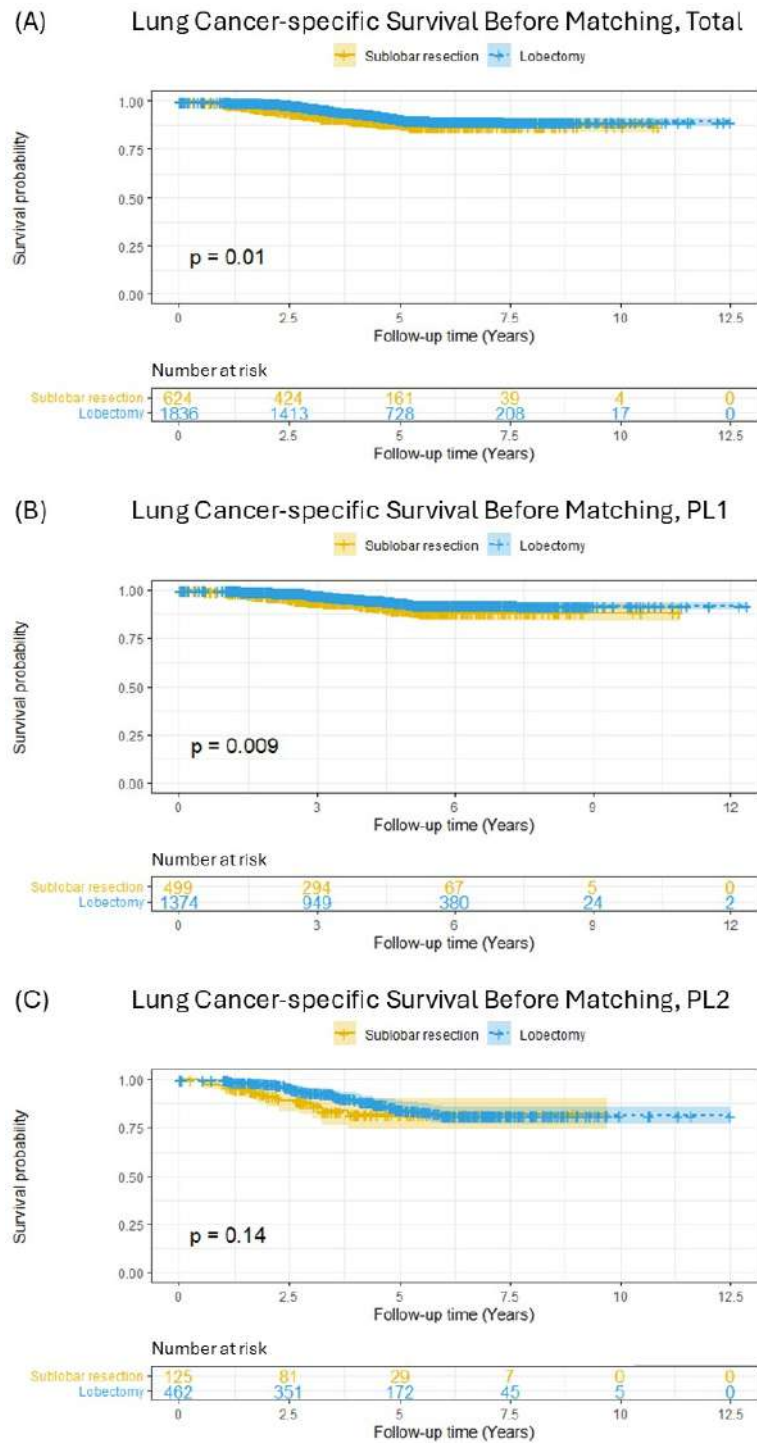


**Figure 2.** Lung-cancer-specific survival in patients with pT2aN0M0 (tumor  $\leq 3$  cm) non-small-cell lung cancer before matching; (A) total included patients, (B) PL1 patients, (C) PL2 patients.

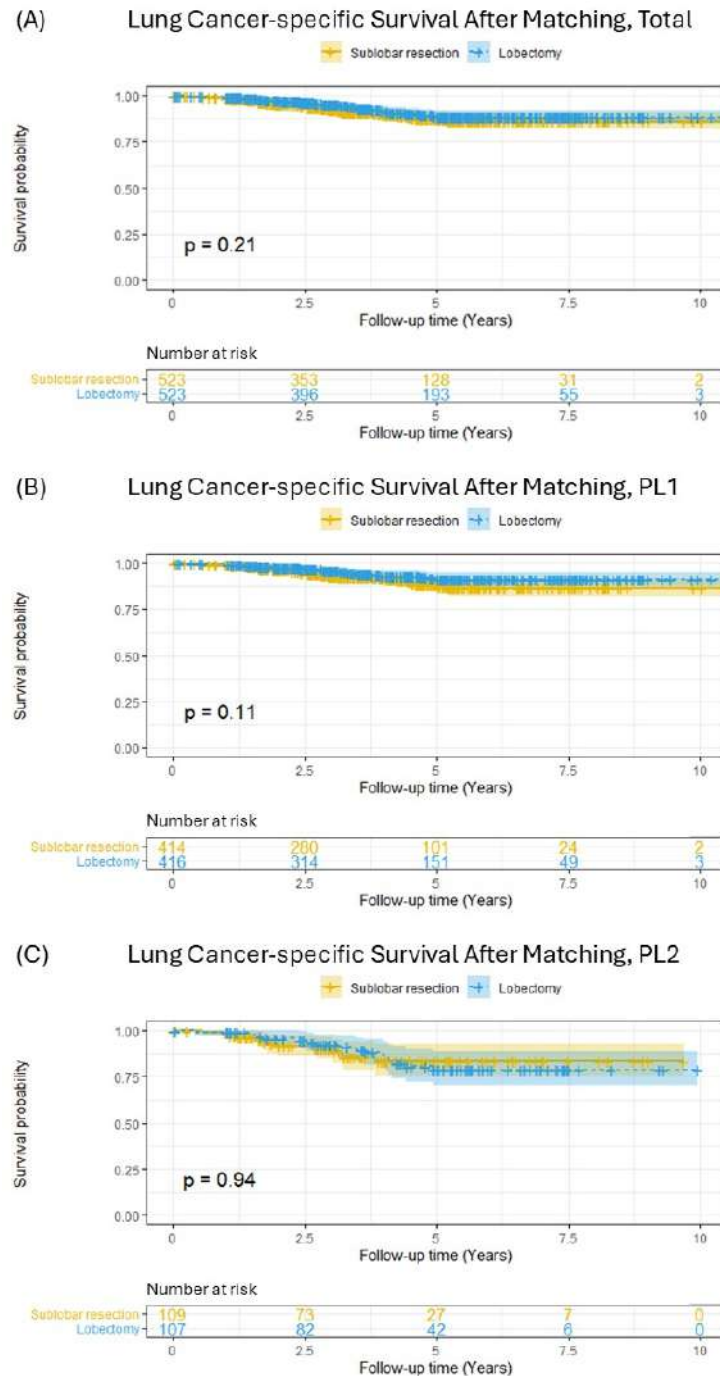


**Figure 3.** Lung-cancer-specific survival in patients with pT2aN0M0 (tumor  $\leq 3$  cm) non-small-cell lung cancer after matching; (A) total included patients, (B) PL1 patients, (C) PL2 patients.

### 3.4. Cox Proportional Hazards Models for LCSS

The results of the Cox proportional hazards regression analyses for LCSS are presented in Table 2. In the univariate analysis, lobectomy was associated with significantly better LCSS, compared to that for SLR (HR 0.66, 95% CI 0.47–0.91,  $p = 0.011$ ). However, after adjusting for other covariates in the multivariate Cox model, the type of surgical procedure (lobectomy vs. SLR) was no longer significantly associated with LCSS (adjusted HR 0.75, 95% CI 0.52–1.08,  $p = 0.124$ ). The multivariate analysis identified several independent prognostic factors significantly associated with worse LCSS: age greater than 75 years

(adjusted HR 1.97, 95% CI 1.40–2.77,  $p < 0.001$ ), presence of PL2 VPI (PL2 vs. PL1; adjusted HR 2.04, 95% CI 1.50–2.77,  $p < 0.001$ ), and presence of LVI (adjusted HR 5.21, 95% CI 2.84–9.57,  $p < 0.001$ ).

**Table 2.** Cox regression analyses of correlations between clinicopathological features and lung-cancer-specific survival for patients with pT2a (<3 cm, with pleural invasion) N0 M0 NSCLC that underwent sublobar resection or lobectomy.

| Variables                    | Lung-Cancer-Specific Mortality |            |                |                       |           |                |
|------------------------------|--------------------------------|------------|----------------|-----------------------|-----------|----------------|
|                              | Univariate Analysis            |            |                | Multivariate Analysis |           |                |
|                              | Hazard Ratio                   | 95% CI     | <i>p</i> Value | Hazard Ratio          | 95% CI    | <i>p</i> Value |
| Surgical method              |                                |            |                |                       |           |                |
| Sublobar resection           |                                |            |                |                       |           |                |
| Lobectomy                    | 0.66                           | 0.47–0.91  | 0.011          | 0.75                  | 0.52–1.08 | 0.124          |
| Smoking                      |                                |            |                |                       |           |                |
| Never smoker                 |                                |            |                |                       |           |                |
| Ever smoker                  | 2.32                           | 1.72–3.13  | <0.001         | 1.43                  | 0.96–2.12 | 0.077          |
| Age                          |                                |            |                |                       |           |                |
| ≤75 yrs                      |                                |            |                |                       |           |                |
| >75 yrs                      | 2.74                           | 1.99–3.77  | <0.001         | 1.97                  | 1.40–2.77 | <0.001         |
| Sex                          |                                |            |                |                       |           |                |
| Male                         |                                |            |                |                       |           |                |
| Female                       | 0.51                           | 0.38–0.69  | <0.001         | 0.80                  | 0.54–1.18 | 0.259          |
| Laterality                   |                                |            |                |                       |           |                |
| Right                        |                                |            |                |                       |           |                |
| Left                         | 0.95                           | 0.70–1.29  | 0.726          | 0.82                  | 0.60–1.13 | 0.231          |
| Differentiation              |                                |            |                |                       |           |                |
| Well                         |                                |            |                |                       |           |                |
| Moderate                     | 1.66                           | 0.84–3.29  | 0.147          | 1.31                  | 0.66–2.60 | 0.446          |
| Poor                         | 3.47                           | 1.73–6.94  | <0.001         | 1.99                  | 0.97–4.06 | 0.060          |
| Tumor size                   |                                |            |                |                       |           |                |
| 0–1 cm                       |                                |            |                |                       |           |                |
| 1–2 cm                       | 1.84                           | 0.67–5.09  | 0.240          | 1.51                  | 0.54–4.21 | 0.430          |
| 2–3 cm                       | 2.76                           | 1.02–7.48  | 0.046          | 2.19                  | 0.80–6.01 | 0.129          |
| Histology                    |                                |            |                |                       |           |                |
| SCC                          |                                |            |                |                       |           |                |
| Adenocarcinoma               | 0.32                           | 0.20–0.51  | <0.001         | 0.60                  | 0.36–1.01 | 0.055          |
| Others                       | 0.88                           | 0.47–1.64  | 0.687          | 0.91                  | 0.48–1.74 | 0.785          |
| Visceral pleural invasion    |                                |            |                |                       |           |                |
| PL1                          |                                |            |                |                       |           |                |
| PL2                          | 2.28                           | 1.69–3.09  | <0.001         | 2.04                  | 1.50–2.77 | <0.001         |
| Lymphovascular invasion      |                                |            |                |                       |           |                |
| No                           |                                |            |                |                       |           |                |
| Yes                          | 8.15                           | 4.54–14.63 | <0.001         | 5.21                  | 2.84–9.57 | <0.001         |
| Lymph node dissection number |                                |            |                |                       |           |                |
| ≥6                           |                                |            |                |                       |           |                |
| <6                           | 2.17                           | 1.45–3.25  | <0.001         | 1.51                  | 0.97–2.35 | 0.067          |

CI, confidence interval; SCC, squamous cell carcinoma.

#### 4. Discussion

The management of early-stage NSCLC has evolved significantly, with recent landmark trials demonstrating the oncological non-inferiority of SLR compared to lobectomy for selected patients with small ( $\leq 2$  cm), peripheral tumors [2,3]. However, the optimal surgical extent for small tumors exhibiting adverse pathological features, such as VPI, remains a subject of debate [13,18]. This study, utilizing a large, nationwide, population-based



cohort in Taiwan, investigated this specific scenario. Our primary finding, derived from propensity-score-matched analysis and multivariate Cox regression, is that after adjusting for significant prognostic factors, SLR and lobectomy provide comparable LCSS for patients with pT2a ( $\leq 3$  cm with VPI) N0M0 NSCLC. While lobectomy showed a survival advantage in the unmatched cohort and univariate analysis, this difference was attenuated and lost statistical significance after balancing baseline characteristics and accounting for confounding factors. This suggests that VPI, in the absence of nodal or distant metastasis for tumors  $\leq 3$  cm, may not independently necessitate more extensive resection, such as lobectomy, to achieve favorable long-term cancer-specific outcomes.

Our findings align with those of several recent studies suggesting that SLR, particularly segmentectomy, can be a viable option, even in the presence of VPI, for appropriately selected small NSCLCs. For instance, Eguchi et al. [12], using the US National Cancer Database (NCDB) and focusing on clinical T1a-bN0 tumors found to have VPI postoperatively, reported no significant difference in overall survival between segmentectomy and lobectomy after PSM. Similarly, a meta-analysis by Dai et al. [11] indicated that while SLR generally showed worse outcomes for VPI-positive tumors  $\leq 3$  cm, the difference was not statistically significant for tumors  $\leq 2$  cm, and segmentectomy achieved comparable survival to lobectomy across the  $\leq 3$  cm VPI-positive group. Other studies focusing on segmentectomy versus lobectomy for VPI-positive small NSCLCs have also reported comparable long-term results, further supporting the potential adequacy of less-extensive resection in this subgroup [19,20]. These concordant findings, despite originating from different databases (TCR, NCDB, SEER) and multicenter studies, and employing varied methodologies, strengthen the hypothesis that anatomical SLR might suffice for small VPI-positive tumors if complete resection and adequate nodal assessment are achieved.

Conversely, our results contrast with those of other investigations that concluded that lobectomy offers superior survival for small, VPI-positive NSCLCs. Zhao et al. [10], analyzing the SEER database for tumors  $\leq 2$  cm with VPI, found that lobectomy was associated with better long-term disease-specific and overall survival compared to those of sublobectomy, even after PSM. Another SEER-based study focusing on stage IB ( $\leq 3$  cm with VPI) reported lobectomy to be superior to wedge resection, but comparable to segmentectomy [21]. Differences between these studies and ours may stem from several factors, including variations in the definition of SLR (some combined wedge and segmentectomy, whereas others analyzed them separately), differences in patient populations across databases (SEER vs. TCR), statistical methodologies (adjustment variables in Cox models, PSM implementation details), and potentially the specific endpoint analyzed (overall survival vs. LCSS) [10,22–24]. Furthermore, residual confounding factors, despite PSM, cannot be entirely excluded from observational studies and may contribute to disparate findings [25,26].

The finding that surgical extent (SLR vs. lobectomy) did not independently impact LCSS in our adjusted analysis, despite the established negative prognostic nature of VPI [7], warrants exploration. One plausible explanation relates to the tumor size restriction ( $\leq 3$  cm) and the nature of resection. For such small lesions, even anatomical SLR (primarily segmentectomy in many centers for oncological indications) often allows for the achievement of adequate surgical margins, potentially negating the theoretical benefit of the wider parenchymal removal offered by lobectomy in terms of local control for truly localized disease [27]. Complete resection with negative margins is paramount, and perhaps more critical than the volume of tissue removed when margins are clear. Second, our stringent exclusion criteria, removing patients with any nodal involvement (N+), distant metastasis (M1), or extensive pleural disease (PL3, potentially implying parietal pleural invasion or M1a pleural seeding), ensured that the analyzed cohort represented truly localized



disease despite the VPI. In such cases where the tumor cells, although invading the visceral pleura, have not demonstrably spread beyond the lung parenchyma or immediate pleura, the systemic risk might be primarily driven by factors like LVI (which remained highly significant in our multivariate analysis) rather than the local extent treatable by the resection type difference between SLR and lobectomy. The biological behavior dictated by factors like LVI, and the inherent tumor aggressiveness reflected partly by VPI status (PL2 was significantly associated with poorer LCSS than PL1) and differentiation grade, may ultimately be stronger determinants of LCSS than the choice between SLR and lobectomy in this specific, localized N0M0 context [9,28].

It is pertinent to address the decision not to include the number of lymph nodes retrieved as a covariate in our propensity-score-matching model. This choice stems from the inherent difference in lymph node yield between lobectomy and sublobar resection (SLR), which is a widely recognized characteristic of these procedures [29]. While the lobectomy group had a significantly higher mean number of lymph nodes retrieved (19.29 vs. 12.99,  $p < 0.001$ ), the mean for the SLR group (12.99) still considerably surpasses the minimum six lymph nodes recommended by international guidelines for adequate pathological evaluation and accurate staging [30]. For our specific pT2a ( $\leq 3$  cm) N0M0 cohort, where patients are clinically node-negative, the probability of this difference materially altering final staging accuracy is deemed low, a view supported by trials on similar early-stage populations [31]. Our matching strategy, therefore, focused on balancing other patient and tumor characteristics that are less directly determined by the surgical extent itself, allowing us to robustly analyze lung-cancer-specific survival as our primary outcome.

This study has several strengths. First, the use of the TCR [14,15], a high-quality, nationwide, population-based database with rigorous validation processes, provided a large and representative cohort, enhancing the generalizability of our findings to the Taiwanese population with this specific stage of NSCLC. The large sample size (initially 2460 patients in this subgroup) allowed for robust statistical analysis. Second, the use of PSM [32] effectively balanced a wide range of measured baseline covariates between the SLR and lobectomy groups, significantly reducing the potential selection bias inherent in observational studies comparing surgical procedures. Third, our focus on LCSS as the primary endpoint, using data linked to the national death registry, minimized bias from competing risks of mortality, providing a clearer assessment of the impact of surgical modality on cancer-related death [16]. Finally, by focusing specifically on the controversial subgroup of small ( $\leq 3$  cm) NSCLC with VPI but without nodal or distant metastasis, this study addressed a pertinent clinical question where high-level evidence is still evolving.

Despite these strengths, our study has limitations inherent to its retrospective, registry-based design. Although the TCR provides comprehensive cancer data [14], it lacks detailed preoperative imaging information, such as the consolidation-to-tumor ratio or precise tumor location, which can influence surgical decisions and prognosis [5]. Furthermore, important perioperative details, including specific surgical techniques within SLR (wedge vs. segmentectomy breakdown), operation time, blood loss, postoperative complications, and length of hospital stay are not captured in the database. This information lack hindered the assessment of potential differences in perioperative outcomes between SLR and lobectomy. Moreover, the database does not include records of preoperative assessments, such as pulmonary function tests or detailed comorbidity indices (beyond age), which are crucial for evaluating surgical candidacy and may represent unmeasured confounders influencing the choice of surgical extent, even after PSM. These limitations, stemming from the nature of secondary data analysis, highlight the need for prospective studies or registries collecting more granular clinical, imaging, and perioperative data to fully compare the comprehensive outcomes of SLR versus lobectomy for this challenging subgroup of early-stage NSCLC.

## 5. Conclusions

In this large, population-based cohort study of patients with pathologic T2a ( $\leq 3$  cm with VPI) N0M0 NSCLC, SLR demonstrated comparable LCSS to lobectomy after PSM and adjustment for prognostic factors. While surgical extent itself was not an independent predictor of LCSS in the adjusted analysis, older age, PL2 VPI, and LVI were significantly associated with worse outcomes. These findings suggest that SLR may be an important oncological alternative to lobectomy for selected patients with small ( $\leq 3$  cm), node-negative NSCLC, even in the presence of VPI. However, further validation through large-scale prospective studies is warranted to confirm these results and solidify their implications for clinical practice.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/cancers17121990/s1>, Figure S1: Propensity Score Distribution and Matching. (A) Scatter plot of logit propensity scores for the segmentectomy and wedge resection groups; (B) Cumulative distribution of propensity scores before and after matching; Figure S2: Lung-Cancer-Specific Survival Following Sublobar Resection in Patients with pT2aN0M0 (tumor  $\leq 3$  cm) Non-Small-Cell Lung Cancer.

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**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of National Taiwan University Hospital (202311023W; date of approval: 20 February 2024).

**Informed Consent Statement:** Patient consent was waived due to the use of data from the Taiwan Cancer Registry Database, a secondary database. Obtaining informed consent from individual patients was not feasible. All data used in this study were de-identified to ensure patient confidentiality and privacy.

**Data Availability Statement:** Restrictions apply to the availability of these data. Data were obtained from Taiwan Cancer Registry Database and are available with the permission of the Taiwan Ministry of Health and Welfare.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

## Abbreviations

The following abbreviations are used in this manuscript:

|       |                                    |
|-------|------------------------------------|
| NSCLC | Non-Small-Cell Lung Cancer         |
| SLR   | Sublobar Resection                 |
| VPI   | Visceral Pleural Invasion          |
| AJCC  | American Joint Committee on Cancer |
| TCR   | Taiwan Cancer Registry             |
| PSM   | Propensity Score Matching          |
| LVI   | Lymphovascular Invasion            |
| LCSS  | Lung-Cancer-Specific Survival      |
| SD    | Standard Deviation                 |
| HR    | Hazard Ratio                       |
| CI    | Confidence Interval                |
| SCC   | Squamous Cell Carcinoma            |

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## Clinical stage-specific prognostic impact of adequate lymphadenectomy in early-stage lung cancer

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### Clinical Stage-Specific Prognostic Impact of Adequate Lymphadenectomy in Early-Stage Lung Cancer

#### Summary

This study analyzed 1,214 patients with clinical stage I–III non-small cell lung cancer who underwent curative surgery, comparing outcomes between those with adequate (R0) and inadequate (R[un]) lymphadenectomy. R0 patients showed improved recurrence-free survival in both the overall matched cohort and the IA3–II subgroup, but not in stages IA1 or IA2.

#### Adequate Lymphadenectomy (R0) (N=440)



#### 10-year RFS

77.2% ( 73.1% - 81.5%)  $p < 0.001$

IA1: 85.7%

$p = 0.300$

IA2: 89.7%

$p = 0.200$

IA3: 80.1%

$p = 0.003$

IB: 70.6%

$p = 0.001$

II: 58.8%

$p = 0.001$

III: 58.3%

$p = 0.400$

#### Inadequate Lymphadenectomy (R[un]) (N = 774, 440 matched)



#### 10-year RFS

61.3% ( 56.7% - 66.3%)

IA1: 95.7%

IA2: 78.9%

IA3: 61.8%

IB: 47.7%

II: 33.8%

III: 21.4%

Legend: RFS, recurrence-free survival

#### Abstract

**OBJECTIVES:** To assess the prognostic impact of adequate lymphadenectomy and determine the optimal nodal assessment for different clinical stages of lung cancer.

**METHODS:** We retrospectively reviewed 1214 patients with clinical stage I–III non-small cell lung cancer who had preoperative positron emission tomography/computed tomography and curative surgery (2006–2017). Patients were categorized based on whether they had adequate (R0) or inadequate lymphadenectomy [R(un)]. Propensity score matching was conducted to minimize bias. Primary end points

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were recurrence-free survival (RFS), overall survival (OS), and cancer-specific survival. Secondary end points included outcomes stratified by clinical stages.

**RESULTS:** Multivariate Cox analysis identified preoperative carcinoembryonic antigen level, tumour size, uptake of tumour on positron emission tomography/computed tomography, R(un) [hazard ratio (HR) = 2.16;  $P < 0.001$ ], angiolymphatic invasion, lymph node involvement and postoperative adjuvant therapy as independent predictors of RFS. The matched cohort included 440 R0 and 440 R(un) patients, with a median follow-up of 94 months. Significant differences were found in 10-year RFS (77.2% vs 61.3%,  $P < 0.001$ ), OS (75.8% vs 64.3%,  $P < 0.001$ ) and cancer-specific survival (83.8% vs 74.2%,  $P < 0.001$ ). Despite longer operative time for R0 (210 vs 195 min,  $P = 0.008$ ), perioperative complications, hospital stay length and blood loss were similar. Subgroup analysis showed R(un) as an independent predictor of RFS in clinical stages IA3 (HR = 2.53,  $P = 0.001$ ), IB (HR = 1.71,  $P = 0.046$ ), and II (HR = 2.44,  $P < 0.001$ ), but not in IA1 or IA2. R0 had significantly better RFS than R(un) in matched cohort of stages IA3 ( $P = 0.003$ ), IB ( $P = 0.001$ ) and II ( $P = 0.001$ ).

**CONCLUSIONS:** Adequate lymph node assessment improves prognosis in patients with clinical stages  $\geq$  IA3. A uniform nodal assessment approach should be reconsidered for different clinical stages.

**Keywords:** Non-small cell lung cancer • Curative-intent surgery • Adequate lymph node dissection • Uncertain resection • Clinical stage

#### ABBREVIATIONS

|        |                                                        |
|--------|--------------------------------------------------------|
| CI     | Confidence interval                                    |
| CSS    | Cancer-specific survival                               |
| CT     | Computed tomography                                    |
| GGO    | ground-glass opacity                                   |
| HR     | Hazard ratio                                           |
| IASLC  | International Association for the Study of Lung Cancer |
| NSCLC  | Non-small-cell lung cancer                             |
| OS     | Overall survival                                       |
| PET/CT | Positron emission tomography/computed tomography       |
| PSM    | Propensity scores matching                             |
| R(un)  | Uncertain resection (inadequate lymphadenectomy)       |
| R0     | Complete resection (adequate lymphadenectomy)          |
| RFS    | Recurrence-free Survival                               |

#### INTRODUCTION

Systematic lymph node dissection and complete resection are crucial components of curative surgery for non-small-cell lung cancer (NSCLC). According to the International Association for the Study of Lung Cancer (IASLC), surgeries that do not involve adequate lymph node dissection are classified as ‘uncertain resections’ [1, 2], even in the absence of detectable residual cancer at the margins.

The widespread implementation of low-dose computed tomography scans has led to the diagnosis of lung cancer at early stages, prompting a re-evaluation of traditional surgical approaches. Clinical trials such as JCOG0802, JCOG1211, JCOG0804 and CALGB-Alliance 140503 show a shift towards minimizing the extent of parenchymal resection for early-stage lung cancer [3–6]. Despite these changes, the extent of lymphadenectomy for early-stage tumours, which typically show a lower incidence of lymph node metastasis, remains debatable.

Guidelines from the IASLC, European Society of Thoracic Surgeons [7] and National Comprehensive Cancer Network consistently recommend systemic lymph node dissection for NSCLC at any stage [8]. Conversely, data from the American College of Surgery Oncology Group Z0030 trial indicates no survival benefit between simple mediastinal lymph node sampling and full dissection in early-stage T1 or T2 tumours [9].

This study aimed to examine the effectiveness of adequate lymph node dissection according to IASLC guidelines and its impact on long-term outcomes across various clinical stages of NSCLC.

#### PATIENTS AND METHODS

##### Patient selection and data collection

Records of patients with stage I–III NSCLC who underwent curative surgeries at Taipei Veterans General Hospital between 2006 and 2017 were retrospectively reviewed. Among 2948 patients, 1214 were included after applying exclusion criteria, namely, synchronous or metachronous lung cancers or prior induction therapy, R1/R2 resection, carcinoid tumour, absence of preoperative whole-body positron emission tomography/computed tomography (PET/CT) to complete staging and pure ground-glass opacity (GGO) lesions (Fig. 1).

Data included clinical and demographic characteristics [i.e. age, sex, Charlson comorbidity index, preoperative lung function, smoking status, serum carcinoembryonic antigen levels, tumour specifics, clinical stage, extent of resection, adjuvant therapy] and perioperative parameters (i.e. lymph node dissection adequacy, operation duration, blood loss, complications, hospital stay). The Institutional Review Board approved the study (approval no. 2024-02-004AC) with waived consent.

##### Clinical staging workup

Clinical staging involved comprehensive imaging and diagnostic procedures. Multi-planar thin-section contrast-enhanced chest CT and whole-body PET/CT scans were used to evaluate the extent of the disease. Brain surveys were conducted using magnetic resonance imaging or CT. Furthermore, suspected metastatic mediastinal lymph nodes were assessed using mediastinoscopy, endobronchial ultrasound-guided fine-needle aspiration or video-assisted thoracoscopic surgery lymph node biopsy to ensure accurate staging and treatment planning.

##### Lymph node dissection

The surgical approach to lymphadenectomy was customized based on patient-specific and tumour-specific factors determined by the surgeons. They prioritized the removal of

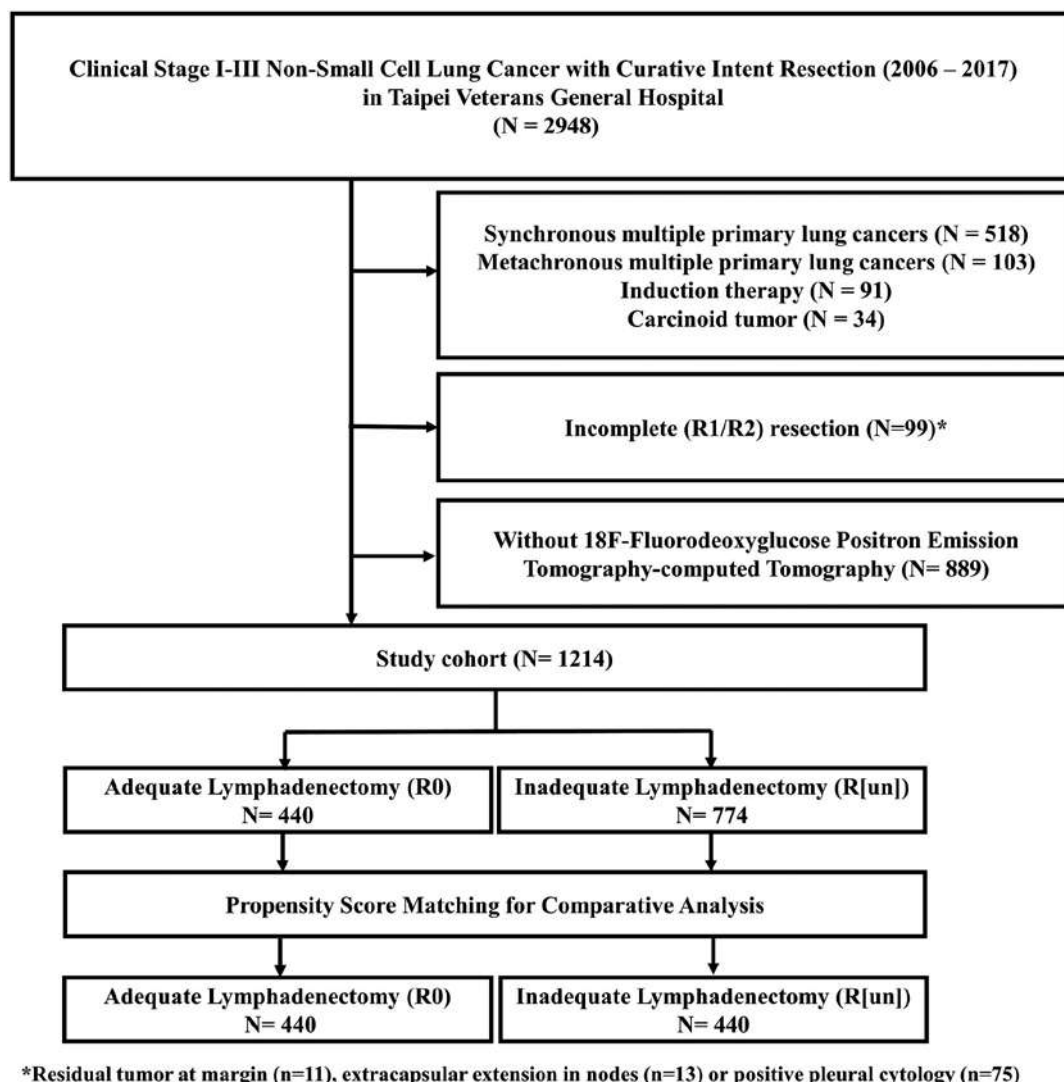


Figure 1: Flowchart illustrating the patient selection process.

preoperatively suspicious lymph nodes and then considered tumour size, the consolidation-to-tumour ratio, location and the maximal standard uptake value on PET. Patients were categorized into 2 groups based on lymphadenectomy adequacy: adequate (R0) and inadequate lymphadenectomy [R(un)]. According to IASLC guidelines, R0 is a systematic nodal dissection that includes at least 3 N1 nodes from 3 distinct N1 stations and 3 N2 nodes from three N2 stations, including the subcarinal nodes. Procedures that did not meet these specifications were classified as R(un). Our analysis primarily evaluated lymphadenectomy adequacy in distinguishing R0 from R(un), without incorporating other potential prognostic variables such as the absence of metastasis in the highest mediastinal lymph node in the cohort selection process.

### Survival and recurrence analysis

Patients had follow-up visits every 3 months for the first 2 years, every 6 months until year 5, and annually thereafter. Chest CT

scans were conducted every 6 months for the first 2 years and then yearly. Patients who missed follow-ups for >1 year were contacted by phone to update their survival status; those uncontactable for >1 year were marked as lost to follow-up. Follow-up extended until 31 May 2023.

The primary end points were recurrence-free survival (RFS), overall survival (OS) and cancer-specific survival (CSS) based on the extensiveness of adequate lymph node dissection. Secondary end points examined stage-specific outcomes. Recurrence detection involved confirmatory tissue biopsy or clinical evaluation by a multidisciplinary team, with localization classified as local (within the ipsilateral hemithorax, mediastinum or supraclavicular lymph nodes) or distant. RFS was measured from the date of surgery to the date of recurrence, death or last follow-up for those alive without recurrence. OS was calculated from the date of the surgical procedure to the date of death or last recorded follow-up, whereas CSS was defined as the time from surgery to death attributable to lung cancer, with patients censored at the last follow-up if death did not occur.



## Statistical analysis

Patient characteristics and perioperative parameters were statistically analysed using the Pearson chi-square or Fisher's exact test for categorical variables, depending on the expected frequencies. Continuous variables were assessed using the Shapiro-Wilk test to determine normality, followed by the use of the *t*-test or Mann-Whitney *U*-test based on normality. Post-matching cohorts were assessed using the Wilcoxon signed-rank test, McNemar's test or the Marginal Homogeneity Test. Factors associated with R(un) were analysed through logistic regression. Cox regression models were applied to investigate prognostic factors affecting OS and RFS. Significant variables from the initial univariate analysis ( $P \leq 0.1$ ) were further evaluated in a multivariate analysis. Results were expressed as hazard ratio (HR) with 95% confidence interval (CI). Statistical significance was established at  $P < 0.05$ . Kaplan-Meier survival curves were compared using the log-rank test for pre-matching analyses and the stratified log-rank test for post-matching analyses.

Propensity scores were estimated using a single-hidden-layer neural network [10, 11] involved following variables: age, sex, Charlson comorbidity score, maximal tumour dimension, surgical approach and clinical stage. Matching was conducted in a blinded manner using a 1:1 ratio. Statistical tests were performed using SPSS for Windows v.25.0 (IBM Corp., Armonk, NY, USA) and R v.4.1.1 (<http://www.R-project.org/>).

## RESULTS

### Patient characteristics

The study included 1214 patients with clinical stage I–III NSCLC (Table 1). Among the patients, 440 (36.2%) received R0 and 774 (63.8%) received R(un) lymphadenectomy. The R0 rates were below 50% across all clinical stages (Supplementary Material, Fig. S1). Within the cohort, 47.8% of the patients were males, with a median age of 64 years, and 37% were smokers. Both groups had similar demographic characteristics, pulmonary function, tumour centrality and pathological N stage.

Sublobar resection was the only independent predictor associated with R(un) in the multivariate analysis (odds ratio, 5.41; 95% CI, 3.30–8.88,  $P < 0.001$ ) (Supplementary Material, Table S1). Patients who received R(un) had higher Charlson comorbidity scores, smaller total tumour size, higher percentage of sublobar resection, lower clinical and pathological stages, fewer dissected lymph nodes and lower likelihood of receiving postoperative adjuvant therapy. After propensity score matching (PSM), each cohort consisted of 440 patients, with standard mean differences indicating balance across both groups ( $< 0.1$ ).

### Survival and recurrence analysis

In the overall cohort, RFS, OS and CSS were significantly better in the R0 than in the R(un) group (10-year RFS, 77.2% vs 66.0%,  $P < 0.001$ ; 10-year OS, 75.8% vs 65.8%,  $P < 0.001$ ; 10-year CSS 83.8% vs 76.7%,  $P = 0.003$ ) (Fig. 2).

The median follow-up period for the post-PSM cohort was 94 months (25th–75th interquartile range: 69–139 months); on the day of last follow-up, 257 patients had developed recurrence [95 patients in the R0 and 162 in the R(un) group]. The R(un) group had higher rates than the R0 group among loco-regional

(12.1% vs 7.7%), distant (13.4% vs 6.8%) and simultaneous local and distant recurrence (11.4% vs 7.1%) (Table 2).

Multivariate Cox analysis identified several independent predictors of RFS and OS, including elevated preoperative carcinoembryonic antigen levels, maximum tumour dimension, R(un) (HR = 2.16; 95% CI, 1.69–2.75,  $P < 0.001$  for RFS; HR = 1.62; 95% CI, 1.28–2.06,  $P < 0.001$  for OS), angiolymphatic invasion and lymph node involvement. Additionally, higher maximum standardized uptake value and postoperative adjuvant therapy were independent predictors for RFS, while smoking history, higher Charlson comorbidity score and preoperative diffusing capacity of the lung for carbon monoxide  $\leq 50\%$  were independent predictors of OS (Supplementary Material, Tables S2 and S3).

After PSM, RFS, OS and CSS remained significantly better in the R0 group than in the R(un) group (10-year RFS, 77.2% vs 61.3%,  $P < 0.001$ ; 10-year OS, 75.8% vs 64.3%,  $P < 0.001$ ; 10-year CSS 83.8% vs 74.2%,  $P < 0.001$ ) (Fig. 3).

### Subgrouping stratified by the clinical stages

Supplementary Material, Table S4 presents the subgroup analysis stratified by clinical stages and details the numbers of patients and 10-year RFS rates for R0 and R(un) patients across different clinical stages. To evaluate the prognostic effects regarding the extent of nodal assessment within each clinical stage, survival risk factors in each subgroup were analysed. Multivariate Cox analysis identified R(un) as an independent predictor of RFS in clinical stages IA3 (HR = 2.53,  $P < 0.001$ ), IB (HR = 1.71,  $P = 0.046$ ) and II (HR = 2.44,  $P < 0.001$ ), but not in stages IA1 and IA2.

Survival outcomes were evaluated for 23, 104, 114, 74 and 66 matched pairs of R0 and R(un) patients in stages IA1, IA2, IA3, IB and II, respectively, and for 13 stage III pairs with age imbalance. Figure 4 illustrates the Kaplan-Meier curves for RFS, comparing post-matching R0 and R(un) patients across different clinical stages. RFS was significantly better in the R0 than in the R(un) group in clinical stages IA3, IB and II. OS was significantly better in the R0 than in the R(un) group in clinical stage IB and III. Additionally, stages IB and II demonstrated a better trend for R0 in CSS (Supplementary Material, Figs S2 and S3). The Kaplan-Meier curves for pre-matching by clinical stages are shown in Supplementary Material, Figs S4–S6.

### Perioperative outcomes

Postoperative complications occurred in 135 (30.7%) and 219 (28.3%) patients in the R0 and R(un) groups, respectively, in the entire cohort ( $P = 0.379$ ). Among them, grade III or higher complications were noted in 50 (11.4%) and 91 (11.8%) patients, respectively (Table 2). Longer operative time (210 vs 190 min,  $P < 0.001$ ) and higher chylothorax rate (3.6% vs 1.8%,  $P = 0.049$ ) were noted in the R0 group. Following PSM, except for longer operative time (195 vs 210 min,  $P = 0.008$ ), no inferior outcomes were noted regarding perioperative complications (30.7% vs 28.4%), hospital length of stay (7 vs 7 days) and estimated blood loss (50 vs 50 ml) in the R0 group (Table 2).

## DISCUSSION

This study analysed a long-term follow-up cohort of resectable lung cancer patients, all of whom underwent preoperative PET

**Table 1:** Clinical, operative and pathologic characteristics of patients undergoing different lymphadenectomy procedures before and after propensity score matching

| Variables<br>n (%) or median (25th–75th IQR) | Before matching   |               |                  |                     | After matching <sup>c</sup> |                  |                     |         |
|----------------------------------------------|-------------------|---------------|------------------|---------------------|-----------------------------|------------------|---------------------|---------|
|                                              | Total<br>n = 1214 | R0<br>n = 440 | R(un)<br>n = 774 | P value             | R0<br>n = 440               | R(un)<br>n = 440 | P value             | SMD     |
| Age (years) <sup>f</sup>                     | 64 (57–72)        | 64 (57–70)    | 65 (57–73)       | 0.071 <sup>a</sup>  | 64 (57–70)                  | 64 (56–72)       | 0.221 <sup>c</sup>  | 0.0608  |
| Sex (male) <sup>f</sup>                      | 580 (47.8)        | 195 (44.3)    | 385 (49.7)       | 0.069 <sup>b</sup>  | 195 (44.3)                  | 206 (46.8)       | 0.444 <sup>d</sup>  | 0.0250  |
| Smoking history (yes)                        | 453 (37.3)        | 163 (37.1)    | 290 (37.5)       | 0.884 <sup>b</sup>  | 163 (37.1)                  | 166 (37.7)       | 0.881 <sup>d</sup>  |         |
| Preoperative serum CEA level (abnormal)      | 210 (17.3)        | 68 (15.5)     | 142 (18.4)       | 0.200 <sup>b</sup>  | 68 (15.5)                   | 87 (19.8)        | 0.110 <sup>d</sup>  |         |
| Charlson comorbidity score <sup>f</sup>      | 3 (2–4)           | 2 (2–3)       | 3 (1–4)          | 0.025 <sup>a</sup>  | 2 (2–3)                     | 2 (1–4)          | 0.207 <sup>c</sup>  | 0.0733  |
| PreOP FEV1 (≤50%)                            | 16 (1.3)          | 6 (1.4)       | 10 (1.3)         | 0.916 <sup>b</sup>  | 6 (1.4)                     | 2 (0.5)          | 0.289 <sup>d</sup>  |         |
| PreOP DLCO (≤50%)                            | 147 (12.1)        | 47 (10.7)     | 100 (12.9)       | 0.251 <sup>b</sup>  | 47 (10.7)                   | 51 (11.6)        | 0.749 <sup>d</sup>  |         |
| Maximum tumour dimension (cm) <sup>f</sup>   | 2 (1.2–3.1)       | 2.2 (1.4–3.2) | 1.9 (1–3)        | <0.001 <sup>a</sup> | 2.2 (1.4–3.2)               | 2.2 (1.4–3.2)    | 0.115 <sup>c</sup>  | 0.0523  |
| Tumour location (central)                    | 277 (22.8)        | 101 (23.0)    | 176 (22.7)       | 0.931 <sup>b</sup>  | 101 (23.0)                  | 120 (27.3)       | 0.143 <sup>d</sup>  |         |
| Consolidation/tumour ratio (≥50%)            | 837 (69.0)        | 318 (72.3)    | 519 (67.1)       | 0.059 <sup>b</sup>  | 318 (72.3)                  | 329 (74.8)       | 0.436 <sup>d</sup>  |         |
| Clinical stage <sup>f</sup>                  |                   |               |                  | <0.001 <sup>b</sup> |                             |                  | 0.490 <sup>e</sup>  |         |
| IA1                                          | 121 (10.0)        | 27 (6.1)      | 94 (12.1)        |                     | 27 (6.1)                    | 29 (6.6)         |                     | 0.0045  |
| IA2                                          | 363 (29.9)        | 108 (24.6)    | 255 (33.0)       |                     | 108 (24.6)                  | 113 (25.7)       |                     | 0.0114  |
| IA3                                          | 302 (24.9)        | 137 (31.1)    | 165 (21.3)       |                     | 137 (31.1)                  | 116 (26.4)       |                     | –0.0477 |
| IB                                           | 198 (16.3)        | 76 (17.3)     | 122 (15.8)       |                     | 76 (17.3)                   | 83 (18.9)        |                     | 0.0159  |
| II                                           | 181 (14.9)        | 76 (17.3)     | 105 (13.6)       |                     | 76 (17.3)                   | 79 (18.0)        |                     | 0.0068  |
| III                                          | 49 (4.0)          | 16 (3.6)      | 33 (4.3)         |                     | 16 (3.6)                    | 20 (4.6)         |                     | 0.0091  |
| Surgical approach                            |                   |               |                  | <0.001 <sup>b</sup> |                             |                  | >0.999 <sup>d</sup> | <0.0001 |
| Sublobar resection                           | 193 (15.9)        | 20 (4.6)      | 173 (22.4)       |                     | 20 (4.6)                    | 20 (4.6)         |                     |         |
| Lobectomy (or above) <sup>f</sup>            | 1021 (84.1)       | 420 (95.5)    | 601 (77.7)       |                     | 420 (95.5)                  | 420 (95.5)       |                     |         |
| Adjuvant chemotherapy (yes)                  | 435 (35.8)        | 183 (41.6)    | 252 (32.6)       | 0.002 <sup>b</sup>  | 183 (41.6)                  | 173 (39.3)       | 0.531 <sup>d</sup>  |         |
| Dissected lymph node number                  | 17 (12–23)        | 22 (18–28)    | 14 (10–19)       | <0.001 <sup>a</sup> | 22 (18–28)                  | 15 (11–19)       | <0.001 <sup>c</sup> |         |
| Dissected lymph node station                 | 5 (4–6)           | 6 (6–7)       | 5 (4–5)          | <0.001 <sup>a</sup> | 6 (6–7)                     | 5 (4–5)          | <0.001 <sup>c</sup> |         |
| Histology                                    |                   |               |                  | 0.109 <sup>b</sup>  |                             |                  | 0.832 <sup>e</sup>  |         |
| Adenocarcinoma                               | 1039 (85.6)       | 373 (84.8)    | 666 (86.1)       |                     | 373 (84.8)                  | 377 (85.7)       |                     |         |
| Squamous cell carcinoma                      | 126 (10.4)        | 54 (12.3)     | 72 (9.3)         |                     | 54 (12.3)                   | 43 (9.8)         |                     |         |
| Others                                       | 49 (4.0)          | 13 (2.9)      | 36 (4.7)         |                     | 13 (2.9)                    | 20 (4.6)         |                     |         |
| Pathologic stage                             |                   |               |                  | <0.001 <sup>b</sup> |                             |                  | 0.247 <sup>e</sup>  |         |
| IA1                                          | 170 (14)          | 38 (8.6)      | 132 (17.1)       |                     | 38 (8.6)                    | 45 (10.2)        |                     |         |
| IA2                                          | 129 (10.6)        | 43 (9.8)      | 86 (11.1)        |                     | 43 (9.8)                    | 40 (9.1)         |                     |         |
| IA3                                          | 70 (5.8)          | 25 (5.7)      | 45 (5.8)         |                     | 25 (5.7)                    | 31 (7.1)         |                     |         |
| IB                                           | 569 (46.9)        | 227 (51.6)    | 342 (44.2)       |                     | 227 (51.6)                  | 202 (45.9)       |                     |         |
| II                                           | 187 (15.4)        | 78 (17.7)     | 109 (14.1)       |                     | 78 (17.7)                   | 83 (18.9)        |                     |         |
| III                                          | 89 (7.3)          | 29 (6.6)      | 60 (7.8)         |                     | 29 (6.6)                    | 39 (8.9)         |                     |         |
| Pathologic N stage                           |                   |               |                  | 0.257 <sup>b</sup>  |                             |                  | 0.308 <sup>e</sup>  |         |
| N0                                           | 1050 (86.5)       | 377 (85.7)    | 673 (87.0)       |                     | 377 (85.7)                  | 371 (84.3)       |                     |         |
| N1                                           | 100 (8.2)         | 43 (9.8)      | 57 (7.4)         |                     | 43 (9.8)                    | 41 (9.3)         |                     |         |
| N2                                           | 64 (5.3)          | 20 (4.6)      | 44 (5.7)         |                     | 20 (4.6)                    | 28 (6.4)         |                     |         |
| Angiolymphatic invasion                      | 307 (25.3)        | 105 (23.9)    | 202 (26.1)       | 0.389 <sup>b</sup>  | 105 (23.9)                  | 141 (32.1)       | 0.008 <sup>d</sup>  |         |

<sup>a</sup>Mann–Whitney U-test.

<sup>b</sup>Chi-squared test.

<sup>c</sup>Wilcoxon sign rank test.

<sup>d</sup>McNemar's test.

<sup>e</sup>Marginal Homogeneity test.

<sup>f</sup>Variables matched: age, sex, Charlson Comorbidity score, maximal tumour dimension, clinical stage, surgical approaches.

CEA: carcinoembryonic antigen; DLCO: diffusion capacity of carbon monoxide; FEV1: forced expiratory volume in one second; IQR: interquartile range; SMD: standardized mean difference.

scans for clinical staging based on the 8th edition of the AJCC TNM system. A more thorough lymph node assessment, indicated by the R0 dissection, significantly improves long-term outcomes such as RFS, OS and CSS compared to a less thorough assessment, indicated by the R(un) dissection, for NSCLC patients who have undergone curative surgical resection. This outcome improvement was observed after a balanced comparison of the 2 groups. Notably, a subgroup analysis investigating the effects of R0 dissection on the prognosis of patients at different clinical stages showed significant RFS advantages in the IA3, IB and II stages, but not in IA2 and IA1.

Generally, surgical interventions involve lymph node dissection for therapeutic purposes, such as removing cancer-bearing lymph

nodes, and diagnostic purposes, including accurate staging and selecting patients who may benefit from adjuvant therapy. In addition to systemic lymph node dissection, strategies such as lobe-specific nodal dissection [12] and selective lymph node dissection [13] have been applied. Consequently, variations in clinical practice emerged, reflecting the diversity of approaches among surgeons. This variability provided an opportunity for comparison and analysis, enabling us to assess the clinical outcomes associated with different lymphadenectomy strategies.

Our study followed the IASLC guidelines, which define R0 as including at least 3 N1 nodes from 3 distinct N1 stations and 3 N2 nodes from 3 N2 stations, including the subcarinal nodes. We utilized lymph node stations to replace the lymph number

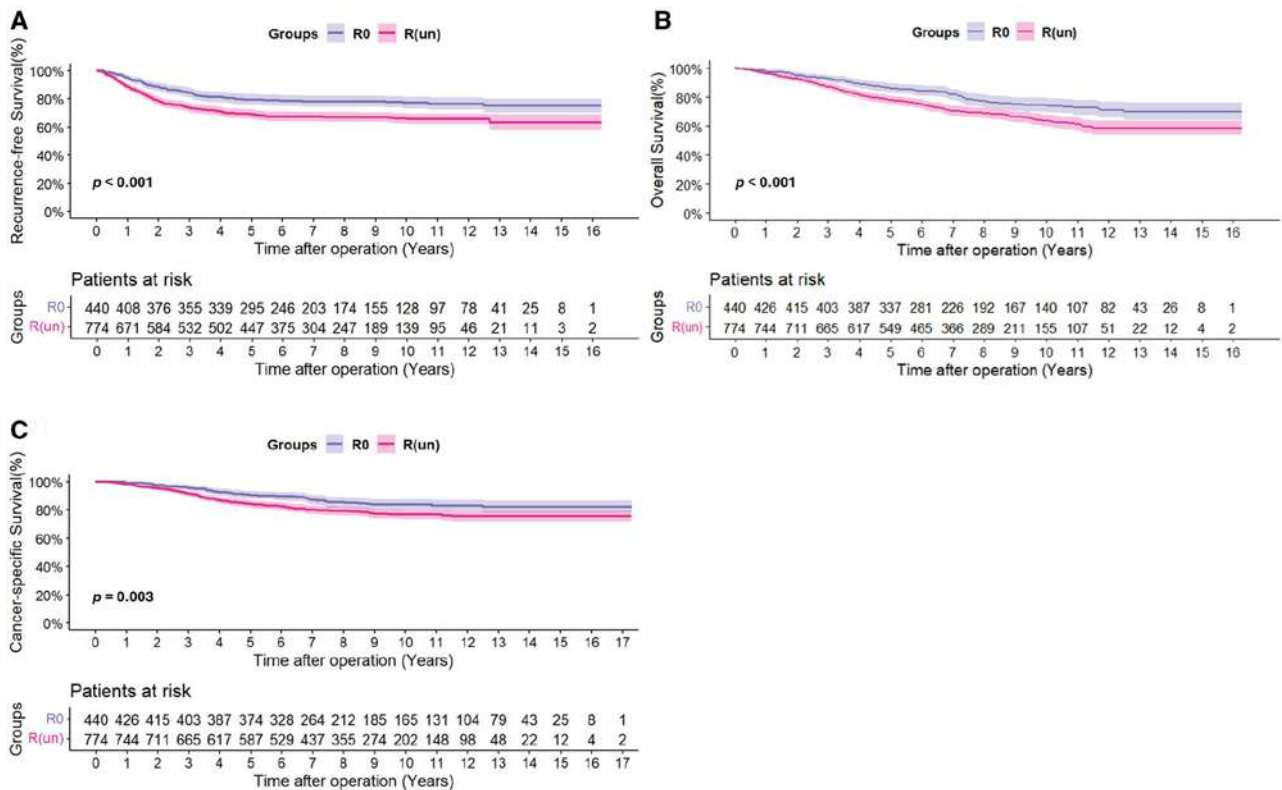


**Figure 2:** Kaplan-Meier curves comparing (a) recurrence-free, (b) overall and (c) cancer-specific survival of patients with R0 (purple) and R(un) (pink) lymphadenectomy before propensity score matching.

**Table 2:** Perioperative comorbidities and recurrence patterns

| Variables, N (%) or median (25th–75th IQR) | Before matching |                    |                     | After matching <sup>d</sup> |                    |                     |
|--------------------------------------------|-----------------|--------------------|---------------------|-----------------------------|--------------------|---------------------|
|                                            | R0 (n = 440; %) | R(un) (n = 774; %) | P value             | R0 (n = 440; %)             | R(un) (n = 440; %) | P value             |
| Operative time (min)                       | 210 (170–260)   | 190 (150–240)      | <0.001 <sup>a</sup> | 210 (170–260)               | 195 (160–241)      | 0.008 <sup>d</sup>  |
| Estimated blood loss (ml)                  | 50 (30–150)     | 50 (30–100)        | 0.114 <sup>a</sup>  | 50 (30–150)                 | 50 (30–120)        | 0.692 <sup>d</sup>  |
| Postoperative complication                 |                 |                    |                     |                             |                    |                     |
| Overall                                    | 135 (30.7)      | 219 (28.3)         | 0.379 <sup>b</sup>  | 135 (30.7)                  | 125 (28.4)         | 0.495 <sup>e</sup>  |
| ≥Grade III                                 | 50 (11.4)       | 91 (11.8)          | 0.837 <sup>b</sup>  | 50 (11.4)                   | 49 (11.1)          | >0.999 <sup>e</sup> |
| 30-day mortality                           | 2 (0.5)         | 3 (0.7)            | 0.299 <sup>c</sup>  | 2 (0.5)                     | 1 (0.2)            | >0.999 <sup>e</sup> |
| 90-days mortality                          | 3 (0.7)         | 5 (0.7)            | 1.000 <sup>c</sup>  | 3 (0.7)                     | 3 (0.7)            | >0.999 <sup>e</sup> |
| Chylothorax (overall)                      | 16 (3.6)        | 14 (1.8)           | 0.049 <sup>b</sup>  | 16 (3.6)                    | 7 (1.6)            | 0.081 <sup>e</sup>  |
| Chylothorax (right)                        | 13 (4.9)        | 9 (2.0)            | 0.035 <sup>b</sup>  | 13 (4.9)                    | 5 (2.0)            | 0.077 <sup>b</sup>  |
| Chylothorax (left)                         | 3 (1.7)         | 5 (1.5)            | 1.000 <sup>c</sup>  | 3 (1.7)                     | 2 (1.1)            | 0.672 <sup>c</sup>  |
| Hospital stays (day) <sup>e</sup>          | 7 (5–10)        | 7 (5–9)            | 0.879 <sup>a</sup>  | 7 (5–10)                    | 7 (6–9)            | 0.771 <sup>d</sup>  |
| Overall death                              | 99 (22.5)       | 248 (32.0)         | <0.001 <sup>b</sup> | 99 (22.5)                   | 154 (35.0)         | <0.001 <sup>e</sup> |
| Non-cancer death                           | 35 (8.0)        | 87 (11.2)          | <0.001 <sup>b</sup> | 35 (8.0)                    | 49 (11.1)          | 0.151 <sup>e</sup>  |
| Disease progression                        | 95 (21.6)       | 247 (31.9)         | <0.001 <sup>b</sup> | 95 (21.6)                   | 162 (36.8)         | <0.001 <sup>e</sup> |
| Time to recurrence (months)                | 22 (13–38)      | 18 (9–32)          | 0.015 <sup>a</sup>  | 22 (13–38)                  | 17 (8–32)          | 0.011 <sup>a</sup>  |
| Recurrent pattern                          |                 |                    | 0.002 <sup>b</sup>  |                             |                    | <0.001 <sup>f</sup> |
| No recurrence                              | 345 (78.4)      | 527 (68.1)         |                     | 345 (78.4)                  | 278 (63.2)         |                     |
| Locoregional                               | 34 (7.7)        | 88 (11.4)          |                     | 34 (7.7)                    | 53 (12.1)          |                     |
| Distant                                    | 30 (6.8)        | 78 (10.1)          |                     | 30 (6.8)                    | 59 (13.4)          |                     |
| Both                                       | 31 (7.1)        | 81 (10.5)          |                     | 31 (7.1)                    | 50 (11.4)          |                     |

<sup>a</sup>Mann-Whitney U-test.

<sup>b</sup>Chi-squared test.

<sup>c</sup>Fisher's exact test.

<sup>d</sup>Wilcoxon sign rank test.

<sup>e</sup>McNemar's test.

<sup>f</sup>Marginal Homogeneity test.

<sup>d</sup>Variables matched: age, sex, Charlson Comorbidity score, maximal tumour dimension, clinical stage, surgical approaches.

<sup>e</sup>Stays for primary lung resection.

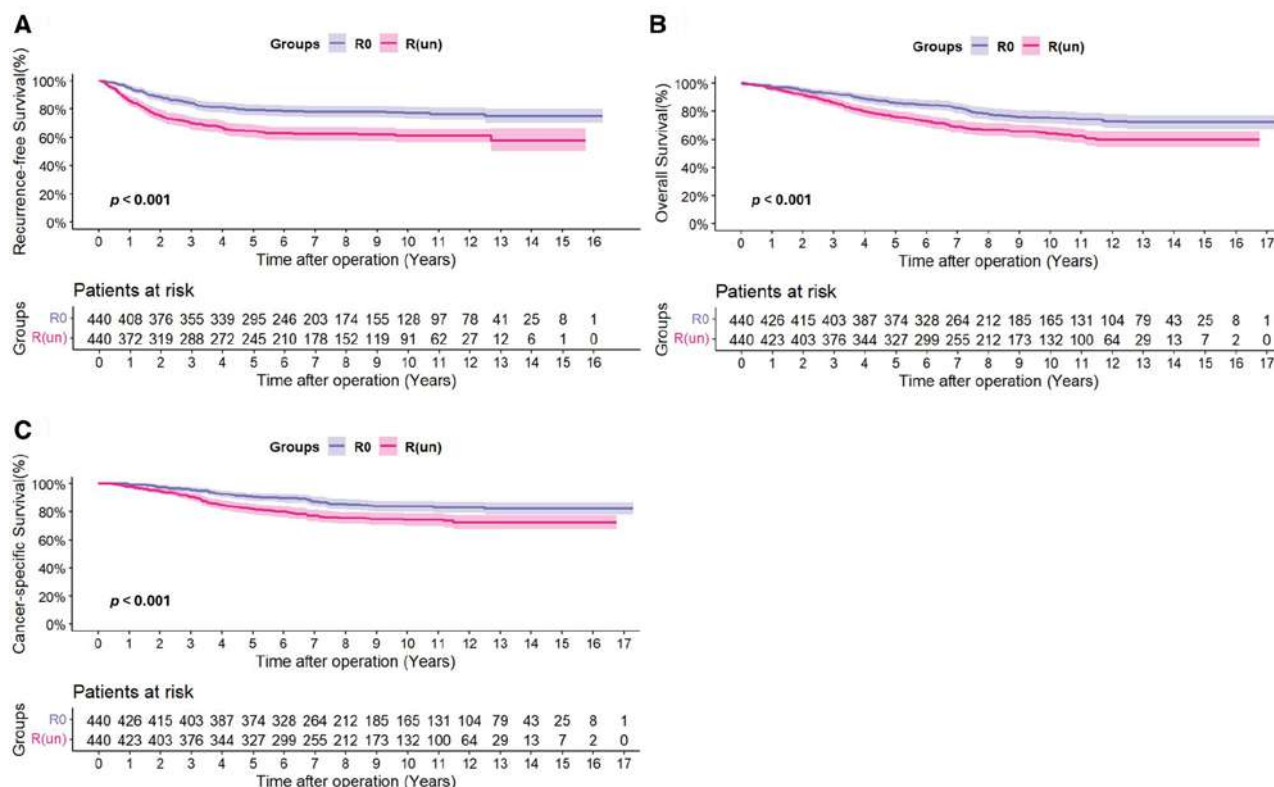


**Figure 3:** Kaplan-Meier curves comparing (a) recurrence-free, (b) overall and (c) cancer-specific survival of patients with R0 (purple) and R(un) (pink) lymphadenectomy after propensity score matching.

because the total lymph node count can often be confounded by fragmentation at the time of surgery; the total number of lymph node stations sampled may be a better surrogate for outcome.

## Lymphadenectomy based on tumour advancement

The extent of lymphadenectomy in lung cancer surgery remains controversial, with ongoing debates about its impact on survival outcomes, particularly in relation to tumour size and invasiveness [2, 9]. For smaller or clinically less-invasive tumours, which yield better surgical outcomes, the need for and extent of lymph node dissection are less clear [14]. Nevertheless, Gulack *et al.* [15], utilizing the National Cancer Database, argue that larger tumours during clinical stage I NSCLC surgeries require more extensive lymph node dissections for improved survival.

GGO component on image implies lepidic component on pathology and is considered less invasive, and its presence influences decisions concerning the extent of nodal assessment. Lee *et al.* [2] found that early-stage NSCLC, specifically pathologic stages IA1 and IA2 with a low-risk histologic subtype, did not show worsened prognoses with less rigorous nodal assessments. Conversely, Maurizi *et al.* [16] demonstrated that a thorough nodal dissection in patients with lepidic adenocarcinoma revealed occult nodal metastases in up to 20% of cases, enhancing the accuracy of pathologic staging. Moreover, supplemental analysis of JCOG0802/WJOG4607L showed radiologic findings

crucial for lymph node metastasis. Among part-solid tumour patients, 1.5% exhibited metastasis and 0.5% had pN2 disease. In the pure-solid group, 10.5, 5.4 and 0.9% had metastasis, pN2 disease and nonadjacent interlobar metastases, respectively [17].

Our research is relatively consistent with these findings. By stratifying patients based on the TNM staging, with a focus on the invasive (T) component rather than the overall tumour size, including the GGO component, we observed that the extent of lymph node removal did not significantly differ in patients with clinical stage IA2 or earlier, indicating that while the size and specific characteristics of the tumour influence lymphadenectomy, the benefits of extensive dissection in early stages may be limited, underscoring the need for a tailored approach based on individual tumour profiles. JCOG clinical trials recommend sublobar resection in tumours <2 cm; however, extensive lymph node dissection may not be necessary for these patients, especially for those with part-solid tumours [17].

A reason that surgeons did not make more effort to perform radical lymph node dissection is associated with high comorbidities and uncertain clinical adverse effects. In the ACOSOG Z0030 trial, the postoperative complication rate was slightly higher in systemic lymph node dissection than in lymph node sampling (38.6% vs 37.9%), although not statistically significant [18]. Similarly, in our study, except for the longer operative time, no increase was noted in estimated blood loss, complication rates (30.7% vs 28.4%) and hospital stay in the R0 and R(un) groups. Overall, removing or sampling multiple lymph node stations of mediastinal (N2) and hilar (N1) nodes during a lung



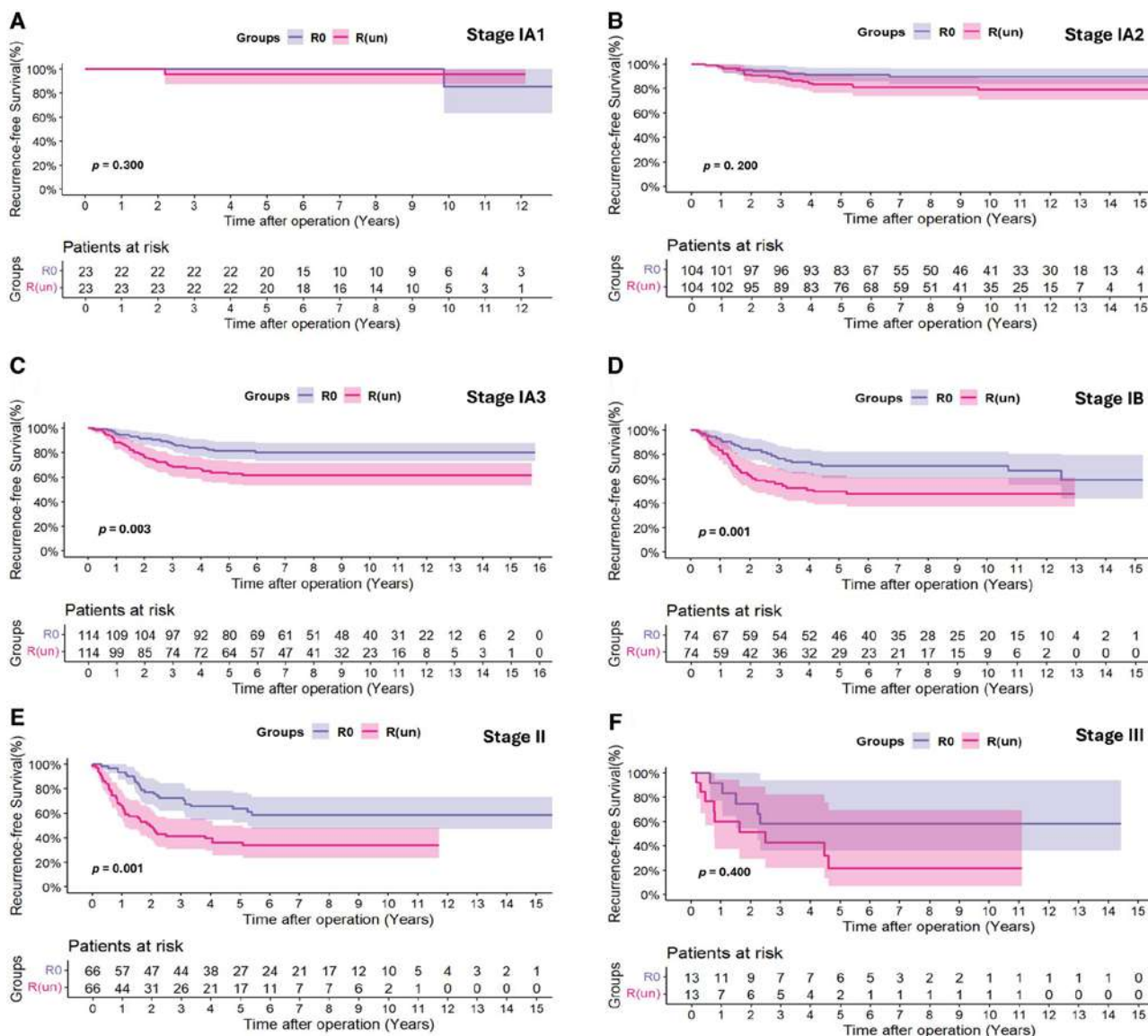


**Figure 4:** Kaplan–Meier curves comparing recurrence-free survival among patients with R0 (purple) and R(un) (pink) lymphadenectomy, categorized based on clinical stages (a) IA1, (b) IA2, (c) IA3, (d) IB, (e) II and (f) III after propensity score matching.

cancer operation is appropriate, and the surgeon has an obligation to perform this thorough nodal assessment on the patient with lung cancer [19], especially those with more aggressive disease, such as in stages IA3, IB and II.

The golden rules of surgical radicalization should be adhered to in routine clinical practice. However, real-world data show that completeness of lymph node dissection as a quality metric is met only in a minority of patients with clinically staged N0 NSCLC, irrespective of the surgical approach, in Europe and the USA [20]. In our cohort, the percentage of R0 dissection was 36%, falling <50% for each clinical stage. Furthermore, our study observed a declining trend in the quality metric lymphadenectomy over time. Possible reasons for inadequate lymphadenectomy may contribute to developing the minimally invasive approaches [21], smaller parenchymal section [22] and subsolid nodules [17].

Although surgeons should prioritize lymph node dissection in lung cancer resection, our study showed that R0 dissection did not induce significant surgical outcomes in clinical stages IA1 and IA2. Therefore, a one-size-fits-all quality metric protocol may not be the best approach for a population with variable risk of recurrence, especially in the era of the prevalent screening program of low-dose computed tomography.

## Limitations

This study had several limitations. First, as a single-centre retrospective study, the findings may not be generalizable to broader populations. Second, the 95% CIs were not adjusted for multiple comparisons, which may reduce the reproducibility of certain inferences. Third, stage migration may have occurred; although patients received a PET scan before surgery, there remains a risk

of underdetection of lymph node metastasis, leading to an inaccurate clinical N stage. Fourth, the small sample size in some subgroups limits the robustness of the findings and the ability to draw definitive conclusions. Fifth, despite PSM, an imbalance in angiolymphatic invasion persisted between the R0 and R(un) groups in the overall cohort, though this imbalance was not present within matched cohorts of each clinical stage. Moreover, most of our patients (96%) underwent lobectomy or more extensive surgical interventions, limiting the data available to assess the role of R0 lymphadenectomy in sublobar resections. Lastly, the long time span of the study precluded the inclusion of newer factors, such as STAS and molecular markers.

## CONCLUSIONS

R0 lymph node assessment contributed to favourable prognosis in patients with clinical stages higher than IA2, without increasing complication incidence. Furthermore, the approach to nodal assessment should be customized based on the specific clinical stage, rather than employing a similar strategy for all patients.

## SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

## FUNDING

None declared.

**Conflict of interest:** none declared.

## DATA AVAILABILITY

Data available on request.

## Author contributions

**Chia Liu:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Writing—original draft. **Ko-Han Lin:** Conceptualization; Data curation; Methodology; Resources. **Hui-Mei Chen:** Conceptualization; Methodology; Resources; Validation. **Lei-Chi Wang:** Conceptualization; Data curation; Investigation; Methodology; Resources. **Yi-Chen Yeh:** Conceptualization; Data curation; Methodology; Resources. **Po-Kuei Hsu:** Conceptualization; Data curation; Resources; Supervision. **Chien-Sheng Huang:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Supervision; Validation; Writing—review & editing. **Chih-Cheng Hsieh:** Conceptualization; Data curation; Resources; Supervision. **Han-Shui Hsu:** Conceptualization; Data curation; Resources; Supervision.

## Reviewer information

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<https://doi.org/10.1093/ejcts/ezaf083>  
Original article



## Room 101C (English) | Sunday, July 12, 2026

### Special Lecture

**Time: 10:00-10:30 (GMT+8)**

|      |             |                                                                                                            |
|------|-------------|------------------------------------------------------------------------------------------------------------|
|      |             | Chair(s): Ching-Yuan Cheng (Taiwan)<br>Yukio Sato (Japan)                                                  |
| SP-1 | 10:00-10:30 | <b>Education and Board-Certification Systems for Thoracic Surgeons in Japan</b><br>Masayoshi Inoue (Japan) |

## **Education and Board-Certification Systems for Thoracic Surgeons in Japan**

**Masayoshi Inoue**

*Division of Thoracic Surgery, Department of Surgery  
 Kyoto Prefectural University of Medicine, Graduate School of Medical Sciences*

A robust surgical education system is necessary to achieve both minimally invasive surgery and medical safety. I herein introduce current surgical education system in Japan, which aims to develop leading-edge thoracic surgeons. After graduating from medical school, we spend two years rotating through all medical departments as initial clinical trainees before moving on to a specialty. Surgeons begin with a three-year surgical specialty training program, rotating through gastroenterological, cardiovascular, thoracic, breast, and pediatric surgery as residents at two or more specialized training facilities, achieving surgical board certification (certified by the Japanese Medical Specialty Board & Japan Surgical Society). A further three years of subspecialty curriculum training leads to attaining board certification (certified by the Japanese Association for Chest Surgery). Separate from these specialist systems, other independent systems exist, such as the Thoracoscopic Safety Technology Certification System and the Robotic Surgeon Certification System, which aim to ensure safe minimally invasive surgery. Current issues in surgical education include mastering the declining number of open-thoracotomy techniques and adapting to new robotic models, as well as a lack of social incentives for specialized board-surgeons.

## Room 101C (English) | Sunday, July 12, 2026

### Lunch Video

Time: 12:30-13:30 (GMT+8)

|      |             |           |                                                                                                                                                                             |
|------|-------------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|      |             | Chair(s): | Masayoshi Inoue (Japan)<br>Hui-Ping Liu (Taiwan)                                                                                                                            |
| LV-1 | 12:30-12:45 |           | <b>The Implementation of Uniportal Robotic SP Surgery, as a Key Tool to Reduce Surgical Trauma and Enhance Postoperative Recovery</b><br>Juan Carlos Trujillo-Reyes (Spain) |
| LV-2 | 12:45-13:00 |           | <b>Uniportal Intercostal Robotic Right Upper Lobe Lobectomy Using the Da Vinci SP System</b><br>Jung Hee Lee (Republic of Korea)                                            |
| LV-3 | 13:00-13:15 |           | <b>Single Port Robotic Assisted Minimally Invasive Esophagectomy (SP-RAMIE): Single Incision Intercostal Thoracic Approach</b><br>Vincent Nestor Abad Venida (Philippines)  |
| LV-4 | 13:15-13:30 |           | <b>Reduced-Port Robotic Gastric Conduit Reconstruction with Tactile Arcade Preservation and Full Instrument Capabilities</b><br>Meng-Hsuan Wu (Taiwan)                      |

## **The Implementation of Uniportal Robotic SP Surgery, as a Key Tool to Reduce Surgical Trauma and Enhance Postoperative Recovery**

**Juan Carlos Trujillo Reyes, MD; PhD**

*Hospital del Mar*

The introduction of robotic single-port (SP) technology represents a new step in the evolution of minimally invasive thoracic surgery. By combining the principles of uniportal access with robotic articulation and visualization, SP surgery aims to further reduce parietal trauma while improving surgical precision and ergonomics.

This presentation will describe the initial implementation of uniportal robotic SP thoracic surgery, the first Spanish experience using this platform in thoracic diseases. Technical aspects including operating room setup, docking strategy, incision placement, instrumentation, and assistant coordination will be reviewed through surgical video demonstrations.

Special focus will be placed on patient selection, learning curve considerations, technical pitfalls, and troubleshooting strategies during the early adoption phase. Preliminary clinical experience regarding feasibility, perioperative outcomes, and postoperative recovery will also be discussed.

The presentation aims to provide a practical and realistic overview of SP robotic implementation and to discuss the future role of this platform in the continued evolution of minimally invasive thoracic surgery.

## **Uniportal Intercostal Robotic Right Upper Lobe Lobectomy Using the Da Vinci SP System**

**Junghee Lee, MD, PhD**

*Division of Thoracic Surgery, Department of Thoracic and Cardiovascular Surgery, Sungkyunkwan University School of Medicine, Samsung Medical Center, Seoul, Republic of Korea*

### **Objective**

The da Vinci SP system has been adopted for thoracic surgery predominantly through subcostal access, which may be constrained by patient habitus. The intercostal approach offers an alternative, and the uniportal configuration further reduces chest-wall trauma. We present a video demonstration of uniportal intercostal robotic right upper lobectomy (RUL) using the da Vinci SP system.

### **Case**

An 86-year-old woman (156.5 cm, 60.1 kg) presented with a 28-mm solid tumor in the right upper lobe. PET-CT and brain MRI showed no evidence of metastasis. Clinical stage was cT1cN0M0 (IA3).

### **Technique**

A single incision was made in the fifth intercostal space. The SP robotic port was introduced through a metal cannula using a floating dock technique, allowing the system to be seated without rib-based fixation and obviating CO<sub>2</sub> insufflation. Systematic mediastinal and hilar lymph node dissection was performed first, before parenchymal resection. Lobectomy was then carried out using a fissureless approach: the truncus anterior was divided first, followed by the posterior ascending artery, the branches of the right superior pulmonary vein, and the upper lobe bronchus. Vascular and bronchial division was accomplished with a 30-mm stapler introduced by the bedside assistant through the shared uniport, and the fissure was completed last.

### **Outcome**

The total operative time was 70 minutes, with no conversion or intraoperative complication. Final pathology confirmed adenocarcinoma (acinar and lepidic pattern), 21 × 20 × 18 mm with a 13-mm invasive component, no vascular/lymphatic/perineural invasion, PL0, and a bronchial margin of 45 mm. Twenty-two lymph nodes were harvested (pT1bN0M0). The postoperative course was uneventful, and the patient was discharged on postoperative day 2.

### **Conclusion**

Uniportal intercostal robotic RUL lobectomy with the da Vinci SP system is technically feasible and safe, achieving complete oncologic resection with rapid recovery even in an elderly patient. The intercostal uniportal approach represents a viable alternative to subcostal access for SP robotic lung surgery.

## **Single port robotic assisted minimally invasive esophagectomy (SP-RAMIE): single incision intercostal thoracic approach**

**Vincent Nestor A. Venida MD, Yin-Kai CHAO MD**

*Chang Gung Memorial Hospital Linkou Taiwan*

Esophagectomy remains a cornerstone in the multidisciplinary management of patients with resectable esophageal cancer. Over the past two decades, the adoption of minimally invasive techniques, particularly robot-assisted minimally invasive esophagectomy (RAMIE), has improved perioperative outcomes compared with conventional open surgery. These benefits include reduced intraoperative blood loss, less postoperative pain, lower rates of cardiopulmonary complications, and improved postoperative quality of life. From an oncological perspective, RAMIE has also been associated with enhanced mediastinal lymphadenectomy, including higher total thoracic lymph node yield and improved harvest of left recurrent laryngeal nerve (RLN) lymph nodes.<sup>1,2</sup>

The introduction of the da Vinci Single-Port (SP) Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA) represents a further evolution in robotic surgery. Unlike conventional multiport robotic platforms, the SP system enables the camera and three articulating instruments to be deployed through a single cannula, potentially reducing the number of access ports, simplifying port placement, and minimizing external instrument collision. Early feasibility studies have demonstrated the technical applicability of the SP platform for esophagectomy using transcervical and subcostal approaches.<sup>3,4,5</sup>

However, the optimal approach for SP-assisted esophagectomy remains undefined. In regions such as East Asia, where esophageal squamous cell carcinoma involving the middle and upper thoracic esophagus predominates, radical mediastinal lymphadenectomy—particularly along the left RLN—remains a fundamental oncological principle. Furthermore, cervical esophagogastric reconstruction via the retrosternal route frequently necessitates intrathoracic transection of the esophagus. In our experience, an intercostal SP approach provides excellent access to the upper mediastinum and facilitates comprehensive left RLN lymph node dissection while permitting intrathoracic esophageal division. Compared with the subcostal approach, this technique also obviates the need for an additional assistant port. Moreover, because the operative view closely resembles that of conventional multiport RAMIE using the da Vinci Xi platform, the transition to the SP system requires only minimal modification of established dissection techniques.

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## **Reduced-Port Robotic Gastric Conduit Reconstruction with Tactile Arcade Preservation and Full Instrument Capabilities**

**Meng-Hsuan Wu, Frank Cheau-Feng Lin, MD, PhD, FACS**

*Department of Thoracic Surgery, Chung Shan Medical University Hospital*

This technical report describes a reduced-port robotic gastric tube reconstruction using a single supra-umbilical glove-port with one accessory 8-mm port, which maintains full Da Vinci Xi articulation while enabling direct palpation of the gastroepiploic arcade before any vascular division. The mini-laparotomy provides tactile vascular confirmation that is not possible with standard four-port robotic or single-port systems. The conduit is then exteriorized through the same incision for extracorporeal construction, with precise calibration of the 4–5 cm width and systematic silk reinforcement of all staple lines. This workflow preserves arcade perfusion, optimizes conduit geometry, and reduces abdominal access trauma without sacrificing the use of advanced energy devices or stapling ergonomics. The debut clinical application achieved reliable conduit viability and rapid recovery. The technical platform establishes a feasibility-proven bridge toward safer and progressively less invasive esophagectomy reconstruction.

**Keywords:** robotic esophagectomy, gastric conduit, reduced-port surgery, Da Vinci Xi, gastric tube reconstruction, minimally invasive surgery

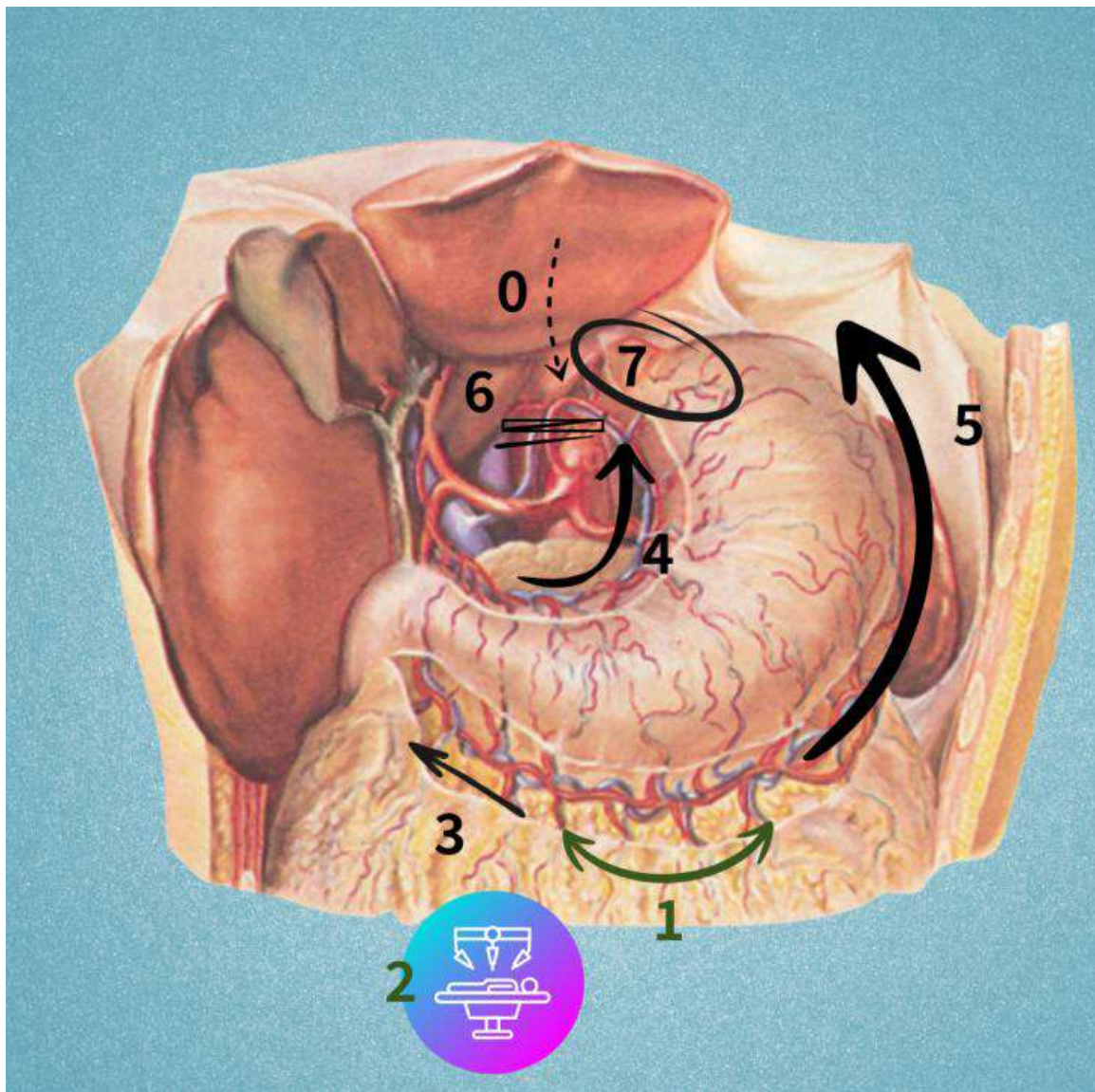


**Figure 1.** The steps of the single port +1 gastric tube creation.



**Figure 2.** The setting of DaVinci Xi for single-port +1 gastric tube creation. The camera is at 12 o'clock, and the working arms are at 4 o'clock and 8 o'clock; the +1 port is at left subcostal area, the accessory assistant port is at 6 o'clock.

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## Room 101C (English) | Sunday, July 12, 2026

### Industry Sponsored Keynote Session (Pfizer Taiwan Limited)

**Time: 14:00-15:00 (GMT+8)**

Chair(s): Han-Shui Hsu (Taiwan)

|      |             |                                                                                                             |
|------|-------------|-------------------------------------------------------------------------------------------------------------|
| K5-1 | 14:00-15:00 | <b>Insights from CROWN Data Update: What's the implication for Our Patients</b><br>Tsai-Wang Huang (Taiwan) |
|------|-------------|-------------------------------------------------------------------------------------------------------------|



## **Insights from CROWN Data Update: What's the implication for our patients**

**Tsai-Wang Huang**

*Division of Thoracic Surgery, Department of Surgery, Tri-Service General Hospital, National  
Defense Medical University*

People with ALK-positive NSCLC tend to be younger and to have never smoked compared with people diagnosed with ALK-negative NSCLC. Overall, only about 4% to 5% of non-small cell lung cancers are ALK-positive. Approximately 25-40% of people with ALK-positive advanced NSCLC may develop brain metastases within two years from initial diagnosis, which are associated with poorer survival and can profoundly affect cognitive function and quality of life.

At seven years of CROWN study, patients treated with Lorlatinib had a 55% likelihood of remaining alive without disease progression (95% Confidence Interval [CI], 46-63) compared to 3% (95% CI, 1-8) in the Xalkori treatment arm. Further, an updated analysis at seven years of median follow-up showed that investigator-assessed median progression-free survival (PFS) had not been reached with Lorlatinib, with an estimated Hazard Ratio (HR) of 0.19 (95% CI, 0.13-0.26), representing an 81% reduction in the risk of disease progression or death compared to Xalkori. Lorlatinib prevented and controlled brain metastases, with a 94% reduction in the risk of developing intracranial (IC) progression (HR, 0.06; 95% CI, 0.03-0.12) and no new IC progression events occurring after the first 30 months.

With median PFS yet to be reached after 7 years of follow-up in CROWN, Lorlatinib continues to show unprecedented long-term benefit in patients with advanced ALK-positive NSCLC. Patients without progression within 24 months on Lorlatinib have a low risk of progression or death at year 7 and may continue long-term treatment. Findings suggest that sustained long-term disease control with first-line Lorlatinib may enable advanced ALK-positive NSCLC to evolve toward a chronic condition.

## Room 105 (Chinese) | Saturday, July 11, 2026

### Industry Sponsored Keynote Session (Chugai Pharma Taiwan Ltd.)

**Time: 15:30-16:00 (GMT+8)**

Chair(s): Han-Shui Hsu (Taiwan)

|      |             |                                                                                                                  |
|------|-------------|------------------------------------------------------------------------------------------------------------------|
| K3-1 | 15:30-16:00 | <b>Reimagining ALK+ NSCLC: From Adjuvant Therapy to Sequential Targeted Strategy</b><br>Tsai-Wang Huang (Taiwan) |
|------|-------------|------------------------------------------------------------------------------------------------------------------|



## **Reimagining ALK+ NSCLC: From Adjuvant Therapy to Sequential Targeted Strategy**

**Tsai-Wang Huang**

*Division of Thoracic Surgery, Department of Surgery, Tri-Service General Hospital, National Defense Medical University*

People with ALK-positive NSCLC tend to be younger and to have never smoked compared with people diagnosed with ALK-negative NSCLC. Overall, only about 4% to 5% of non-small cell lung cancers are ALK-positive. Alectinib targets cancer cells that have specific changes, called rearrangements, in the ALK gene. The drug has been shown to increase how long people with ALK-positive metastatic NSCLC live and has become a mainstay for treatment of people with this form of lung cancer.

From ALEX study, the median OS was 81.1 [95% confidence interval (CI) 62.3 months-not estimable] versus 54.2 (95% CI 34.6-75.6 months) months, respectively [hazard ratio (HR) 0.78; 95% CI 0.56-1.08]. These final OS data show the sustained long-term systemic and intracranial efficacy of Alectinib in the first-line treatment of ALK-positive NSCLC and confirm Alectinib as a standard of care in this setting.

In ALINA study, the overall study population with median DFS not reached in the alectinib arm and 41.3 months in the chemotherapy arm (HR 0.24 ;  $p < 0.0001$ ). Alectinib is the first ALK inhibitor to show a consistent DFS benefit over chemotherapy in patients with resected early-stage ALK-positive NSCLC, regardless of disease stage, nodal status, or tumor size.

Alectinib is the preferred first-line treatment for advanced ALK-positive lung cancer. In addition, Alectinib after surgery significantly reduces the risk of the cancer returning compared to standard chemotherapy.

## Room 105 (Chinese) | Saturday, July 11, 2026

### Industry Sponsored Keynote Session (Era Biotech Co., Ltd.)

**Time: 16:00-16:30 (GMT+8)**

|      |             |           |                                                                                                                                                         |
|------|-------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
|      |             | Chair(s): | Po-Kuei Hsu (Taiwan)<br>Kuang-Tai Kuo (Taiwan)                                                                                                          |
| K4-1 | 16:00-16:30 |           | <b>New Trends in Minimally Invasive Airway Management: From CRYO2<br/>Tissue Acquisition to fiAPC Fine Lesion Treatment</b><br>Wen-Chien Huang (Taiwan) |

## **New Trends in Minimally Invasive Airway Management: From CRYO2 Tissue Acquisition to fiAPC Fine Lesion Treatment**

**Wen-Chien Huang**

*MacKay Memorial Hospital*

Interventional pulmonology has experienced a transformative shift toward highly precise, minimally invasive techniques for diagnosing and treating central and peripheral airway diseases. Traditional modalities often present challenges, including limited diagnostic yields from small biopsy samples, risk of thermal injury, and high procedural failure rates in high-oxygen environments. These tools collectively elevate diagnostic accuracy, expand treatment options for high-risk patients, and minimize procedural complications, establishing a new standard of care in modern interventional pulmonology. Clinical evaluations demonstrate that combining CRYO2 and fiAPC optimizes the full continuum of airway care. CRYO2 achieves a superior diagnostic yield (often exceeding 80–90% in large cohorts) and provides immediate relief for central airway obstructions via rapid debulking, with a remarkably low incidence of massive hemorrhage. Meanwhile, the integration of fiAPC ensures that residual fine lesions or bleeding margins can be managed with micro-precision. These tools collectively elevate diagnostic accuracy, expand treatment options for high-risk patients, and minimize procedural complications, establishing a new standard of care in modern interventional pulmonology.

## Room 105 (Chinese) | Sunday, July 12, 2026

| Surgical Fundamentals Course               |             | *Lunch Provided                                                                                                                                     |
|--------------------------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Time: 08:30-12:30 (GMT+8)                  |             |                                                                                                                                                     |
| Monarch Platform Deep Dive Experience Room |             |                                                                                                                                                     |
| Time: 12:30-13:30 (GMT+8)                  |             |                                                                                                                                                     |
| Chair(s): Tsai-Wang Huang (Taiwan)         |             |                                                                                                                                                     |
| SC-1                                       | 12:30-13:00 | <b>Clinical Experience with the Monarch Platform and Its Advantages in Advancing Precise Pulmonology Intervention</b><br>Calvin S.H. Ng (Hong Kong) |
| SC-2                                       | 13:00-13:30 | <b>Taiwan's First Experience in Robotic-Assisted Bronchoscopy with the Monarch Platform</b><br>Hsin-Yueh Fang (Taiwan)                              |

## Clinical Experience with the Monarch Platform and Its Advantages in Advancing Precise Pulmonology Intervention

**Calvin S.H. Ng \***

*Division of Cardiothoracic Surgery, The Chinese University of Hong Kong*

Monarch robotic-assisted bronchoscopy (RAB) platform is one of several FDA approved RABs that can be used for the diagnosis and management of lung pathologies in the market. It's dual robotic arm design utilizes a “mother-baby” robotic catheter that provides more stability, particularly during interventions within the lung; and navigates by electromagnetic, airway recognition and mapping, scope in distance, and movement artefact correction software to guide the user towards the target within the lung. The scope provides a generous 2.1mm working channel and continuous white light vision.

The stability, accuracy and robotic catheter design of the RAB allows precise diagnostic biopsy of small, and difficult to reach lesions such as those sitting above the aortic arch, while making multiple lung lesion biopsies effortless and ergonomically superior to conventional hand-held scopes. More recently, the introduction of upgrade version Monarch QUEST with its improved hardware , software and perhaps most importantly, the integration of real-time mobile CT or CBCT images into the Monarch navigation during the procedure have further improved speed, precision and accuracy for lung tumour diagnosis by correcting CT-body divergence and drive correction.

Apart from diagnostic indications, RABs such as Monarch can be used for dye (ICG / methylene blue) marking localization for precision sublobar lung resection as well as placement of fiducial markers for tracking for SBRT / SABR. Furthermore, Monarch can be used to deliver therapeutic tools and catheters quickly and accurately into tumours in the lung for procedures such as thermal (microwave , RF) and non-thermal (PEF) ablation, as well as drugs (radiosensitizers). The continuous vision offers the user to more accurately tunnel and subsequently deliver the therapeutic catheter into the track and tumour, while monitoring the ablation in real-time and observe for any complications such as bleeding. Studies looking at use of these treatment modalities through RAB platforms are on-going.

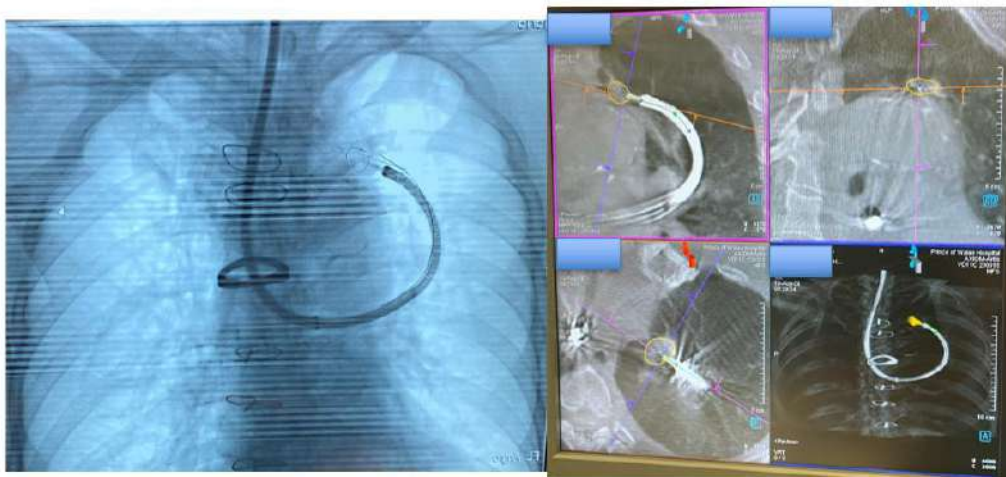


Figure 1: Monarch biopsy of lung tumour resting on aortic arch

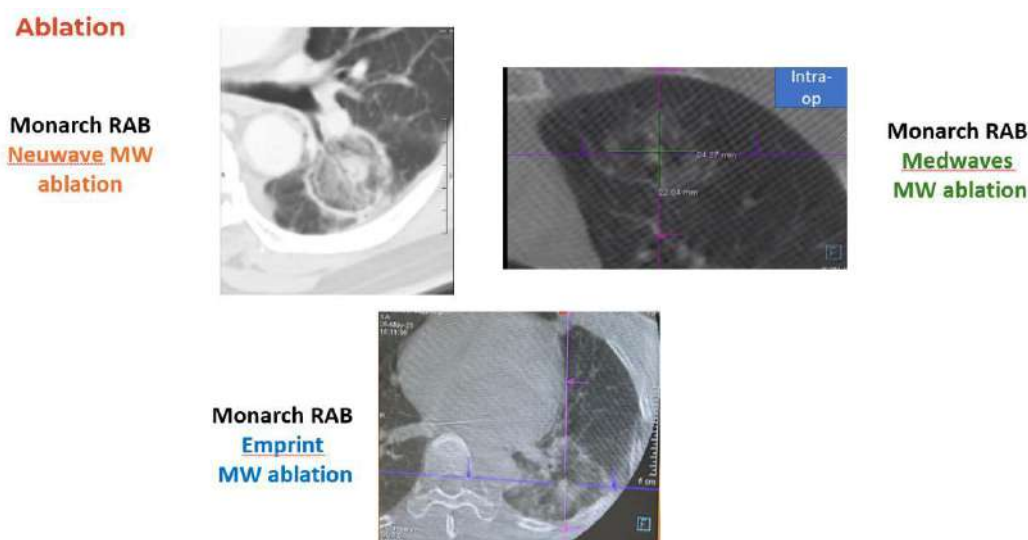


Figure 2: Monarch thermal ablation of lung tumour using different ablation platforms (post-ablation CBCT images).

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## **Taiwan's First Experience in Robot-Assisted Bronchoscopy with the MONARCH Platform**

**Dr. Hsin-yueh Fang**

*Thoracic surgeon, Chang-Gung memorial hospital, Linkou, Taiwan  
Assistant Supervisor, CGMH iVATS center, Taiwan*

Robot-assisted bronchoscopy is an important emerging approach for the evaluation and management of peripheral pulmonary lesions. Since 2023, the Taoyuan City Government Department of Public Health has expanded lung cancer screening eligibility beyond national policy criteria, contributing to the increased detection of small, difficult-to-access pulmonary nodules. As advanced screening programs identify a growing number of nodules and lesions, timely and accurate diagnosis has become increasingly critical. This keynote session will introduce Taiwan's first clinical experience with the MONARCH Platform and explore its potential role in contemporary thoracic care. The session will provide a concise overview of clinical considerations, implementation perspectives, and future opportunities for integrating new technologies into lung nodule diagnosis and treatment pathways.

## Room 105 (Chinese) | Sunday, July 12, 2026

### LDCT Educational Session

**Time: 14:00-15:00 (GMT+8)**

|           |             |                                                                                                                                                                  |
|-----------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chair(s): |             | Huang-Chou Chang (Taiwan)<br>Jing-Bo Cheng (Taiwan)<br>Chia-ying Li (Taiwan)<br>Ying-Chieh Su (Taiwan)                                                           |
| LDCT-1    | 14:00-14:20 | <b>From Screening to Cure: Clinical Evidence, Surgical Strategies, and Future Perspectives of LDCT Lung Cancer Screening in Taiwan</b><br>Chih-Jen Yang (Taiwan) |
| LDCT-2    | 14:20-14:40 | <b>LDCT Interpretation with ACR Lung-RADS v2022</b><br>Ying-Chi Lee (Taiwan)                                                                                     |
| LDCT-3    | 14:40-15:00 | <b>Lung Cancer Screening: The Latest Evidence and the Spanish Programme</b> 【English】<br>Juan Carlos Trujillo-Reyes (Spain)                                      |

LDCT-1

**From Screening to Cure: Clinical Evidence, Surgical Strategies, and Future Perspectives of LDCT Lung Cancer Screening in Taiwan**

**Chih-Jen Yang**

*Kaohsiung Medical University Hospital*

## **LDCT Interpretation with ACR Lung-RADS v2022**

**Ying-Chi Lee**

*Department of Radiology, Taipei Veterans General Hospital*

Lung cancer remains a leading cause of cancer-related mortality globally and in Taiwan. Taiwan launched its national lung cancer screening program in July 2022. By January 2025, the eligibility criteria were expanded to include individuals with a family history of lung cancer (males aged 45–74; females aged 40–74) or heavy smokers ( $\geq 20$  pack-years) aged 50–74.

Image interpretation and management recommendations are currently based on the ACR Lung-RADS v2022, which categorizes findings into 0, 1, 2, 3, 4A, and 4B/4X, along with an "S" modifier. Pulmonary nodules are managed based on their type—non-solid nodule (GGN), part solid nodule and solid nodule—and their mean diameter. Core updates in ACR Lung-RADS v2022 include:

- New and Expanded Sub-Categories: Atypical pulmonary cysts, airway nodules, inflammatory or infectious findings, and juxta-pleural nodules.
- Clarifications: Growth definitions, the use of S modifier.
- Stepped management

This lecture will review the role and current status of ACR-Lung RADS v2022 in lung cancer screening, illustrated with imaging examples from clinical practice.

## **Lung Cancer Screening: The Latest Evidence and the Spanish Programme**

**Juan Carlos Trujillo Reyes, MD; PhD**

*Hospital del Mar*

Lung cancer screening with low-dose computed tomography (LDCT) has emerged as an effective strategy to reduce lung cancer mortality through earlier detection and stage migration toward potentially curable disease. Large randomized trials, including NLST and NELSON, have demonstrated significant mortality benefits, supporting the progressive incorporation of screening programs into international clinical guidelines.

This presentation will review the latest evidence regarding LDCT screening, including patient selection criteria, benefits, limitations, and current controversies such as false positives, overdiagnosis, adherence, and cost-effectiveness. Emerging developments involving artificial intelligence, radiomics, circulating biomarkers, and personalized risk prediction models will also be discussed as key tools for the next generation of screening strategies.

Special attention will be paid to the current implementation of lung cancer screening in Spain, focusing on the CASSANDRA project as one of the most relevant national initiatives. The structure of the programme, multidisciplinary coordination, incorporation of biomarker research, and the role of thoracic surgeons within diagnostic and therapeutic pathways will be presented as part of a modern and integrated screening model.

The session aims to provide an updated overview of contemporary lung cancer screening and to discuss how national programmes such as CASSANDRA may contribute to the future implementation of precision-based early detection strategies in Europe.



# Free Paper Presentation

MINIMALLY INVASIVE  
**MAX**IMALLY EFFECTIVE

## Room 102 (English) | Saturday, July 11, 2026

### APITS Free Paper Session I

Time: 08:00-09:00 (GMT+8)

|           |             |                                                                                                                                                                                                           |
|-----------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chair(s): |             | Christopher Cao (Australia)<br>Mong-Wei Lin (Taiwan)<br>Yi-Cheng Wu (Taiwan)                                                                                                                              |
| FP1-1     | 08:00-08:08 | <b>Early Clinical and Economic Outcomes of Uniportal Robotic- and Video-Assisted Thoracoscopic Surgery for Lung Anatomic Resection: A Retrospective Study</b><br>Ching-Feng Wu (Taiwan)                   |
| FP1-2     | 08:08-08:16 | <b>Comparison of neoDRATS and Uniportal VATS Lobectomy for Clinical Stage I Lung Cancer Performed by a Single Surgeon</b><br>Hiroki Ebana (Japan)                                                         |
| FP1-3     | 08:16-08:24 | <b>Early Outcomes of Reduced-Port Robot-Assisted Thoracic Surgery for Anatomical Lung Resections</b><br>Takahiro Negi (Japan)                                                                             |
| FP1-4     | 08:24-08:32 | <b>Uniportal Robotic-Assisted Thoracic Surgery Using the Da Vinci Xi System: Surgical Technique and Short-Term Outcomes</b><br>Kumiko Hashimoto (Japan)                                                   |
| FP1-5     | 08:32-08:40 | <b>Subcostal Single-Port Versus Multiport Robotic Anatomic Lung Resection: A Retrospective Comparative Study</b><br>Ramaswamy Rajendran (India)                                                           |
| FP1-6     | 08:40-08:48 | <b>Early Outcomes and Learning Curve of Subxiphoid Robotic Thymectomy Using the Single-Port Robotic System: An International Multicenter Retrospective study</b><br>Jun Hee Lee (Republic of Korea)       |
| FP1-7     | 08:48-08:56 | <b>From Trial to Routine Practice: Single-Surgeon Outcomes of Single-Port Robotic Trans-Subxiphoid Surgery for Anterior Mediastinal Disease in the Real World</b><br>Frances Denise Cabrera (Philippines) |



## Early clinical and economic outcomes of uniportal robotic- and video-assisted thoracoscopic surgery for lung anatomic resection: a retrospective study

**Chingfeng Wu\*<sup>1</sup>; Ming Ju Hsieh<sup>2</sup>; Ching Yang Wu<sup>1</sup>; Yu Fu Wu<sup>3</sup>; Kuei An Chen<sup>3</sup>; Diego Gonzalez-Rivas<sup>4</sup>**

<sup>1</sup>Thoracic Surgery, Chang Gung Memorial Hospital, Taiwan, Taiwan <sup>2</sup>Thoracic Surgery, Chang Gung Memorial Hospital, Taiwan, Spain <sup>3</sup>Medical Imaging and Intervention, Chang Gung Memorial Hospital, Taiwan, Taiwan <sup>4</sup>Minimally Invasive Thoracic Surgery Unit (UCTMI), Coruña University Hospital, A Coruna, Spain

### Objective

Uniportal video-assisted thoracoscopic surgery (uVATS) is an established minimally invasive approach for lung cancer. Uniportal robotic-assisted thoracoscopic surgery (uRATS) is a recent innovation integrating robotic technology with single-incision access. Comparative data between these techniques remain scarce.

### Methods

We retrospectively analyzed patients who underwent anatomic pulmonary resection via uVATS or uRATS at Chang Gung Memorial Hospital between July 2023 and July 2025. Propensity score matching (1:1) was applied using key baseline variables. Perioperative outcomes and cost-effectiveness were assessed.

### Results

A total of 356 patients (251 uVATS, 105 uRATS) were included; 98 matched pairs were analyzed. Operative time was longer with uRATS (median 179.50 vs. 117.00 minutes,  $p < 0.001$ ). uRATS was associated with shorter hospital stay (2.70 vs. 3.00 days,  $p < 0.001$ ), reduced chest drainage duration (1.45 vs. 2.00 days,  $p < 0.001$ ), and lower postoperative day 1 pain scores ( $p = 0.04$ ). Median N1 and N2 lymph node counts were similar in uRATS and uVATS. Postoperative complication rates did not differ significantly between groups (2.04% vs. 9.18%,  $p = 0.06$ ). Cost analyses quantified the incremental costs associated with short-term recovery benefits of uRATS

### Conclusions

uRATS was associated with modest, short-term differences in selected early postoperative recovery parameters compared with uVATS, accompanied by longer operative time and higher cost. Oncologic surrogate outcomes were comparable between groups, while definitive conclusions regarding long-term oncologic and economic benefits require confirmation in larger, multicenter studies with extended follow-up.

### Keyword(s)

Uvats, Urats, Anatomic Resection, Lung Cancer

## Early Clinical and Economic Outcomes of Unilateral Robotic- and Video-Assisted Thoracoscopic Surgery for Lung Resection: Retrospective Study

### Summary

- uRATS showed modest short-term recovery benefits compared with vRATS.
- Those benefits were accompanied by longer operative time and higher cost.
- Early oncologic surrogates were comparable; long-term value requires confirmation.

### da Vinci Xi uRATS

### uVATS



|       | Charge/Operation | Post-Op Hospital Stay | Complications |
|-------|------------------|-----------------------|---------------|
| uRATS | 1,451 (\$1.5)    | 2.72 (3)              | 3/98          |
| vRATS | 3,623 (\$)       | 3.623 (\$)            | 9/98          |



ICERs represent the additional cost required to achieve one unit of improvement in each perioperative outcome.

uVATS: unilateral video-assisted thoracoscopic surgery; uRATS: unilateral robotic thoracoscopic surgery; Op: operation

## Comparison of neoDRATS and Uniportal VATS Lobectomy for Clinical Stage I Lung Cancer Performed by a Single Surgeon

**Hiroki Ebana<sup>\*1</sup>; Sari Yasuta<sup>1</sup>; Daisuke Simuzu<sup>1</sup>; Ryuhei Sakata<sup>1</sup>; Aki Kobayashi<sup>1</sup>**

<sup>1</sup>*Thoracic Surgery, Tokyo Metropolitan Bokutoh Hospital, Tokyo, Japan*

### Objective

neoDRATS (non-assistant help dual-portal robotic-assisted thoracic surgery) is a reduced-port robotic technique using all four robotic arms through two ports, which we previously reported in JTCVS Techniques (2024). This study aimed to compare perioperative outcomes between neoDRATS and uniportal video-assisted thoracic surgery (UP) lobectomy for clinical stage I lung cancer performed by a single surgeon after robotic surgery proctor certification.

### Methods

Among 324 thoracic surgeries performed at our institution between January and December 2025, patients with clinical stage I primary lung cancer (or suspected lung cancer) who consecutively underwent lobectomy by a single surgeon were retrospectively analyzed. Patients were divided into neoDRATS and UP groups.

### Results

Thirty-one patients were included in this study (neoDRATS 18, UP 13). Median age was 70 [IQR 65–74] years in the neoDRATS group and 72 [IQR 66–75] years in the UP group. The male/female ratio was 11/7 and 8/5, respectively. The distribution of resected lobes (RUL/RML/RLL/LUL/LLL) was 3/3/2/3/2 in the UP group and 4/3/6/3/2 in the neoDRATS group. Operative time was longer in the neoDRATS group (172 [IQR 147–192] min vs 140 [IQR 111–175] min,  $P=0.043$ ). There were no significant differences in blood loss, number of dissected lymph nodes, or incidence of Clavien–Dindo grade  $\geq$ II complications. Chest tube duration (1 [IQR 0–1] vs 0 [IQR 0–1] days,  $P=0.79$ ) and postoperative hospital stay (3 [IQR 2–4] vs 3 [IQR 2–4] days,  $P=0.64$ ) were comparable between groups. Postoperative pain scores, analgesic use, 30-day readmission, in-hospital mortality, and 30-day mortality were similar. The median follow-up period was 6.5 months in the neoDRATS group and 9.0 months in the UP group ( $P=0.093$ ). No thoracotomy conversions occurred. One elective additional port (UP) and one elective conversion to DVATS (neoDRATS) were performed due to anatomical or body habitus considerations, with no emergency conversions.

### Conclusions

For clinical stage I lung cancer, neoDRATS required longer operative time than UP; however, perioperative safety and postoperative recovery were comparable. neoDRATS appears to be a feasible reduced-port robotic approach while maintaining the advantages of robotic surgery. Longer follow-up and larger cohorts are warranted to confirm oncologic durability.

### Keyword(s)

Neodrats, Uniportal VATS, Lobectomy, Clinical Stage I Lung Cancer, Reduced-Port Robotic Surgery, Robotic-Assisted Thoracic Surgery

## ***Early Outcomes of Reduced-Port Robot-Assisted Thoracic Surgery for Anatomical Lung Resections***

**Takahiro Negi<sup>\*1</sup>; Hiroyuki Masuda<sup>1</sup>; Daisuke Tochii<sup>1</sup>; Sachiko Tochii<sup>1</sup>; Takashi Suda<sup>1</sup>**

<sup>1</sup>*Thoracic surgery, Fujita Health University Okazaki Medical Center, Aichi, Japan*

### **Objective**

Reduced-port robotic-assisted thoracic surgery (RATS) has recently gained significant attention, with an increasing number of institutions adopting this approach. We aim to evaluate the early surgical outcomes of reduced-port RATS at our institution.

### **Methods**

We retrospectively reviewed 73 consecutive patients who underwent reduced-port RATS between January 2022 and December 2025. The series included 72 cases of uniportal RATS and one case of dual-port RATS. The robotic platforms utilized were the da Vinci Xi (n=72) and the Hinotori Surgical Robot System (n=1).

### **Results**

The median operative time was 172.5 min (IQR: 147.5–191.0), and the median blood loss was 50 mL (IQR:14.75–100). Postoperative complications of Clavien-Dindo grade III or higher occurred in 12 patients (16.9%). The median duration of chest tube drainage was 1 days (IQR: 1–2), and the median postoperative hospital stay was 7 days (IQR:5–7). There was no in-hospital mortality. The median Numerical Rating Scale (NRS) score was 0 (IQR:0–1) both at discharge.

### **Conclusions**

Reduced-port RATS was a feasible procedure in this series. Although complications occurred, all cases were curable, and no in-hospital mortality was observed. While uniportal RATS was performed using the da Vinci Xi, a dual-port approach was required for the Hinotori system due to its mechanical characteristics. Previous studies have demonstrated that minimizing the number of intercostal spaces involved in VATS reduces both the incidence and severity of post-thoracotomy pain syndrome. Similarly, reduced-port RATS, which utilizes fewer intercostal incisions, may offer comparable clinical benefits in mitigating postoperative pain.

### **Keyword(s)**

Minimally Invasive Surgery, RATS

## **Uniportal robotic-assisted thoracic surgery using the da Vinci Xi system: surgical technique and short-term outcomes**

**Kumiko Hashimoto<sup>\*1</sup>; Yasuhiro Sengoku<sup>1</sup>; Shunsuke Date<sup>1</sup>**

<sup>1</sup>*Thoracic Surgery, Toyohashi municipal hospital, Aichi, Japan*

### **Objective**

The da Vinci Xi Surgical System is one of the most widely adopted multiport robotic platforms worldwide. In thoracic surgery, including lobectomy, a multiport approach is generally used; however, interest in uniportal surgery has increased to further reduce surgical invasiveness. We have performed uniportal robotic-assisted thoracic surgery using the da Vinci Xi system without introducing a dedicated single-port robotic platform. By optimizing port placement to minimize arm interference and enabling surgeon-driven stapling, safe and effective procedures were achieved. This study aimed to describe the key technical aspects and evaluate short-term surgical outcomes.

### **Methods**

Between 2023 and 2025, 120 consecutive patients underwent uniportal robotic-assisted pulmonary resection using the da Vinci Xi system at our institution. A single 4-cm incision was placed at the fifth intercostal space for upper and middle lobes and at the sixth intercostal space for lower lobes. A 30-degree endoscope was positioned in a look-up orientation, and a cross-arm technique was adopted to reduce instrument interference and facilitate surgeon-driven stapling. Perioperative outcomes, conversion rates, and postoperative complications were retrospectively analyzed.

### **Results**

All procedures were completed through a single incision without the need for additional ports. Conversion to thoracotomy occurred in 6 patients (5.0%), mainly due to vascular injury. The median operative time was 145 minutes (range, 69–293 minutes), and the median blood loss was 17 mL (range, 0–2021 mL). Postoperative complications occurred in 13 patients (10.8%), with prolonged air leak being the most frequent. No surgery-related mortality was observed.

### **Conclusions**

Uniportal robotic-assisted thoracic surgery using the da Vinci Xi system is feasible and safe, with acceptable short-term outcomes. This approach enables surgeon-driven stapling using an existing multiport robotic platform and allows rapid conversion when necessary, offering a versatile and minimally invasive surgical option.

### **Keyword(s)**

Uniportal Robotic-Assisted Thoracic Surgery, Da Vinci Xi, Lung Surgery

## Subcostal Single-Port Versus Multiport Robotic Anatomic Lung Resection: A Retrospective Comparative Study

**Ramaswamy Rajendran<sup>\*1</sup>; Yin Kai Chao<sup>2</sup>**

<sup>1</sup>*Thoracic Surgery, Santosham Chest Hospital, Chennai, India* <sup>2</sup>*Thoracic Surgery, Chang Gung Memorial Hospital, Linkou, Taiwan, Linkou, Taiwan*

### Objective

To compare the perioperative outcomes of robotic lobectomy using the single port (SP) system via the subcostal approach with those of multiport (MP) robotic lobectomy using the Xi system via the intercostal approach.

### Methods

A single institution retrospective comparative study of patients who underwent robotic lobectomy for non-small cell lung cancers. The patients were divided into the SP and MP groups based on the surgical approaches. And their perioperative and pathological outcomes were analyzed.

### Results

A total of 167 patients were included in the study, 38 in the SP group and 129 in the MP group. Tumours were smaller in the SP group, *median 1.7cm [range 0.7 – 3.8]* compared to the MP group *2.6 cm [range 0.4 – 7.6]*. Tumour location distribution across lobes was broadly similar with right upper lobe being more common (*34.3% SP vs 33.3% MP*). Pathologic T stages in both the cohorts were comparable with predominantly comprising *T1b, T1c and T2a*. Nodal status was predominantly pN0 in both groups (*94.8% SP vs 86% MP*). Oncologic quality metrics were comparable, with a median lymph node harvest of 15 [*Interquartile range (IQR) 13 – 23*] in the SP group and 18 [*IQR (11 – 25)*] in the MP group, and a *median of 7 [range 4 – 9]* versus 6 [*range 3 – 11*] lymph node stations dissected in the SP and MP group, respectively. Median console time was similar (*161.1 vs 166.5 minutes*) for SP and MP respectively. Postoperative length of stay was identical at 3 days [*IQR(2 – 4) in the SP group and IQR (2 – 5) in the MP group*]. Overall complication rates were comparable (*15.6% SP vs 17.1% MP*) majority being *grade I and II* according to Clavien – Dindo classification.

### Conclusions

Robotic lobectomy using the SP system showed favourable peri-operative outcomes comparable to the multiport (MP) robotic group. These findings support the adoption of the single-port robotic system as an effective minimally invasive alternative in appropriately selected patients undergoing robotic pulmonary resection. However, further large-scale studies are required to validate our findings.

### Keyword(s)

Da Vinci SP Robotic Lobectomy, Single Port Subcostal Robotic Lobectomy, Robotic Lobectomy

Randomized Single Port versus Robotic Robot-Assisted Lung Resection: A Randomized Controlled Study

| Variable                                              | Single port (SP)<br>n=30 | Robotic port (RP)<br>n=30 |
|-------------------------------------------------------|--------------------------|---------------------------|
| Age, median (range)                                   | 66 (54–78)               | 67 (54–78)                |
| Sex, n (%)                                            |                          |                           |
| Male                                                  | 17 (57%)                 | 15 (50%)                  |
| Female                                                | 13 (43%)                 | 15 (50%)                  |
| Body mass index, kg/m <sup>2</sup> , median (range)   | 23.5 (19.5–29)           | 23.5 (17.7–28.3)          |
| Smoking status, n (%)                                 |                          |                           |
| Never                                                 | 17 (57%)                 | 15 (50%)                  |
| Former                                                | 13 (43%)                 | 15 (50%)                  |
| Current                                               | 0 (0%)                   | 0 (0%)                    |
| Preoperative length of stay, d, median (range)        | 3 (2–4)                  | 3 (2–4)                   |
| Total number of lymph nodes harvested, median (range) | 11 (11–13)               | 11 (11–13)                |
| Total number of lymph nodes harvested, median (range) | 11 (11–13)               | 11 (11–13)                |
| Number of lymph nodes harvested, median (range)       | 11 (11–13)               | 11 (11–13)                |
| Number of lymph nodes harvested, median (range)       | 11 (11–13)               | 11 (11–13)                |

SP, single port; RP, robotic port.



## Early Outcomes and Learning Curve of Subxiphoid Robotic Thymectomy Using the Single-Port Robotic System: An International Multicenter Retrospective study

**Jun Hee Lee<sup>\*1</sup>; Yin-Kai Chao<sup>2</sup>; Will Kuo Kuo<sup>2</sup>; Byung Mo Gu<sup>1</sup>; René Horsleben Petersen<sup>3</sup>; Hyun Koo Kim<sup>1</sup>**

<sup>1</sup>*Thoracic and Cardiovascular Surgery, Korea University Guro Hospital, Seoul, Republic of Korea*

<sup>2</sup>*Division of Thoracic Surgery, Linkou Chang Gung Memorial Hospital, Taiwan, Taoyuan, Taiwan*

<sup>3</sup>*Department of Cardiothoracic Surgery, Copenhagen University Hospital, Rigshospitalet, Copenhagen, Denmark*

### Objective

The feasibility of subxiphoid robotic thymectomy using the single-port robotic system has been established. However, evidence regarding the early clinical outcomes and learning curve remains limited. Therefore, this study aimed to evaluate the early clinical outcomes and to assess the learning curve of this technique.

### Methods

This multicenter retrospective study included patients who underwent subxiphoid robotic thymectomy using the single-port robotic system at three international institutions between November 2020 and December 2025. All procedures were performed by three experienced thoracic surgeons, one of whom had no prior experience in robotic thymectomy. Baseline characteristics and perioperative outcomes were collected. The primary endpoint was the learning curve of total operative time, assessed using cumulative sum (CUSUM) analysis.

### Results

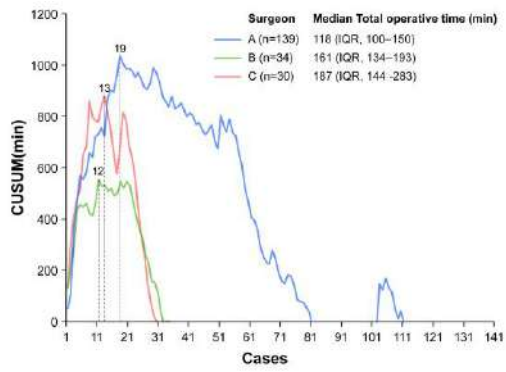
A total of 203 patients were included in the analysis. The median age was 57 years (IQR, 46–65), and 95 patients (47%) were male. The median chest tube duration was 1 day (IQR, 1–1), and the median postoperative length of stay was 2 days (IQR, 2–3). Pathology revealed thymoma in 87 patients (43%), thymic carcinoma in 15 (7%), benign cyst in 71 (35%), and other diagnoses in 30 (15%). Postoperative complications were observed in 16 patients (8%), with no 30-day mortality. The median total operative time was 132 minutes (IQR, 106–173). Two Surgeons (A and C) with prior experience in subxiphoid robotic thymectomy using the Xi system reached their CUSUM peaks at the 19th and 13th cases, respectively, whereas the surgeon B, who had no prior experience in robotic thymectomy, reached the CUSUM peak at the 12th case.

### Conclusions

Subxiphoid robotic thymectomy using the single-port robotic system is a feasible and safe surgical procedure with a relatively short learning curve, even for a novice robotic surgeon. These findings may encourage surgeons who are beginning their robotic surgery practice to adopt this approach.

### Keyword(s)

## Learning Curve, Single-Port Robotic System, Robotic Thymectomy, Subxiphoid Approach, Robotic Thoracic Surgery



## ***From Trial to Routine Practice: Single-Surgeon Outcomes of Single-Port Robotic Trans-Subxiphoid Surgery for Anterior Mediastinal Disease in the Real World***

**Frances Denise Cabrera<sup>\*1</sup>; Chuan Cheng<sup>2</sup>; Yin Kai Chao<sup>2</sup>**

<sup>1</sup>*Surgery/ Division of Thoracic Surgery, The Medical City - Ortigas, Metro Manila, Philippines*

<sup>2</sup>*Thoracic Surgery, Chang Gung Memorial Hospital - Linkou, Taoyuan, Taiwan*

### **Objective**

To determine if perioperative outcomes of single-port robotic trans-subxiphoid surgery for anterior mediastinal disease achieved under a clinical trial setting can be reproduced after regulatory approval and broader clinical adoption

### **Methods**

The authors conducted a retrospective comparative study of consecutive patients undergoing single-port robotic trans-subxiphoid surgery for anterior mediastinal disease by a single surgeon. The initial 15 cases were performed under a prospective clinical trial protocol (trial phase). Following regulatory approval for routine clinical use, the subsequent 17 consecutive cases constituted the real-world phase. Patient characteristics, procedural complexity, and perioperative outcomes were compared.

### **Results**

The real-world cohort reflected broader clinical adoption, with more complex anterior mediastinal pathology; two patients required concomitant procedures (one lung resection and one phrenic nerve resection with reconstruction). Despite this expansion in case complexity, all procedures were completed successfully without conversion to open surgery or the need for additional ports. Console time showed a numerical reduction in the real-world phase (median, 152 vs. 117 minutes;  $p = 0.082$ ). Hospital length of stay was comparable between the two phases (median, 2 vs. 2 days;  $p = 0.882$ ).

### **Conclusions**

After regulatory approval and expansion to more complex anterior mediastinal disease, single-port robotic trans-subxiphoid surgery demonstrated improved procedural efficiency without compromising surgical safety or quality. These findings support the reproducibility and scalability of this approach beyond the clinical trial setting.

### **Keyword(s)**

Robotic Thoracic Surgery, Single-Port Robotic Trans-Subxiphoid Surgery, Anterior Mediastinal Disease, Surgical Efficiency

## Room 102 (English) | Sunday, July 12, 2026

### APITS Free Paper Session II

Time: 08:30-09:30 (GMT+8)

|       |             |                                                                                                                                                                                                                                       |
|-------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |             | Wei-Hsun Chen (Taiwan)<br>Chair(s): Edmund Villaroman (Philippines)<br>Bing-Yen Wang (Taiwan)                                                                                                                                         |
| FP2-1 | 08:30-08:38 | <b>Prognostic Implications of Total mTOR Expression in Solitary Non-Mucinous Lung Adenocarcinoma</b><br>Chen-Sung Lin (Taiwan)                                                                                                        |
| FP2-2 | 08:38-08:46 | <b>Comparison of Parenchymal-Sparing Surgery and Lobectomy for Early NSCLC with Visceral Pleural Invasion</b><br>Xu-Heng Chiang (Taiwan)                                                                                              |
| FP2-3 | 08:46-08:54 | <b>Perioperative Outcomes of Uniportal VATS According to Surgeon Certification Status: A Nationwide Matched Analysis from the JUVIG Database</b><br>Takuya Watanabe (Japan)                                                           |
| FP2-4 | 08:54-09:02 | <b>Comparison Between Lymph Node Station- and Zone-Based Classification: An Extended Analysis with the 9th Edition IASLC Lymph Node Descriptors in Surgically Resected Non-Small-Cell Lung Cancer</b><br>Shia Kim (Republic of Korea) |
| FP2-5 | 09:02-09:10 | <b>Optimal Number of Bilateral Recurrent Laryngeal Nerve Lymph Node Dissection for Adequate Nodal Staging and Improved Survival in Esophageal Squamous Cell Carcinoma</b><br>Yeong Jeong Jeon (Republic of Korea)                     |
| FP2-6 | 09:10-09:18 | <b>Comparative Analysis of VATS versus RATS for Esophageal Leiomyoma Enucleation: A Multiinstitutional Propensity Score-weighted Study</b><br>Jeonga Son (Republic of Korea)                                                          |
| FP2-7 | 09:18-09:26 | <b>Clinical Utility of Yellow Enhance (YE) Mode in Thoracoscopic Lung Surgery: Experience from Fifteen Cases</b><br>Takehisa Fukada (Japan)                                                                                           |

## ***Prognostic Implications of Total mTOR Expression in Solitary Non-Mucinous Lung Adenocarcinoma***

**Chen-Sung Lin<sup>\*1</sup>**

<sup>1</sup>*Thoracic Division, Department of Surgery, Taipei Hospital, Ministry of Health and Welfare, New Taipei City, Taiwan*

### **Objective**

Although activation of the phosphatidylinositol 3-kinase (PI3K)/protein kinase B (AKT)/mammalian target of rapamycin (mTOR) signaling pathway has been well documented in lung cancer, the clinical relevance of total mTOR protein expression in solitary non-mucinous adenocarcinoma (SNM adenocarcinoma) remains unclear.

### **Methods**

Fifty-four SNM adenocarcinomas (10 adenocarcinoma in situ [AIS] and 44 invasive adenocarcinomas) from 54 patients who underwent video-assisted thoracoscopic surgery at Taipei Hospital were retrospectively analyzed. Total mTOR expression was evaluated by immunohistochemistry, digitized as whole-slide images, and semiquantified using pixelwise H-scores (range 0–300) with an ImageJ-based plugin. The optimal cutoff for survival discrimination was determined using receiver operating characteristic (ROC) curve analysis and the Youden index. Associations between mTOR expression, clinicopathological variables, and overall survival were assessed using Cox regression and Kaplan–Meier analyses.

### **Results**

The mean total mTOR H-score was  $15.3 \pm 17.7$  (median, 15.3). No significant difference in mTOR expression was observed between AIS and invasive adenocarcinoma ( $p = 0.578$ ). In univariate Cox analysis, higher mTOR H-scores showed a trend toward reduced mortality risk (hazard ratio [HR] = 0.941 per unit increase; 95% confidence interval [CI], 0.879–1.006;  $p = 0.076$ ). ROC analysis identified an optimal cutoff H-score of 22.1 (AUC = 0.716; 95% CI, 0.573–0.859;  $p = 0.034$ ), stratifying patients into low- and high-expression groups. Log-rank analysis demonstrated that advanced T stage, nodal involvement, distant metastasis, poor differentiation, spread through air spaces, pleural invasion, and low mTOR expression were associated with shorter overall survival (all  $p < 0.05$  except lymphovascular invasion,  $p = 0.096$ ). However, none remained independently significant in multivariate analysis. Among 29 patients with available preoperative <sup>18</sup>F-fluorodeoxyglucose positron emission tomography, total mTOR expression was inversely correlated with tumor maximum standardized uptake value (SUVmax) (Spearman's  $\rho = -0.371$ ,  $p = 0.048$ ).

### **Conclusions**

Lower total mTOR expression was associated with poorer survival at the univariate level in SNM adenocarcinoma. Although not an independent prognostic factor, its inverse relationship with metabolic activity suggests that total mTOR expression may reflect tumor phenotype rather than pathway activation alone. Larger studies are warranted for validation.

**Keyword(s)**

Mammalian Target Of Rapamycin (Mtor), Non-Mucinous Adenocarcinoma (SNM Adenocarcinoma), Whole-Slide Image, Pixelwise H-Score, Prognosis

## Comparison of Parenchymal-Sparing Surgery and Lobectomy for Early NSCLC with Visceral Pleural Invasion

**Xu-Heng Chiang<sup>\*1</sup>; Chi-Jen Chen<sup>2</sup>; Chih-Fu Wei<sup>3</sup>; Yu-An Zheng<sup>4</sup>; Ching-Chun Lin<sup>5</sup>; Mong-Wei Lin<sup>4</sup>; Chun-Ju Chiang<sup>2</sup>; Wen-Chung Lee<sup>2</sup>; Jin-Shing Chen<sup>4</sup>; Pau-Chung Chen<sup>5</sup>**

<sup>1</sup>Department of Medical Education, National Taiwan University Hospital, Taipei, Taiwan <sup>2</sup>Institute of Epidemiology and Preventive Medicine, College of Public Health, National Taiwan University, Taipei, Taiwan <sup>3</sup>Department of Environmental and Occupational Medicine, National Taiwan University Hospital, Taipei, Taiwan <sup>4</sup>Department of Surgery, National Taiwan University Hospital, Taipei, Taiwan <sup>5</sup>Institute of Environmental and Occupational Health Sciences, College of Public Health, National Taiwan University, Taipei, Taiwan

### Objective

The optimal surgical extent for early-stage non-small-cell lung cancer (NSCLC) presenting with visceral pleural invasion (VPI) is still controversial. We sought to evaluate disease-specific mortality outcomes comparing lobar and sublobar lung resections in patients with node-negative, early-stage disease (tumors measuring 3 cm or less) using a large-scale national registry.

### Methods

We analyzed records from the Taiwan Cancer Registry spanning 2011 to 2018. The inclusion criteria focused on individuals diagnosed with N0M0 NSCLC tumors up to 3 cm accompanied by VPI, who received either limited resection or standard lobectomy. To mitigate baseline disparities, we applied 1:1 propensity score matching (PSM). We then assessed lung-cancer-specific survival utilizing log-rank testing and Cox regression modeling across both the unmatched and balanced cohorts.

### Results

Among 2,460 eligible cases (1,836 lobectomies and 624 sublobar procedures), initial unmatched evaluations showed a survival benefit favoring lobectomy, particularly within the PL1 subgroup. However, after establishing 523 balanced patient pairs via PSM, these survival advantages disappeared. Disease-specific survival rates became statistically indistinguishable between the two surgical approaches, regardless of whether VPI was categorized as PL1 or PL2. Furthermore, multivariate assessment of the balanced group demonstrated that surgical modality did not independently influence survival. Conversely, factors such as advanced age, lymphovascular spread, and PL2 status significantly correlated with poorer prognoses.

### Conclusions

Following comprehensive covariate adjustment, limited pulmonary resection yields long-term cancer-specific survival equivalent to traditional lobectomy for small-sized NSCLC complicated by VPI. These findings support the viability of parenchymal-sparing surgeries in this specific demographic, though future prospective trials remain necessary to corroborate these results.

### Keyword(s)



Non-Small-Cell Lung Cancer (NSCLC), Visceral Pleural Invasion (VPI), Lobectomy, Sublobar Resection, Early Lung Cancer

## Perioperative Outcomes of Uniportal VATS According to Surgeon Certification Status: A Nationwide Matched Analysis from the JUVIG Database

**Takuwa Watanabe<sup>\*1</sup>; Hitoshi Igai<sup>2</sup>; Takahiro Homma<sup>3</sup>; Masayuki Tanahashi<sup>4</sup>; Toshiaki Morikawa<sup>5</sup>; Katsuhiko Okuda<sup>1</sup>; Hisashi Saji<sup>3</sup>; Takashi Suda<sup>6</sup>**

<sup>1</sup>Department of Thoracic and Pediatric Surgery, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan <sup>2</sup>Department of General Thoracic Surgery, Japanese Red Cross Maebashi Hospital, Maebashi, Japan <sup>3</sup>Department of Thoracic Surgery, St. Marianna University School of Medicine, Kawasaki, Japan <sup>4</sup>Division of Thoracic Surgery, Respiratory Disease Center, Seirei Mikatahara General Hospital, Hamamatsu, Japan <sup>5</sup>Department of General Thoracic Surgery, Tokyo General Hospital, Tokyo, Japan <sup>6</sup>Department of Thoracic Surgery, Fujita Health University Okazaki Medical Center, Okazaki, Japan

### Objective

Uniportal video-assisted thoracic surgery (U-VATS) is a minimally invasive approach, while remaining technically demanding. In Japan, there remains concern that U-VATS performed by non-board-certified surgeons may increase the risk of surgery-related complications. This study aimed to evaluate perioperative outcomes of U-VATS according to surgeon certification status using a nationwide database.

### Methods

This nationwide retrospective study was conducted by the Japanese Uniportal VATS Interest Group (JUVIG). Between April 2018 and March 2022, 3,969 patients underwent anatomic lung resection by U-VATS at 43 institutions. Board certification in thoracic surgery in Japan requires completion of a defined training period, academic achievements, and passing a written examination. Of the total cohort, 406 procedures were performed by non-board-certified surgeons and 3,563 by board-certified surgeons. Propensity score matching yielded 406 matched pairs for analysis. The primary endpoint was surgery-related complications, defined as a composite of intraoperative complications, reoperation within 24 hours, and postoperative complications.

### Results

The distribution of lobectomy/segmentectomy was similar between non-board-certified and board-certified surgeons (76.1%/23.9% vs. 76.8%/23.2%). The incidence of surgery-related complications did not differ significantly between the two groups (14.0% vs. 15.8%; odds ratio 0.87, 95% confidence interval 0.59–1.28,  $p=0.491$ ). Specifically, intraoperative complications occurred in 4.7% vs. 4.2%, reoperation in 0.7% vs. 0%, and postoperative complications in 9.6% vs. 12.3%. Conversion to thoracotomy (3.9% vs. 3.4%) and additional port placement (1.0% vs. 2.0%) did not differ significantly. Operative time and blood loss were lower in the non-board-certified group (159 vs. 168 min,  $p=0.041$ ; 7 vs. 19 mL,  $p=0.036$ ). Drainage duration (1 vs. 2 days) and length of hospital stay (6 vs. 7 days) were also shorter in this group (both  $p<0.001$ ). 30-day mortality (0.2% vs. 0.5%) and 90-day mortality (0.7% vs. 0.7%) were comparable. Interaction analyses demonstrated that the association between non-board-certified surgeons and the risk of surgery-related complications was not modified by procedure type (segmentectomy) or institutional volume.



## **Comparison Between Lymph Node Station- and Zone-Based Classification: An Extended Analysis with the 9th Edition IASLC Lymph Node Descriptors in Surgically Resected Non-Small-Cell Lung Cancer**

**Shia Kim<sup>\*1</sup>; Geun Dong Lee<sup>2</sup>; Sehoon Choi<sup>2</sup>; Hyeong Ryul Kim<sup>2</sup>; Yong-Hee Kim<sup>2</sup>; Dong Kwan Kim<sup>2</sup>; Seung-Il Park<sup>2</sup>; Jae Kwang Yun<sup>2</sup>**

<sup>1</sup>*Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, Seoul, Republic of Korea* <sup>2</sup>*Department of Thoracic and Cardiovascular Surgery, Asan medical center, Seoul, Republic of Korea*

### **Objective**

The 9th edition of the tumor-node-metastasis (TNM) classification by the International Association for the Study of Lung Cancer subdivides pN2 disease into N2a and N2b based on the number of involved lymph node (LN) stations. This study compares the prognostic performance of station-based versus zone-based LN classification in surgically resected non-small cell lung cancer (NSCLC).

### **Methods**

We retrospectively analyzed 11,047 patients who underwent curative resection with systematic LN dissection for NSCLC between 2005 and 2022. In the zone-based system, LN stations were grouped into broader anatomical regions: peripheral or hilar zones for N1 node; and upper mediastinal, lower mediastinal, aortopulmonary, and subcarinal zones for N2 nodes. Patients were classified as N2a or N2b based on single- versus multi-zone or station involvement. Overall survival (OS) and freedom from recurrence (FFR) were evaluated using Kaplan–Meier analysis and Cox regression. Prognostic performance was compared using Harrell’s C-index, Akaike Information Criterion, and R<sup>2</sup>.

### **Results**

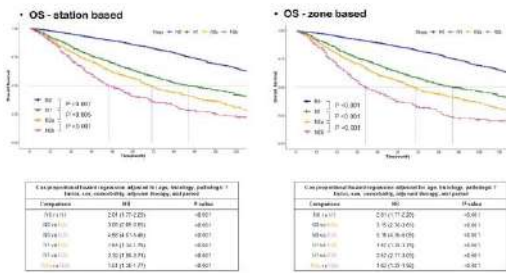
Both classification systems significantly stratified OS and FFR ( $p < 0.001$ ). Zone-based classification showed clearer separation between N2a and N2b groups, particularly in OS (5-year OS: 55.6% vs. 37.2%). Multivariable analysis confirmed both systems as independent prognostic factors, with zone-based N2b showing the highest hazard ratios. Model fit was slightly better with zone-based classification. Notably, 28.8% of station-based N2b patients were reclassified as zone-based N2a, revealing prognostic heterogeneity.

### **Conclusions**

Zone-based LN classification improves prognostic discrimination compared to station-based grouping and may complement future refinements of the TNM nodal staging system.

### **Keyword(s)**

Lung Cancer, Staging, Lymph Node Zone, Non-Small-Cell Lung Cancer



## Optimal Number of Bilateral Recurrent Laryngeal Nerve Lymph Node Dissection for Adequate Nodal Staging and Improved Survival in Esophageal Squamous Cell Carcinoma

**Yeong Jeong Jeon<sup>\*1</sup>; Seong Yong Park<sup>1</sup>**

<sup>1</sup>Thoracic Surgery, Samsung Medical Center, Seoul, Republic of Korea

### Objective

The optimal number of bilateral recurrent laryngeal nerve lymph nodes (BRLN) to be dissected for adequate staging and survival benefit in esophageal squamous cell carcinoma (ESCC) remains unclear, particularly in patients treated with neoadjuvant concurrent chemoradiotherapy (nCCRT), which can alter lymph node morphology and yield.

### Methods

We analyzed 731 patients with ESCC who underwent nCCRT followed by esophagectomy. Restricted cubic spline analysis was used to determine the optimal cut-off value for BRLN dissection. Survival outcomes, probability of false-negative (P(FN)) nodal disease, and nodal staging score (NSS) were evaluated according to the number of BRLN dissected, stratified by clinical and pathological stages.

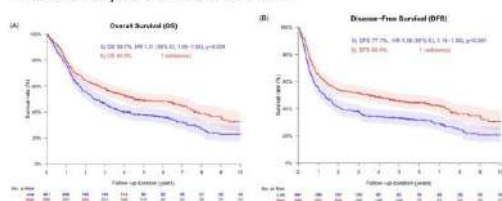
### Results

The median number of total BRLN dissected was 6 (IQR: 3-8). Restricted cubic spline analysis identified 6 as the optimal cut-off value for both overall survival (OS) and disease-free survival (DFS). Patients with  $\geq 6$  BRLN dissected showed significantly better survival outcomes compared to those with  $< 6$  BRLN (5-year OS: 93.3% vs 89.7%,  $p=0.004$ ; 5-year DFS: 86.4% vs 77.1%,  $p<0.001$ ). The survival benefit was consistent across most clinical and pathological subgroups. When 6 BRLN were dissected, the P(FN) was 21.4% overall and NSS exceeded 90% in most stages.

### Conclusions

In ESCC patients who have undergone neoadjuvant CCRT, dissection of at least 6 BRLN provides optimal survival benefit and adequate nodal staging. Validation of these findings in larger, multi-institutional cohorts is needed to establish their generalizability

\* Patients with  $\geq 6$  BRLN dissected showed significantly better survival outcomes compared to those with  $< 6$  BRLN



## **Comparative Analysis of VATS versus RATS for Esophageal Leiomyoma Enucleation: A Multiinstitutional Propensity Score-weighted Study**

**Jeonga Son<sup>\*1</sup>**

<sup>1</sup>*Department of Cardiovascular and Thoracic Surgery, Samsung Medical Center, Seoul, Republic of Korea*

### **Objective**

Evidence from comparative studies of video-assisted thoracoscopic surgery (VATS) and robotic-assisted thoracoscopic surgery (RATS) for the management of esophageal leiomyoma remains limited. We compared the perioperative outcomes of VATS and RATS.

### **Methods**

This multi-institutional retrospective study included 112 patients (VATS group: 84, RATS group: 28) treated at 3 tertiary centers between January 2010 and June 2025. The primary outcomes were intraoperative mucosal injury and postoperative esophageal leakage. Propensity score inverse probability of treatment weighting (IPTW) was applied to minimize selection bias.

### **Results**

The VATS and RATS groups had comparable baseline characteristics, including age (mean: 43.6 vs. 40.7 years,  $p = 0.252$ ), sex (male: 69.0% vs. 71.4%,  $p = 1.0$ ), and body mass index (24.5 vs. 24.6 kg/m<sup>2</sup>,  $p = 0.856$ ). After IPTW adjustment, the rates of mucosal injury (14.7% vs. 11.8%,  $p = 0.751$ ) and esophageal leakage (4.3% vs. 4.2%,  $p = 0.988$ ) were comparable between the groups. RATS was associated with a significantly lower conversion rate (5.7% vs. 0%,  $p = 0.02$ ) and a trend toward reduced intraoperative blood loss (52.6 vs. 80.3 mL,  $p = 0.053$ ), compared with VATS. Thirty-day postoperative complication rates were similar between the groups (17.1% vs. 11.7%,  $p = 0.549$ ).

### **Conclusions**

RATS demonstrated superior intraoperative stability, reflected by a significantly reduced conversion rate, while maintaining postoperative safety comparable to VATS. This multicenter analysis supports the feasibility and safety of RATS for the enucleation of esophageal leiomyomas.

### **Keyword(s)**

Leiomyoma, Robot-Assisted Surgery, Video-Assisted Thoracic Surgery



## **Clinical Utility of Yellow Enhance (YE) Mode in Thoracoscopic Lung Surgery: Experience from Fifteen Cases**

**Takehisa Fukada<sup>\*1</sup>; Shinnosuke Hayashida<sup>1</sup>; Tetsuji Moriya<sup>1</sup>; Hideaki Miyamoto<sup>1</sup>; Takahisa Matsuoka<sup>1</sup>; Hiroaki Sakai<sup>1</sup>**

<sup>1</sup>*Thoracic Surgery, Hyogo Prefectural Amagasaki General Medical Center, Amagasaki, Japan*

### **Objective**

Optimal intraoperative visualization is essential for safe and precise thoracoscopic lung surgery. The Yellow Enhance (YE) mode, incorporated into the VISERA ELITE III endoscopic system, selectively enhances yellow components through color modulation without the use of contrast agents. This study aimed to evaluate the visual characteristics and clinical utility of YE mode in thoracoscopic lung surgery.

### **Methods**

YE mode was applied in 15 video-assisted thoracoscopic surgery (VATS) procedures for lung diseases performed at a single institution between September 2024 and February 2026. During surgery, imaging was alternated between conventional white light imaging (WLI) and YE mode. The visibility of key anatomical structures—including pulmonary arteries, nerves, lymph nodes, and dissection planes—was qualitatively assessed, with particular attention to fissure dissection, lymphadenectomy, and adhesiolysis.

### **Results**

Compared with WLI, YE mode consistently enhanced tissue contrast. Fatty tissue was selectively highlighted, allowing clearer differentiation of vessels, nerves, and surrounding connective tissue. Pulmonary artery sheaths were more distinctly visualized, facilitating safer dissection, particularly in cases with incomplete fissures or mediastinal-type pulmonary arteries. Neural structures, including the vagus and phrenic nerves, were more readily identified. During lymph node dissection, the extent of tissue removal and residual adipose tissue were easily recognized. Thermally coagulated tissues exhibited persistent yellowish discoloration, enabling visual identification of cauterized areas and improved awareness of potential thermal spread. No adverse events or visualization-related complications attributable to YE mode were observed.

### **Conclusions**

In this series of 15 thoracoscopic lung surgeries, YE mode improved visualization of anatomical structures and dissection planes through color-based image processing. Its use supported safer surgical manipulation and enhanced intraoperative anatomical recognition, while also offering educational benefits. YE mode may serve as a practical and effective adjunct in thoracoscopic lung surgery.

### **Keyword(s)**

Thoracoscopic Lung Surgery, Yellow Enhance (YE) Mode, Intraoperative Visualization,  
Pulmonary Artery, Neural Structures, Lymph Node Dissection

## Room 105 (Chinese) | Saturday, July 11, 2026

### TSTS Free Paper Session I - General Thoracic Surgery

Time: 10:30-11:30 (GMT+8)

|       |             |                                                                                                                                                                                                           |
|-------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |             | Yi-Chen Chang (Taiwan)<br>Chair(s): Chih-Cheng Hsieh (Taiwan)<br>Hsu-Chih Huang (Taiwan)                                                                                                                  |
| FP3-1 | 10:30-10:40 | <b>Endoscopic Submucosal Dissection of Early Hypopharyngeal Cancer Following or Concurrent with Esophageal Cancer: Insights from a Single-Surgeon Series</b><br>Chia-Yu Chan (Taiwan)                     |
| FP3-2 | 10:40-10:50 | <b>Bronchoscopy During ICU Admission after Mediastinal Tumor Resection: A Matched Cohort Study</b><br>Chang Wei Shu (Taiwan)                                                                              |
| FP3-3 | 10:50-11:00 | <b>Multiple Drug Resistant Airway Bacterial Infection for Lung Transplantation</b><br>Kuan-Jui Huang (Taiwan)                                                                                             |
| FP3-4 | 11:00-11:10 | <b>Local Management of Pulmonary Metastases (including Primary Lung Cancer with Intrapulmonary Spread): A Comparison of Thoracoscopic Resection and Cryoablation</b><br>Hsing-Hua Lai (Taiwan)            |
| FP3-5 | 11:10-11:20 | <b>Sarcopenia Does Not Increase Postoperative Complications after Thoracoscopic Lobectomy in Lung Cancer Patients: An Analysis Using the Thoracic CT Skeletal Muscle Index</b><br>Yu-Cheng Chang (Taiwan) |
| FP3-6 | 11:20-11:30 | <b>Exploratory Prognostic Evaluation of AJCC 9th Edition N-Subclassification: Insights into N1a/N1b and N2a1/N2a2 in Resected Lung Cancer</b><br>Yi-Hsiang Lai (Taiwan)                                   |

## **Endoscopic Submucosal Dissection of Early Hypopharyngeal Cancer Following or Concurrent with Esophageal Cancer: Insights from a Single Surgeon Series**

**Chia-yu Chang<sup>1</sup> Po-chun Chang<sup>1</sup> Tzu-ping Chen<sup>1</sup> Yin-Kai Chao<sup>2</sup> Chi-hsiao Yeh<sup>2</sup> Yun-hen Liu<sup>2</sup>**

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<sup>2</sup>*Division of Thoracic and Cardiovascular Surgery, Chang-Gung Memorial Hospital, Linkou*

### **Purpose**

Patients with esophageal cancer are at increased risk of developing second primary head and neck malignancies, particularly hypopharyngeal cancer, either synchronously or metachronously. Treatment is often challenging due to prior therapy and anatomical constraints. Endoscopic submucosal dissection (ESD) has emerged as a minimally invasive option for early hypopharyngeal lesions, but evidence in this subset of patients remains limited.

### **Materials and Methods**

We retrospectively reviewed 22 consecutive patients who underwent ESD for early stage hypopharyngeal cancer performed by a single surgeon between 2016 and 2024. Clinical characteristics, procedural outcomes, pathological findings, complications, and survival were analyzed. Patients were classified as having prior or synchronous esophageal cancer, and follow-up data were collected to assess oncologic outcomes.

### **Results**

A total of 22 patients (21 males, 1 female; mean age 63.2 years, range 49–76) underwent ESD for early hypopharyngeal cancer following or concurrent with esophageal cancer. Fifteen patients had a prior history of esophageal cancer, while seven had synchronous disease, with a median interval of 35 months between diagnoses in the prior group. Pathological staging revealed carcinoma in situ (Tis) in 16 cases and T1 lesions in 5 cases. En bloc resection was achieved in all patients, with an R0 resection rate of 81.8% (18/22) and R1 in 4 cases. Procedure-related complications included transient hoarseness due to recurrent laryngeal nerve injury in two patients. The median duration of nasogastric tube placement was 6 days. During follow-up, no local recurrence was observed. At last follow-up, 19 patients were alive and 3 had died from causes unrelated to local hypopharyngeal recurrence.

### **Conclusions**

ESD is a feasible and effective treatment for early hypopharyngeal cancer in patients with a history of prior or synchronous esophageal cancer. High rates of en bloc and curative resection were achieved with acceptable complication rates. This single-surgeon series supports ESD as a valuable minimally invasive therapeutic option in this complex patient population.

## **Bronchoscopy During ICU Admission After Mediastinal Tumor Resection: A Matched Cohort Study**

**Yi-Hung Sung<sup>1</sup> Pei-Hsing Chen<sup>1</sup> Mong-Wei Lin<sup>1</sup> Hsao-Hsun Hsu<sup>1,2</sup> Jin-Shing Chen<sup>1</sup>**

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### **Purpose**

Bronchoscopy is frequently used in critically ill patients for secretion clearance, airway inspection, and alveolar sampling—such as in lung transplantation or complex esophageal/mediastinal pathology. However, data on its safety and clinical effectiveness specifically among postoperative mediastinal tumor patients admitted to the intensive care unit (ICU) remain limited.

### **Materials and Methods**

We conducted a retrospective matched cohort study of adults admitted to the ICU after mediastinal tumor resection (January 2014–December 2020). Patients who underwent bronchoscopy during the ICU stay were matched 1:2 to those who did not receive bronchoscopy based on Acute Physiology and Chronic Health Evaluation (APACHE) score to balance baseline illness severity. The primary outcomes were postoperative pneumonia and duration of mechanical ventilation. Secondary descriptors included ICU length of stay and in-hospital outcomes. Associations between bronchoscopy and outcomes were evaluated in the matched cohort.

### **Results**

Among 230 postoperative ICU admissions, 27 patients received bronchoscopy and were successfully matched to 54 controls (total n=81). In the matched analysis, patients who underwent bronchoscopy experienced a more favorable perioperative course compared with non-bronchoscopy controls, including a lower incidence of postoperative pneumonia and a shorter ventilator interval. Safety signals were acceptable, with no procedure-related serious adverse events documented in the cohort.

### **Conclusions**

In postoperative mediastinal tumor patients requiring ICU care, bronchoscopy—when applied for routine clinical indications—appeared safe and was associated with improved short-term respiratory outcomes. Prospective studies are warranted to confirm causality, refine patient selection, and define risk factors that identify subgroups most likely to benefit.

## Multiple Drug Resistant Airway Bacterial Infection for Lung Transplantation

**Kuan-Jui Huang<sup>1</sup> Pin-Li Chou<sup>1</sup> Hsin-Yueh Fang<sup>1</sup> Chien-Hung Chiu<sup>1</sup> Yun-Hen Liu<sup>1</sup> Wei-Hsun Chen<sup>1</sup>**

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### Purpose

Lung transplantation is a life-saving surgery for end-stage lung disease. The lung is the solid organ most likely to carry bacterial pathogens. Donor-to-host transmitted infections are a challenge in solid organ transplantation. MDR Gram-Positive bacteria is around 30% and MDR Gram-Negative bacteria 50%. This study discusses the impact of multiple drug resistant airway bacterial Infection for patients with lung transplantation.

### Materials and Methods

This is a retrospective study conducted from 2016 to 2024 involving 75 patients who underwent bilateral lung transplantation at LinKou CGMH. The patients were followed for one year after transplantation. Culture data was collected from three different time points: donor BAL (bronchoalveolar lavage) at allocation, bronchial swab and tissue culture perioperatively, and BAL and sputum culture post operatively.

Patients were divided into two groups: those with peri-operative MDR infection and those with post-operative MDR infection. The primary endpoints was overall survival. Secondary endpoints included mechanical ventilation use, ICU stay, hospital stay, surgical complications, FEV1 recovery, and PGD3 (72-hour primary graft dysfunction).

### Results

15% of the donor lungs with resistant bacterial infection before lung transplantation. 19% of the recipients have drug resistant airway bacterial infection after lung transplantation. There were no significant differences between the peri-operative resistant bacterial infection and post-operative resistant bacterial infection groups in terms of age, sex, BMI, and other baseline characteristics. The study found no significant difference between the two groups in operation time, second lung ischemia time, ECLS support, blood loss, or fluid input/output. There were no significant differences in mechanical ventilation duration, ICU stay or PGD3. However, in our study, there were significant longer hospital stays and less overall survival time with the group of post-operative resistant bacterial infection.

### Conclusions

In our study, longer survival of lung transplantation for donor lung grafts with MDR bacterial infection compared with recipient detected after lung transplantation. Furthermore, our study also suggests that with appropriate management using broad-spectrum antibiotics, donor lung grafts with positive cultures can be safely used, which helps to extend the limited donor pool.

## **Local Management of Pulmonary Metastases (including primary lung cancer with intrapulmonary spread): A Comparison of Thoracoscopic Resection and Cryoablation**

**Hsing-Hua Lai<sup>1</sup> Chien-Ming Lo<sup>1</sup> Hung-I Lu<sup>1</sup> Yu Chen<sup>1</sup> Kai-Hao Chuang<sup>1</sup> Li-Chun Chen<sup>1</sup> Yu-Hsin Hsiao<sup>1</sup> Yu-Chi Fang<sup>1</sup> Ruei-Ti Ke<sup>1</sup> Daniel Huang<sup>1</sup>**

*<sup>1</sup>Department of Thoracic & Cardiovascular Surgery*

### **Purpose**

Surgical resection remains a commonly used local treatment option for selected patients with pulmonary metastases. However, a subset of patients, particularly those with limited pulmonary reserve or prior ipsilateral thoracic surgery, may not tolerate the procedure well. Percutaneous cryoablation is a less invasive option; however, comparisons of perioperative outcomes with those of surgery are limited. We aimed to compare the perioperative outcomes between these two modalities.

### **Materials and Methods**

We retrospectively analyzed 85 patients with metastatic pulmonary tumors treated at a single tertiary center between June 2022 and September 2024. The patients underwent thoracoscopic pulmonary metastasectomy (n = 70) or percutaneous cryoablation (n = 15). Clinical parameters, including operative time, chest drainage, and length of hospital stay, were compared between the groups.

### **Results**

Patients selected for cryoablation had a higher incidence of ipsilateral thoracic surgery (66.7% vs. 18.6%;  $P < 0.001$ ), compared with those selected for thoracic surgery. Although the average procedure time was longer (4.26 vs. 2.22 h,  $P = 0.123$ ), the need for chest tube placement (46.0% vs. 2.8%,  $P = 0.000$ ) and number and size of drains were significantly lower ( $P < 0.01$ ) in the cryoablation group versus the thoracic surgery group. The length of hospital stay was similar in both groups.

### **Conclusions**

In selected patients, particularly those with previous thoracic interventions or impaired pulmonary function, percutaneous cryoablation may be a less invasive and tubeless alternative to surgery. These findings support its role as a practical local treatment option when surgery is contraindicated or carries increased risk.



## **Sarcopenia Does Not Increase Postoperative Complications After Thoracoscopic Lobectomy in Lung Cancer Patients: An Analysis Using the Thoracic CT Skeletal Muscle Index**

**Yu-Cheng Chang<sup>1</sup> Ying-Hsuan Chen<sup>2</sup> Hsin-Ying Lee<sup>1</sup> Li-Chieh Chou<sup>2</sup> Li-Wei Chen<sup>2</sup> Xu-Heng Chiang<sup>1,3</sup> Chung-Ming Chen<sup>2</sup> Mong-Wei Lin<sup>1</sup> Jin-Shing Chen<sup>1</sup>**

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### **Purpose**

Sarcopenia has emerged as an important factor affecting surgical outcomes in cancer patients. However, whether sarcopenia increases the risk of complications after thoracoscopic lobectomy remains unclear.

### **Materials and Methods**

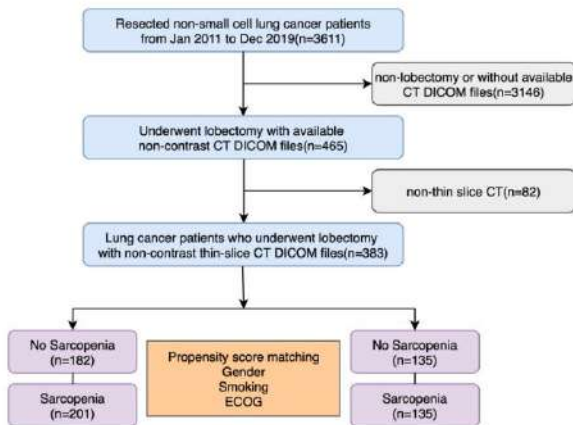
We conducted a retrospective study of 383 patients who underwent thoracoscopic lobectomy for primary lung cancer between 2011 and 2019. Skeletal muscle indices (SMIs) were calculated from thoracic CT images (T9–T12 levels) to assess sarcopenia risk. Propensity score matching (PSM) was performed based on gender, smoking status, and ECOG performance score to minimize confounding. And multivariate logistic regression analyses were subsequently conducted to adjust for potential confounders. Postoperative complications were evaluated according to the Clavien-Dindo classification.

### **Results**

Among the cohort, 52.5% were classified as at risk for sarcopenia. Prior to matching, gender, smoking status, and ECOG performance status were significantly associated with sarcopenia. Following propensity score matching, these baseline differences were minimized. Multivariate logistic regression further demonstrated that, apart from PEV1 < 80%, no pathological characteristics or perioperative factors were independently associated with postoperative complication rates between the sarcopenia and non-sarcopenia groups.

### **Conclusions**

In patients undergoing thoracoscopic lobectomy, sarcopenia assessed by chest CT was not significantly associated with an increased risk of postoperative complications. Therefore, thoracoscopic lobectomy appears to be a safe and feasible surgical option for patients with sarcopenia.



Flow diagram of patient selection

| Pathological Features       | Before Matching |                       |                    | p value | After Matching |                       |                    | p value |
|-----------------------------|-----------------|-----------------------|--------------------|---------|----------------|-----------------------|--------------------|---------|
|                             | All (n=383)     | No sarcopenia (n=182) | Sarcopenia (n=201) |         | All (n=270)    | No sarcopenia (n=135) | Sarcopenia (n=135) |         |
| Histology                   |                 |                       |                    |         |                |                       |                    |         |
| Non-adenocarcinoma          | 16(4.1%)        | 7(1.1%)               | 9(2.3%)            | 0.07    | 13(4.8%)       | 6(4.4%)               | 7(5.2%)            | 0.78    |
| Adenocarcinoma              | 367(95.9%)      | 175(45.7%)            | 192(50.2%)         |         | 257(95.2%)     | 129(95.6%)            | 128(94.8%)         |         |
| Differentiation             |                 |                       |                    |         |                |                       |                    |         |
| Poor                        | 35(14.4%)       | 28(7.3%)              | 7(7.1%)            | 0.78    | 36(13.8%)      | 19(14.1%)             | 17(12.6%)          | 0.76    |
| Well or moderate            | 328(85.6%)      | 154(40.2%)            | 174(45.4%)         |         | 234(86.2%)     | 116(85.9%)            | 118(87.4%)         |         |
| VPI-positive                | 78(20.4%)       | 36(9.4%)              | 42(11.0%)          | 0.02    | 53(19.6%)      | 25(18.5%)             | 28(20.7%)          | 0.88    |
| VPI-negative                | 79(19.2%)       | 32(8.4%)              | 47(11.0%)          | 0.17    | 56(20.7%)      | 26(19.3%)             | 30(22.2%)          | 0.55    |
| Pathological tumor size, cm |                 |                       |                    | 0.35    |                |                       |                    | 0.81    |
| ≤3                          | 32(8.5%)        | 15(4.1%)              | 16(4.1%)           |         | 18(7.0%)       | 9(6.7%)               | 9(7.1%)            |         |
| 3-5                         | 47(12.3%)       | 17(4.4%)              | 30(7.3%)           |         | 26(10.0%)      | 12(9.0%)              | 14(10.4%)          |         |
| 5-7                         | 8(2.1%)         | 6(1.6%)               | 2(0.5%)            |         | 7(2.6%)        | 4(3.0%)               | 3(2.2%)            |         |
| >7                          | 0(0.0%)         | 0(0.0%)               | 0(0.0%)            |         | 0(0.0%)        | 0(0.0%)               | 0(0.0%)            |         |
| pN stage                    |                 |                       |                    | 0.45    |                |                       |                    | 0.94    |
| N0                          | 33(8.6%)        | 15(4.1%)              | 18(4.5%)           |         | 22(8.1%)       | 11(8.1%)              | 11(8.1%)           |         |
| N1                          | 22(5.7%)        | 10(2.6%)              | 12(3.0%)           |         | 17(6.3%)       | 8(6.0%)               | 9(6.7%)            |         |
| N2                          | 31(8.1%)        | 14(3.6%)              | 17(4.5%)           | 0.48    | 25(9.3%)       | 12(9.0%)              | 13(9.7%)           | 0.24    |
| Pathological stage          |                 |                       |                    |         |                |                       |                    |         |
| IA                          | 24(6.3%)        | 12(3.1%)              | 12(3.0%)           |         | 18(6.7%)       | 10(7.4%)              | 8(6.0%)            |         |
| IB                          | 22(5.7%)        | 11(2.8%)              | 11(2.8%)           |         | 18(6.7%)       | 9(6.7%)               | 9(6.7%)            |         |
| II                          | 84(22.0%)       | 38(9.9%)              | 46(11.8%)          |         | 52(19.3%)      | 26(19.3%)             | 26(19.3%)          |         |
| III                         | 34(8.9%)        | 16(4.2%)              | 18(4.5%)           |         | 27(10.0%)      | 13(9.6%)              | 14(10.4%)          |         |
| IV                          | 0(0.0%)         | 0(0.0%)               | 0(0.0%)            | 0.29    | 0(0.0%)        | 0(0.0%)               | 0(0.0%)            | 0.00    |
| Resection margin            |                 |                       |                    |         |                |                       |                    |         |
| Negative                    | 361(94.3%)      | 172(45.0%)            | 189(46.9%)         | 0.28    | 254(94.1%)     | 127(94.1%)            | 127(94.1%)         |         |
| Positive                    | 22(5.7%)        | 10(2.6%)              | 12(3.1%)           |         | 16(5.9%)       | 8(5.9%)               | 8(5.9%)            |         |

Data are presented as mean (SD) (range) or number (%).  
Abbreviations: VPI, Visceral pleural invasion; pN, pathological N stage; VPI, Visceral pleural invasion.

Pathological features of the excised tumors of lung cancer patients undergoing lobectomy

Table 1. Demographic and clinical features of lung cancer patients undergoing lobectomy

| Clinical Features | Before Matching |                       |                    | p value | After Matching |                       |                    | p value |
|-------------------|-----------------|-----------------------|--------------------|---------|----------------|-----------------------|--------------------|---------|
|                   | All (n=383)     | No sarcopenia (n=182) | Sarcopenia (n=201) |         | All (n=270)    | No sarcopenia (n=135) | Sarcopenia (n=135) |         |
| Age, yr           | 60.5 ± 9.8      | 61.0 ± 9.7            | 60.1 ± 10.0        | 0.64    | 61.4 ± 9.9     | 61.1 ± 9.6            | 61.7 ± 10.1        | 0.62    |
| Gender            |                 |                       |                    |         |                |                       |                    |         |
| Male              | 141(36.8%)      | 62(33.5%)             | 79(39.4%)          | 0.02    | 96(35.6%)      | 48(35.6%)             | 48(35.6%)          | 0.55    |
| Female            | 141(36.8%)      | 62(33.5%)             | 79(39.4%)          |         | 96(35.6%)      | 48(35.6%)             | 48(35.6%)          |         |
| Smoking status    |                 |                       |                    |         |                |                       |                    |         |
| ECOG              |                 |                       |                    |         |                |                       |                    |         |
| 0                 | 29(7.6%)        | 13(7.2%)              | 16(8.0%)           | 0.02    | 19(7.0%)       | 9(7.0%)               | 9(7.0%)            | 0.43    |
| 1                 | 91(23.8%)       | 51(28.1%)             | 40(19.9%)          |         | 74(27.4%)      | 37(27.4%)             | 37(27.4%)          | 0.55    |
| FEV1              |                 |                       |                    |         |                |                       |                    |         |
| FVC               | 108.7 ± 14.7    | 107.8 ± 14.7          | 109.7 ± 14.0       | 0.26    | 110.5 ± 14.7   | 109.8 ± 15.5          | 111.1 ± 13.8       | 0.63    |
| FEV1              | 14.7 ± 3.6      | 14.7 ± 3.6            | 14.7 ± 3.6         | 0.74    | 14.7 ± 3.6     | 14.7 ± 3.6            | 14.7 ± 3.6         | 0.36    |
| Family history    |                 |                       |                    |         |                |                       |                    |         |
| Family history    | 71(18.5%)       | 29(15.9%)             | 42(20.9%)          | 0.09    | 32(11.9%)      | 14(10.4%)             | 18(13.3%)          | 0.20    |
| Comorbidity       |                 |                       |                    |         |                |                       |                    |         |
| ECOG              | 2.3 ± 1.7       | 2.3 ± 1.6             | 2.3 ± 1.8          | 0.14    | 2.4 ± 1.6      | 2.3 ± 1.7             | 2.3 ± 1.6          | 0.84    |
| CEA level         |                 |                       |                    |         |                |                       |                    |         |
| normal            | 336             | 160(87.9%)            | 176(87.0%)         | 0.87    | 223            | 110(81.5%)            | 113(82.6%)         | 0.56    |
| abnormal          | 47(12.3%)       | 22(12.1%)             | 25(12.4%)          |         | 31(11.5%)      | 14(10.4%)             | 17(12.6%)          |         |
| BMI               | 23.3 ± 3.1      | 24.8 ± 3.2            | 22.8 ± 2.8         | 0.46    | 23.8 ± 3.1     | 24.9 ± 3.1            | 22.4 ± 2.6         | 0.37    |
| ASA               | 1.5 ± 0.7       | 1.5 ± 0.7             | 1.5 ± 0.7          | 0.82    | 1.5 ± 0.7      | 1.5 ± 0.7             | 1.5 ± 0.7          | 0.79    |

All the enrolled patients were Asian.  
Data are presented as mean ± SD (range) or number (%).  
Abbreviations: BMI, Body Mass Index; ASA, body surface area; CEA, carcinoembryonic antigen; ECOG, Eastern Cooperative Oncology Group performance status; Family history: lung cancer family history; FEV1, Forced expiratory volume in 1 second; FVC, forced vital capacity; HTN, hypertension; N/A, not available; PFT, pulmonary function test.

Demographic and clinical features of lung cancer patients undergoing lobectomy.

Table 3. Perioperative outcomes of lung cancer patients undergoing lobectomy

| Perioperative Outcomes         | Before Matching |                       |                    | p value | After Matching |                       |                    | p value |
|--------------------------------|-----------------|-----------------------|--------------------|---------|----------------|-----------------------|--------------------|---------|
|                                | All (n=383)     | No sarcopenia (n=182) | Sarcopenia (n=201) |         | All (n=270)    | No sarcopenia (n=135) | Sarcopenia (n=135) |         |
| Approach method                |                 |                       |                    | 0.99    |                |                       |                    | 0.99    |
| Thoracotomy                    | 0(0.0%)         | 0(0.0%)               | 0(0.0%)            |         | 0(0.0%)        | 0(0.0%)               | 0(0.0%)            |         |
| VATS                           | 383(100%)       | 182(100%)             | 201(100%)          |         | 270(100%)      | 135(100%)             | 135(100%)          |         |
| Conversion to thoracotomy      | 21(5.5%)        | 1(0.5%)               | 20(10.0%)          |         | 0(0.0%)        | 0(0.0%)               | 0(0.0%)            |         |
| Dissected lymph nodes          |                 |                       |                    |         |                |                       |                    |         |
| Total number                   | 13.8 ± 7.5      | 13.5 ± 7.5            | 14.0 ± 7.5         | 0.39    | 13.9 ± 7.4     | 13.7 ± 7.5            | 14.2 ± 6.9         | 0.57    |
| Total station                  |                 |                       |                    |         |                |                       |                    |         |
| Unilateral VATS                | 4.6 ± 1.3       | 4.6 ± 1.3             | 4.6 ± 1.3          | 0.47    | 4.6 ± 1.4      | 4.6 ± 1.4             | 4.7 ± 1.3          | 0.77    |
| Operative bleeding, mL         | 112(29.2%)      | 28(15.4%)             | 84(41.8%)          | 0.37    | 87(32.2%)      | 45(33.3%)             | 42(31.1%)          | 0.70    |
| Postoperative ICU stay, d      | 41.9 ± 1.9      | 41.9 ± 1.9            | 41.9 ± 1.9         | 0.09    | 41.3 ± 1.7     | 41.3 ± 1.7            | 41.3 ± 1.7         | 0.69    |
| Postoperative hospital stay, d | 10.8            | 10.8                  | 10.8               |         | 10.8           | 10.8                  | 10.8               |         |
| Chest tube duration, d         | 0.5 ± 1.0       | 0.5 ± 1.0             | 0.5 ± 1.0          | 0.01    | 0.5 ± 1.0      | 0.5 ± 1.0             | 0.5 ± 1.0          | 0.48    |
| Chest tube > 3 days            | 5.8 ± 1.3       | 5.8 ± 1.3             | 5.8 ± 1.3          | 0.15    | 5.7 ± 1.3      | 5.7 ± 1.3             | 5.7 ± 1.3          | 0.77    |
| Chest tube > 5 days            | 3.1 ± 1.3       | 3.1 ± 1.3             | 3.1 ± 1.3          | 0.07    | 3.1 ± 1.3      | 3.1 ± 1.3             | 3.1 ± 1.3          | 0.60    |
| Post-operative complication    |                 |                       |                    |         |                |                       |                    |         |
| All complications              | 16(4.2%)        | 5(2.7%)               | 11(5.5%)           | 0.03    | 13(4.8%)       | 6(4.4%)               | 7(5.2%)            | 0.99    |
| Grade 3b or greater            | 3(0.8%)         | 1(0.5%)               | 2(1.0%)            | 0.22    | 2(0.7%)        | 1(0.7%)               | 1(0.7%)            | 0.58    |
| Grade 3b or greater            | 4(1.0%)         | 2(1.1%)               | 2(1.0%)            | 0.62    | 2(0.7%)        | 2(1.5%)               | 0(0.0%)            | 0.18    |
| 30-day mortality               | 0(0.0%)         | 0(0.0%)               | 0(0.0%)            | N/A     | 0(0.0%)        | 0(0.0%)               | 0(0.0%)            | N/A     |

Data are presented as mean (SD) (range) or number (%).  
Abbreviations: ICU, intensive care unit; VATS, video-assisted thoracoscopic surgery; N/A, not available.

Perioperative outcomes of lung cancer patients undergoing lobectomy

Table 4. Multivariate analysis of correlations between clinicopathological features and overall complications(all grades) for sarcopenia patients who underwent VATS lobectomy

| Variables                    | Hazard ratio | 95% CI       | P value |
|------------------------------|--------------|--------------|---------|
| Age                          |              |              |         |
| Age<80                       | 0.949        | 0.063-14.355 | 0.970   |
| Age≥80                       | 1.000        |              |         |
| Gender                       |              |              |         |
| Male                         | 1.401        | 0.618-3.177  | 0.419   |
| Female                       | 1.000        |              |         |
| Smoking status               |              |              |         |
| No                           | 1.039        | 0.383-2.820  | 0.940   |
| Yes                          | 1.000        |              |         |
| ECOG                         |              |              |         |
| 0                            | 1.000        | 0.906-3.459  | 0.095   |
| ≥1                           | 1.770        |              |         |
| PFT                          |              |              |         |
| FEV1<80%                     | 1.000        | 1.009-28.741 | 0.049   |
| FEV1≥80%                     | 5.384        |              |         |
| Family History               |              |              |         |
| Yes                          | 1.000        | 0.286-1.271  | 0.184   |
| No                           | 0.603        |              |         |
| Comorbidities Index<br>(CCI) |              |              |         |
| <5                           | 2.042        | 0.642-6.494  | 0.227   |
| ≥5                           | 1.000        |              |         |
| CEA level                    |              |              |         |
| Normal                       | 1.044        | 0.386-2.826  | 0.932   |
| Abnormal                     | 1.000        |              |         |
| Histology                    |              |              |         |
| Non-adenocarcinoma           | 0.298        | 0.420-2.129  | 0.228   |
| Adenocarcinoma               | 1.000        |              |         |
| Differentiation              |              |              |         |
| Poor                         | 1.132        | 0.437-2.930  | 0.799   |
| Well or moderate             | 1.000        |              |         |
| VPI                          |              |              |         |
| Negative                     | 1.125        | 0.381-3.932  | 0.733   |
| Positive                     | 1.000        |              |         |
| LVI                          |              |              |         |
| Negative                     | 0.727        | 0.305-1.734  | 0.472   |
| Positive                     | 1.000        |              |         |
| Pathological tumor size      |              |              |         |
| <3                           | 0.962        | 0.099-9.345  | 0.974   |
| ≥3                           | 1.000        |              |         |
| Pathological stage           |              |              |         |
| 1                            | 0.729        | 0.205-2.594  | 0.626   |
| 2-3                          | 1.000        |              |         |
| Resection margin             |              |              |         |
| Negative                     | 1.297        | 0.338-4.972  | 0.705   |
| Positive                     | 1.000        |              |         |
| Sarcopenia                   |              |              |         |
| Yes                          | 1.168        | 0.661-2.062  | 0.593   |
| No                           | 1.000        |              |         |

Multivariate analysis of correlations between  
clinicopathological features and overall complications

## **Exploratory Prognostic Evaluation of AJCC 9th Edition N-Subclassification: Insights into N1a/N1b and N2a1/N2a2 in Resected Lung Cancer**

**Yi-Hsiang Lai<sup>1,2</sup> Kuan-Hsun Lin<sup>1,2</sup> Yen-Shou Kuo<sup>1,2</sup> Ying-Yi Chen<sup>1,2</sup> Yuan-Ming Tsai<sup>1,2</sup> Hsu-Kai Huang<sup>1,2</sup> Tsai-Wang Huang<sup>1,2</sup>**

*<sup>1</sup>Division of Thoracic Surgery, Department of Surgery, Tri-Service General Hospital <sup>2</sup>National Defense Medical University*

### **Purpose**

The 9th edition of the TNM staging system by the American Joint Committee on Cancer (AJCC) introduced a formal subclassification of mediastinal nodal (N2) involvement into N2a (single-station) and N2b (multi-station) disease. However, N1a/N1b (single- vs. multi-station N1) and N2a1/N2a2 (single-station N2 without vs. with N1 involvement) were not included in the official staging system and remain exploratory categories discussed in prior studies. This study aimed to evaluate the prognostic implications of these exploratory nodal subclassifications using a single-institution cohort.

### **Materials and Methods**

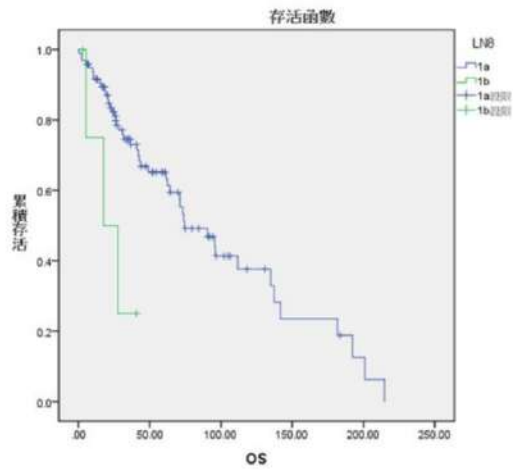
We retrospectively analyzed patients with pathologically confirmed N1 or N2 disease who underwent complete surgical resection and systematic lymph node dissection at our institution. Patients were reclassified as N1a (single-station N1), N1b (multi-station N1), N2a1 (single-station microscopic N2), and N2a2 (single station macroscopic N2). Overall survival (OS) and disease-free survival (DFS) were estimated using Kaplan-Meier methods, and group differences were tested using the log-rank method.

### **Results**

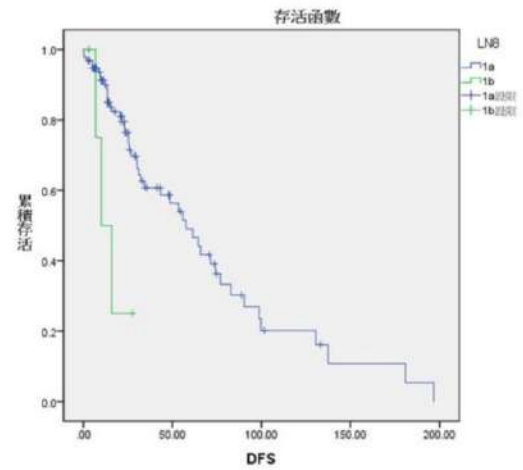
A total of 101 N1 and 108 N2a patients were included. N1a patients showed significantly longer OS (mean: 97.2 months) and DFS (mean: 69.8 months) than N1b (mean OS: 22.9 months; mean DFS: 15.1 months;  $p = 0.014$  and  $p = 0.012$ , respectively). Within the N2a subgroup, N2a2 patients had numerically superior OS (83.6 vs. 69.8 months) and DFS (68.5 vs. 47.6 months) compared to N2a1, though not reaching statistical significance ( $p = 0.236$  and  $p = 0.206$ ).

### **Conclusions**

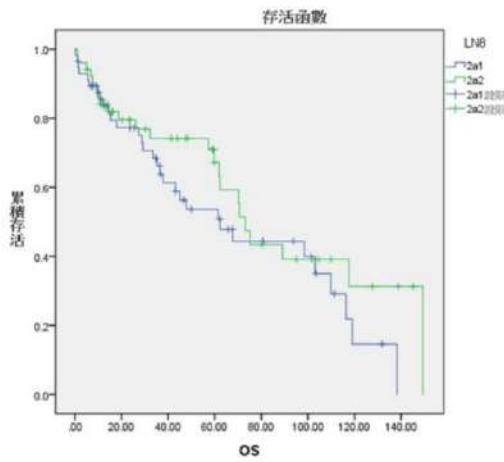
While only N2a/N2b has been adopted in the 9th TNM edition, our data suggest that N1a/N1b and N2a1/N2a2 subclassifications may also offer additional prognostic stratification. The significant survival gap between N1a and N1b, and the trend favoring N2a2 over N2a1, support further validation of these exploratory nodal categories in larger cohorts.



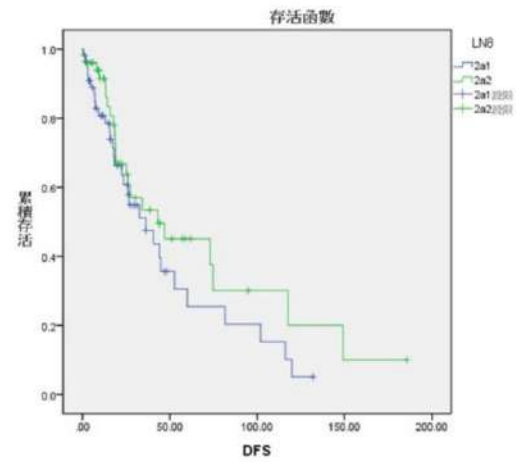
OS of N1a/N1b



DFS of N1a/N1b



OS of N2a1/N2a2



DFS of N2a1/N2a2

## Room 105 (Chinese) | Saturday, July 11, 2026

### TSTS Free Paper Session II - Surgical Techniques

**Time: 11:30-12:30 (GMT+8)**

|       |             |                                                                                                                                                      |
|-------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |             | Chair(s): Cheng-Yen Chuang (Taiwan)<br>Chih-Ming Lin (Taiwan)<br>Yu-Sen Lin (Taiwan)                                                                 |
| FP4-1 | 11:30-11:40 | <b>One Step Treatment: The Localization and Surgical Resection of Small Pulmonary Nodules in a Hybrid Theater</b><br>Chih-Ming Lin (Taiwan)          |
| FP4-2 | 11:40-11:50 | <b>Dye Localization Extended Segmentectomy Versus Lobectomy for Deep Intersegmental Early-Stage Lung Adenocarcinoma</b><br>Ting-Fang Kuo (Taiwan)    |
| FP4-3 | 11:50-12:00 | <b>Clinical Applications of Indocyanine Green (ICG) in Early Lung Cancer Surgery: An Institutional Experience</b><br>Chen-Sung Lin (Taiwan)          |
| FP4-4 | 12:00-12:10 | <b>Drainless Thoracoscopic Surgery for Primary Spontaneous Pneumothorax: A Propensity-Matched Study</b><br>Yun-Shao Wu (Taiwan)                      |
| FP4-5 | 12:10-12:20 | <b>Talc Pleurodesis for Persistent Postoperative Air Leak in Patients with Emphysema: Case Series from Chi Mei Hospital</b><br>Li-Chun Chen (Taiwan) |
| FP4-6 | 12:20-12:30 | <b>Perioperative Outcomes of Completion Lobectomy after Sublobar Resection: A Single-Institution Experience</b><br>Chin-Hao Yu (Taiwan)              |

## **One Step Treatment: The Localization and Surgical Resection of Small Pulmonary Nodules in a Hybrid Theater**

**Chih-Ming Lin<sup>1</sup> Chien-Ho Tsai<sup>1</sup>**

<sup>1</sup>*Department of Surgery, National Yang Ming Chiao Tung University Hospital, Taiwan*

### **Purpose**

Several studies reported their experiences of preoperative localization in the hybrid operating room. Therefore, we compared the outcomes of preoperative localization in the hybrid and CT rooms, included the dye and micro-coil implantation.

### **Materials and Methods**

This was a retrospective study conducted from June 2018 to January 2025. A total of 110 patients underwent 111 unilateral localization procedures, encompassing 126 lesions in total. Localization was performed either in the hybrid operating room (ARTIS pheno, IOCT, n = 67) or in the CT room (POCT, n = 44) at our hospital. We compared the characteristics of the localized nodules, including nodule size, depth of the localization needle, localization method (dye vs. coil), procedure time, peri-procedural complications, and the success rate of subsequent surgical resection.

### **Results**

Between the POCT and IOCT groups, there were no significant differences in age, gender, BMI, number of target lesions, prevalence of lung disease, or proportion of malignancy. Compare the IOCT group, the POCT showed Predominantly on the right. In terms of localization methods, the POCT group primarily used coils. Regarding procedural complications, pulmonary hemorrhage was more common in the POCT group, whereas there were three cases of localization failure in the IOCT group owing to pneumothorax. Especially, the localization failure in the POCT group was due to marker dislodgement after the procedure, while the failures in the IOCT group were caused by lung atelectasis resulting from large pneumothorax. Neither group required chest tube drainage for pneumothorax, nor did any thromboembolic events occur. In addition, the POCT group demonstrated a higher risk of pulmonary hemorrhage.

### **Conclusions**

This is a retrospective cohort study. The IOCT was shown to be as effective and safe as POCT, with shorter procedure duration in the IOCT group, regardless of whether micro-coil implantation or dye injection was performed. Compared with another IOCT study, our cohort included a higher proportion of micro-coil implantations for nodule localization.



## **Dye Localization Extended Segmentectomy Versus Lobectomy for Deep Intersegmental Early-Stage Lung Adenocarcinoma**

**Wen-Yao Lee<sup>1</sup> Ting-Fang Kuo<sup>2</sup> Hsaio-Hung Lu<sup>3</sup> Min-Shu Hsieh<sup>4</sup> Hsao-Hsun, Hsu<sup>5</sup> Jin-Shing Chen<sup>2</sup>**

<sup>1</sup>*Department of Surgery, Fu Jen Catholic University Hospital, New Taipei, Taiwan* <sup>2</sup>*Department of Surgery, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan* <sup>3</sup>*Department of Surgery, Shin Kong Wu Ho-Su Memorial Hospital, Taipei, Taiwan* <sup>4</sup>*Department of Pathology, National Taiwan University Hospital, Taipei, Taiwan* <sup>5</sup>*Department of Surgical Oncology, National Taiwan University Cancer Center, Taipei, Taiwan*

### **Purpose**

Computed tomography–guided dye localization facilitates extended segmentectomy with reliable oncologic margins for deep intersegmental early stage lung adenocarcinoma. This study evaluated its perioperative and long-term outcomes in comparison with lobectomy.

### **Materials and Methods**

We retrospectively reviewed patients with early-stage lung adenocarcinoma  $\leq 2$ cm who underwent lung resection between 2011 and 2019. Patients who received computed tomography–guided dye localization extended segmentectomy from 2013 to 2019 were compared with those who underwent lobectomy between 2011 and 2016. After 1:1 propensity score matching based on demographic and clinical variables, 30 matched pairs were included for analysis.

### **Results**

Compared to lobectomy, extended segmentectomy with computed tomography–guided dye localization was associated with shorter operation time ( $102 \pm 34$  vs.  $181 \pm 42$  mins,  $p < 0.001$ ), less blood loss ( $0[0-0]$  vs.  $0[0-62.5]$  ml,  $p < 0.001$ ), shorter chest tube duration ( $1[1-2]$  vs.  $2[2-3]$  days,  $p = 0.002$ ), and reduced hospital stay ( $3[3-4]$  vs.  $5[4-6]$  days,  $p < 0.001$ ). The pathological margin was  $1.0 \pm 0.4$  cm in the segmentectomy group. Lymph node yield was lower in the segmentectomy group ( $p < 0.001$ ) but 5-year overall and disease-free survival rates were comparable.

### **Conclusions**

Computed tomography–guided dye localization extended segmentectomy was associated with favorable perioperative outcomes and may offer acceptable oncologic control in selected patients with deep intersegmental early-stage lung adenocarcinoma, representing a potential alternative to lobectomy.

## **Clinical Applications of Indocyanine Green (ICG) in Early Lung Cancer Surgery: An Institutional Experience**

**Chen-Sung Lin<sup>1,4</sup> Chao-Yu Liu<sup>2,4</sup> Cheng-Hong Lin<sup>3</sup> Chia-Chuan Liu<sup>4</sup>**

*<sup>1</sup>Division of Thoracic Surgery, Department of Surgery, Taipei Hospital, Ministry of Health and Welfare, New Taipei City <sup>2</sup>Division of Thoracic Surgery, Department of Surgery, Far Eastern Memorial Hospital, New Taipei City <sup>3</sup>Diagnostic Radiology, Taipei Hospital, Ministry of Health and Welfare, New Taipei City <sup>4</sup>Division of Thoracic Surgery, Koo-Foundation Sun Yat-sen Cancer Center, Taipei, Taiwan*

### **Purpose**

Lung cancer remains the leading cause of cancer-related mortality in Taiwan. Precise resection of early-stage lung cancer continues to present a clinical challenge. This retrospective study aimed to share our institutional experience with the application of indocyanine green (ICG) in achieving accurate early lung cancer resection.

### **Materials and Methods**

Between December 2020 and June 2025, 55 early lung cancer nodules with a mean maximal diameter of 1.0 cm were resected using ICG-guided VATS. These included 32 Tis, 19 T1, and 4 T2 lesions. Of these, 44 underwent wedge resection following CT-guided ICG tumor localization (Group 1, peripheral lesions), 5 underwent (sub)segmentectomy using intravenous ICG for segmental plane delineation (Group 2, non-peripheral lesions), and 6 underwent (sub)segmentectomy with both CT-guided localization and intravenous ICG mapping (Group 3, non peripheral lesions). The shortest distance from the resection margin to the tumor was used as the endpoint to compare the efficacy of these approaches.

### **Results**

The mean maximal tumor diameters and T-status distribution (Tis/T1/T2) were 0.9 cm (28 Tis, 15 T1, 1 T2) in Group 1, 2.4 cm (2 T1, 3 T2) in Group 2, and 0.8 cm (4 Tis, 2 T1) in Group 3 ( $p = 0.022$ , Kruskal–Wallis test for tumor size;  $p = 0.002$ , Fisher's exact test for T-status). The mean shortest margin-to-tumor distances were 0.9 cm, 1.4 cm, and 1.5 cm for Groups 1, 2, and 3, respectively ( $p = 0.373$ , Kruskal–Wallis test).

### **Conclusions**

Our preliminary results demonstrate that CT-guided ICG localization with wedge resection is feasible for small peripheral lung cancers. For non-peripheral lesions, (sub)segmentectomy using intravenous ICG for segmental plane delineation is appropriate, while a combined approach of CT-guided localization and intravenous ICG mapping is preferable for smaller non-peripheral lesions. All three strategies achieved comparable safety in terms of resection margins.

## **Drainless Thoracoscopic Surgery for Primary Spontaneous Pneumothorax: A Propensity-Matched Study**

**Cheng-Wei Wu<sup>1,2</sup> Chen-Sung Lin<sup>2</sup> Ka-I Leong<sup>1</sup> Cheng-Hung How<sup>1</sup> Hu-Lin Christina Wang<sup>1,3</sup> Chieh-Kuo Lin<sup>1</sup> Chao-Yu Liu<sup>1</sup> Yun-Shao Wu<sup>1</sup>**

*<sup>1</sup>Division of Thoracic Surgery, Department of Surgery, Far-Eastern Memorial Hospital, New Taipei City, Taiwan <sup>2</sup>Division of Thoracic Surgery, Department of Surgery, Taipei Hospital, Ministry of Health and Welfare, New Taipei City, Taiwan <sup>3</sup>Division of Trauma, Department of Surgery, Far-Eastern Memorial Hospital, New Taipei City, Taiwan*

### **Purpose**

Drainless thoracoscopic surgery, which avoids chest drainage after surgery, has been controversial for the treatment of primary spontaneous pneumothorax. This study aimed to demonstrate the postoperative outcomes of drainless thoracoscopic surgery in a select cohort of patients with primary spontaneous pneumothorax.

### **Materials and Methods**

This retrospective study enrolled patients who underwent thoracoscopic surgery for primary spontaneous pneumothorax between August 2016 and December 2021 at Far-Eastern Memorial Hospital, New Taipei City, Taiwan. A group of patients was carefully selected from the cohort to undergo a drainless procedure. Clinical characteristics and postoperative outcomes were compared between propensity score-matched patients with and without chest drains.

### **Results**

Among the 198 patients enrolled, 54 and 144 were assigned to the drainless and drain groups, respectively. After propensity score matching, 54 patients in both the groups had similar clinical characteristics. Compared to the drain group, the drainless group had a shorter hospital stay [Median (Interquartile range), 2 (1–2) versus 2 (2–3),  $p < 0.001$ ] and lesser postoperative pain [1 (0–2) versus 3 (2–3),  $p < 0.001$ ], but there were no significant between-group differences in postoperative complications [3 (5.55 %) cases in drainless group versus 2 (3.70 %) in drain group,  $p = 0.480$ ] and disease recurrence [3 (5.56 %) cases in the drainless group versus 5 (9.26 %) in the drain group,  $p = 0.727$ ].

### **Conclusions**

Drainless thoracoscopic surgery is associated with reduced pain and shorter hospital stay without compromising postoperative outcomes including disease recurrence. Hence, it may be advantageous for a carefully selected cohort of patients with primary spontaneous pneumothorax.

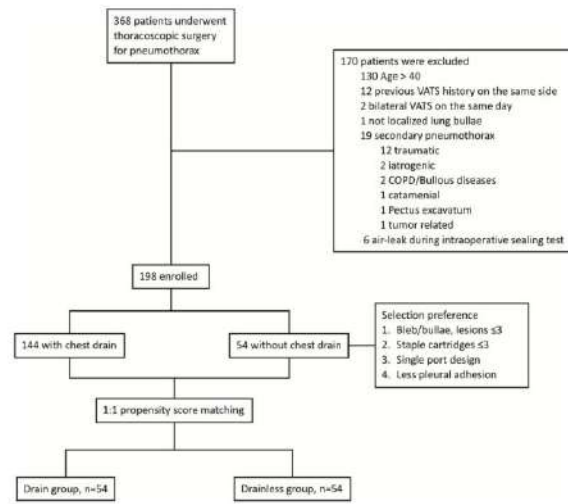


Fig. 1. Flow chart of patient selection. VATS, video-assisted thoracic surgery; COPD, chronic obstructive pulmonary disease.

Fig1

|                                                 | All Patients (n = 198) |                       | p value | After propensity score matching (n = 108) |                       | p value |
|-------------------------------------------------|------------------------|-----------------------|---------|-------------------------------------------|-----------------------|---------|
|                                                 | Drain<br>(n = 144)     | Drainless<br>(n = 54) |         | Drain<br>(n = 54)                         | Drainless<br>(n = 54) |         |
| First postoperative X-ray, CX                   |                        |                       | <0.001* |                                           |                       | 0.002*  |
| Full expansion                                  | 40 (51.56 %)           | 13 (24.07 %)          |         | 31 (57.41 %)                              | 13 (24.07 %)          |         |
| Residual space                                  | 54 (44.44 %)           | 41 (75.93 %)          |         | 23 (42.59 %)                              | 41 (75.93 %)          |         |
| Postoperative hospital stay (day), Median (IQR) | 2 (2-3)                | 2 (1-3)               | <0.001* | 2 (1-3)                                   | 2 (1-3)               | 0.001*  |
| Postoperative Day 1 VAS score, Median (IQR)     | 3 (2-3)                | 1 (0-2)               | <0.001* | 3 (2-3)                                   | 1 (0-2)               | <0.001* |
| Postoperative Complication†, n(%)               |                        |                       | 0.023*  |                                           |                       | 0.002*  |
| No                                              | 120 (83.97 %)          | 31 (57.41 %)          |         | 52 (96.29 %)                              | 31 (57.41 %)          |         |
| Grade I-II                                      | 8 (5.56 %)             | 2 (3.70 %)            |         | 2 (3.70 %)                                | 2 (3.70 %)            |         |
| Grade III                                       | 1 (0.69 %)             | 1 (1.85 %)            |         | 1 (1.85 %)                                | 1 (1.85 %)            |         |
| Overall recurrence of PSP, n(%)                 | 10 (6.94 %)            | 3 (5.56 %)            | 0.563*  | 0 (0.00 %)                                | 3 (5.56 %)            | 0.727*  |

Table2

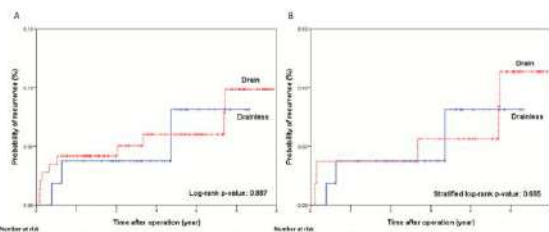


Fig. 2. Pneumothorax recurrence of the drain group versus the drainless group before (A) and after (B) propensity score matching.

Fig 2

**Table 1**  
Clinical characteristics of patients before and after propensity score matching.

| Characteristics               | All Patients (n = 198) |                       | SMD   | After propensity score matching (n = 108) |                       | SMD   |
|-------------------------------|------------------------|-----------------------|-------|-------------------------------------------|-----------------------|-------|
|                               | Drain<br>(n = 144)     | Drainless<br>(n = 54) |       | Drain<br>(n = 54)                         | Drainless<br>(n = 54) |       |
| Age (Y)                       | 22.01 ± 6.40           | 22.08 ± 6.28          | 0.003 | 22.22 ± 6.32                              | 22.08 ± 6.28          | 0.038 |
| Sex                           |                        |                       | 0.155 |                                           |                       | 0.054 |
| Male                          | 130 (89.27 %)          | 46 (85.19 %)          |       | 47 (87.04 %)                              | 46 (85.19 %)          |       |
| Female                        | 14 (9.73 %)            | 8 (14.81 %)           |       | 7 (12.96 %)                               | 8 (14.81 %)           |       |
| Body mass index               | 19.43 ± 2.39           | 19.37 ± 2.39          | 0.021 | 19.62 ± 2.07                              | 19.27 ± 2.08          | 0.083 |
| Smoking history               |                        |                       | 0.257 |                                           |                       | 0.002 |
| Yes                           | 108 (75.0 %)           | 46 (85.19 %)          |       | 46 (85.19 %)                              | 46 (85.19 %)          |       |
| No                            | 36 (25.0 %)            | 8 (14.81 %)           |       | 8 (14.81 %)                               | 8 (14.81 %)           |       |
| First episode of pneumothorax |                        |                       | 0.281 |                                           |                       | 0.000 |
| Yes                           | 84 (58.33 %)           | 34 (62.96 %)          |       | 34 (62.96 %)                              | 34 (62.96 %)          |       |
| No                            | 60 (41.67 %)           | 20 (37.04 %)          |       | 20 (37.04 %)                              | 20 (37.04 %)          |       |
| Lesion Location               |                        |                       | 0.010 |                                           |                       | 0.074 |
| Left                          | 78 (54.17 %)           | 28 (51.85 %)          |       | 27 (50.00 %)                              | 28 (51.85 %)          |       |
| Right                         | 66 (45.83 %)           | 26 (48.15 %)          |       | 27 (50.00 %)                              | 25 (46.30 %)          |       |
| Alveolar pleurodesis          |                        |                       | 0.341 |                                           |                       | 0.000 |
| Yes                           | 37 (25.69 %)           | 4 (7.41 %)            |       | 4 (7.41 %)                                | 4 (7.41 %)            |       |
| No                            | 117 (81.31 %)          | 50 (92.59 %)          |       | 50 (92.59 %)                              | 50 (92.59 %)          |       |
| Staple Coverage               |                        |                       | 0.009 |                                           |                       | 0.163 |
| Yes                           | 133 (92.36 %)          | 30 (55.56 %)          |       | 30 (55.56 %)                              | 30 (55.56 %)          |       |
| No                            | 11 (7.64 %)            | 4 (7.41 %)            |       | 4 (7.41 %)                                | 4 (7.41 %)            |       |
| Specimen number               |                        |                       | 0.117 |                                           |                       | 0.163 |
| ≤2                            | 126 (87.5 %)           | 52 (96.29 %)          |       | 52 (96.29 %)                              | 52 (96.29 %)          |       |
| >2                            | 18 (12.5 %)            | 2 (3.70 %)            |       | 2 (3.70 %)                                | 2 (3.70 %)            |       |
| Staple cartridge number       |                        |                       | 0.309 |                                           |                       | 0.095 |
| ≤2                            | 103 (71.53 %)          | 43 (79.63 %)          |       | 43 (79.63 %)                              | 43 (79.63 %)          |       |
| >2                            | 41 (28.47 %)           | 11 (20.37 %)          |       | 11 (20.37 %)                              | 11 (20.37 %)          |       |

n = number; y = years-old.  
SMD, standardized mean difference.  
Values are presented as n (%), or mean ± standard deviation.

Table1

**Table 3**  
Postoperative complications.

| Patient                | Age/Gender | Complication             | Management (Clavien-Dindo Grade)              | Postoperative hospital stay (days) |
|------------------------|------------|--------------------------|-----------------------------------------------|------------------------------------|
| <b>Drain group</b>     |            |                          |                                               |                                    |
| Case 1                 | 31/F       | Pneumonia                | Antibiotics (II)                              | 5                                  |
| Case 2                 | 21/M       | Subcutaneous emphysema   | O <sub>2</sub> supplement and observation (I) | 3                                  |
| Case 3                 | 24/M       | Residual pneumothorax    | O <sub>2</sub> supplement and observation (I) | 2                                  |
| Case 4                 | 21/M       | Subcutaneous emphysema   | O <sub>2</sub> supplement and observation (I) | 3                                  |
| Case 5                 | 23/M       | Residual pneumothorax    | O <sub>2</sub> supplement and observation (I) | 3                                  |
| Case 6                 | 21/M       | Subcutaneous emphysema   | O <sub>2</sub> supplement and observation (I) | 3                                  |
| Case 7                 | 19/M       | Pleural effusion         | Chemical pleurodesis                          | 8                                  |
| Case 8                 | 30/M       | Progressive pneumothorax | Additional pigtail drain required (IIIa)      | 7                                  |
| Case 9                 | 31/M       | Pleural effusion         | Chemical pleurodesis (II)                     | 7                                  |
| Case 10                | 31/M       | Residual pneumothorax    | O <sub>2</sub> supplement and observation (I) | 3                                  |
| Case 11                | 31/M       | Subcutaneous emphysema   | O <sub>2</sub> supplement and observation (I) | 3                                  |
| <b>Drainless group</b> |            |                          |                                               |                                    |
| Case 1                 | 31/F       | Pleural effusion         | O <sub>2</sub> supplement and observation (I) | 3                                  |
| Case 2                 | 19/M       | Subcutaneous emphysema   | Needle thoracocentesis (IIa)                  | 2                                  |
| Case 3                 | 22/M       | Residual pneumothorax    | O <sub>2</sub> supplement and observation (I) | 2                                  |

M = male; F = female; O<sub>2</sub> = oxygenation.

Table3

## **Talc Pleurodesis for Persistent Postoperative Air Leak in Patients with Emphysema: Case Series from Chi Mei Hospital**

**Li-Chun Chen<sup>1,2</sup> Ying-Chieh Su<sup>1,2,3</sup> Chao-Kun Chen<sup>1,2</sup>**

<sup>1</sup>*Department of Thoracic Surgery, Chi Mei Medical Center, Tainan, Taiwan* <sup>2</sup>*Department of Surgery, Chi Mei Medical Center, Tainan, Taiwan* <sup>3</sup>*Department of Biotechnology and Bioindustry Sciences, National Cheng Kung University*

### **Purpose**

Emphysema identified on chest CT has been shown to correlate with higher mortality, increased risk of lung cancer, and prolonged postoperative air leak (PAL). Even mild emphysema is associated with postoperative complications, and its predictive value for PAL is stronger than FEV1/FEV. Traditional management of PAL relies mainly on prolonged chest tube drainage or chemical pleurodesis. Although bronchial valve placement has supporting evidence, it is often not feasible in emphysematous lungs without a localized leak site. At our institution, bedside pleurodesis with minocycline was initially used, but its effect was limited due to local deposition. This study aimed to evaluate the outcomes of talc pleurodesis in patients with emphysema and PAL.

### **Materials and Methods**

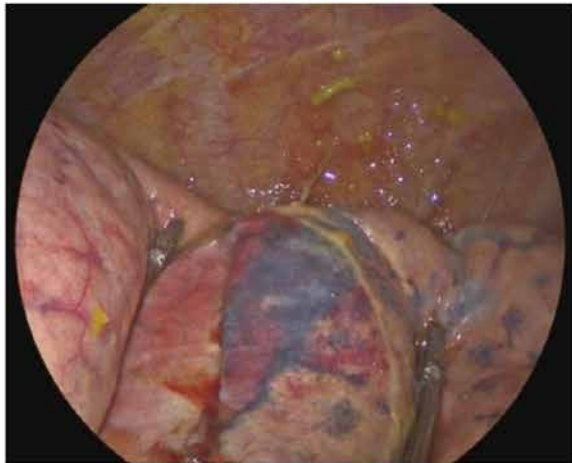
We retrospectively reviewed patients with emphysema and PAL who underwent talc pleurodesis at Chi Mei Hospital between 2023 and 2025. Both talc slurry via chest tube and thoracoscopic talc poudrage were performed. Clinical data including baseline condition, type of pleurodesis, chest tube duration, radiographic follow-up, and recurrence were analyzed.

### **Results**

In the talc slurry group, chest tube drainage lasted 2–54 days (average 18.8, median 9.5), with one case of persistent leak. In the talc poudrage group, drainage lasted 2–27 days (average 10.8, median 6.5), and no recurrence was observed to date. Thoracoscopic poudrage provided uniform coverage of the pleural cavity and led to effective pleural adhesion. Postoperative chest radiographs and CT scans demonstrated sustained lung expansion during follow-up.

### **Conclusions**

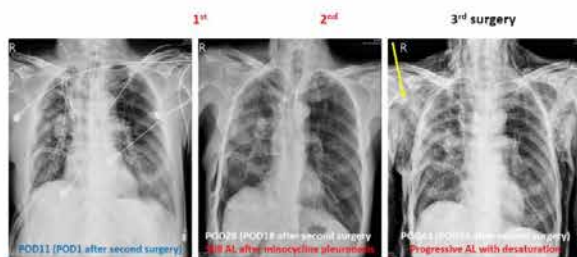
Talc pleurodesis is a feasible and effective option for managing PAL in emphysematous patients. In our series, poudrage provided uniform pleural adhesion with shorter drainage duration and no recurrence observed during follow up. These findings indicate that talc pleurodesis may be a reasonable alternative to conventional methods such as minocycline pleurodesis, but further studies with larger case numbers are required to confirm its clinical efficacy.



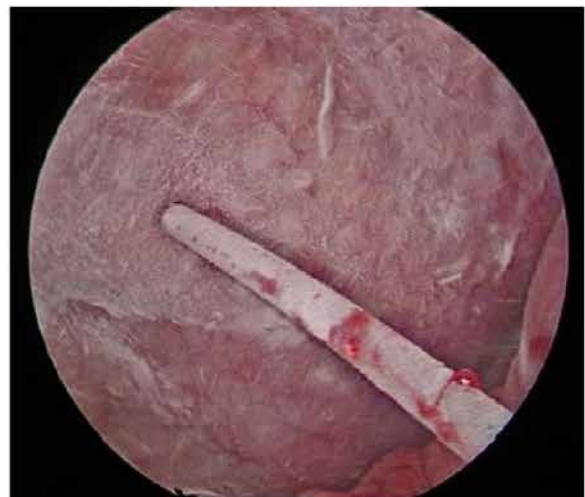
Localized adhesion; limited effect of bedside minocycline pleurodesis



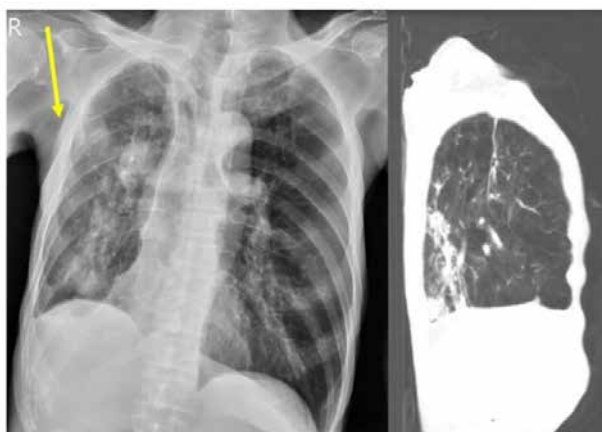
75M with RUL adenocarcinoma; CT: severe panlobular emphysema



Empyema (s/p decortication on POD10) and progressive AL with desaturation after lobectomy



Pleurolysis, lung repair, talc pleurodesis (in 3rd operation)



Follow-up CXR two years later: good expansion, no recurrence



## Perioperative Outcomes of Completion Lobectomy After Sublobar Resection: A Single-Institution Experience

**Chih-Hao Yu<sup>1</sup> Po-Kuei Hsu<sup>1,2</sup>**

<sup>1</sup>*Division of Thoracic Surgery, Department of Surgery, Taipei Veterans General Hospital* <sup>2</sup>*School of Medicine, College of Medicine, National Yang Ming Chiao Tung University*

### Purpose

Completion lobectomy (CL) is technically challenging and infrequently performed. With its growing clinical relevance, this study aimed to evaluate the perioperative outcomes of CL at our institution and to identify factors associated with surgical difficulty and postoperative recovery.

### Materials and Methods

We retrospectively reviewed 36 patients who underwent completion lobectomy following prior sublobar resection at Taipei Veterans General Hospital between September 2011 and August 2025. Perioperative parameters, including operative time, blood loss, and postoperative recovery metrics, were collected. Patients were stratified by surgical side (left vs. right), lobe location (upper vs. non-upper), prior resection type (wedge vs. segmentectomy), pathology (primary lung cancer vs. metastasis), and indication (pathological upstaging vs. tumor recurrence).

### Results

A total of 36 patients were included. The median operative time was 215 minutes (IQR: 157–276), and the median blood loss was 50 mL (IQR: 30–200). The median duration of chest drainage was 6 days (IQR: 4–8.8), and the median hospital stay was 7 days (IQR: 5–9.8). Postoperative air leak occurred in 27.8% (10/36) of patients, and ICU admission was required in 16.7% (6/36). Surgical outcomes did not differ by surgical side, lobe location, prior resection type, or pathology. However, CL performed for tumor recurrence was associated with a significantly longer hospital stay compared with CL for pathological upstaging (9.4 vs. 6.5 days,  $p = 0.034$ ).

### Conclusions

Completion lobectomy after prior sublobar resection can be performed with acceptable perioperative outcomes. Nonetheless, CL for tumor recurrence is associated with a longer length of hospital stay compared to CL for pathological upstaging.



## Room 105 (Chinese) | Saturday, July 11, 2026

### TSTS Free Paper Session III - Thoracic Oncology

Time: 14:00-15:00 (GMT+8)

|       |             |                                                                                                                                                                        |
|-------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |             | Chair(s): Ke-Cheng Chen (Taiwan)<br>Wei-Hsun Chen (Taiwan)<br>En-Kuei Tang (Taiwan)                                                                                    |
| FP5-1 | 14:00-14:10 | <b>Impact of Spread Through Air Spaces on Recurrence and Surgical Patterns in Stage I Non-Small Cell Lung Cancer: A Real-World Cohort Study</b><br>Yu-Wei Liu (Taiwan) |
| FP5-2 | 14:10-14:20 | <b>Real-World Outcomes of Neoadjuvant Treatment in Stage I - III Non-Small Cell Lung Cancer: A Single Medical Center Experience</b><br>Yi-Wen Chen (Taiwan)            |
| FP5-3 | 14:20-14:30 | <b>Impact of Neoadjuvant Treatment Strategies on Surgical Complexity and Perioperative Outcomes in Resectable Non-Small Cell Lung Cancer</b><br>Hsiang Teng (Taiwan)   |
| FP5-4 | 14:30-14:40 | <b>Neoadjuvant Immunotherapy Strategies for Resectable Non-Small Cell Lung cancer - Real World Data</b><br>Shih-Han Huang (Taiwan)                                     |
| FP5-5 | 14:40-14:50 | <b>Recurrence Patterns and Safety After Extended-Duration Adjuvant Osimertinib in Resected EGFR-Mutant NSCLC</b><br>Yu-Fu Lin (Taiwan)                                 |
| FP5-6 | 14:50-15:00 | <b>Association Between EGFR-TKI Generations and Oral Microbiota Diversity in Lung Cancer Patients A Comparative Study</b><br>Yueh Hsun Tsai (Taiwan)                   |

## **Impact of Spread Through Air Spaces on Recurrence and Surgical Patterns in Stage I Non-Small Cell Lung Cancer: A Real-World Cohort Study**

**Yu-Wei Liu<sup>1</sup> Cheng-Hao Chuang<sup>2</sup> Wei-An Lai<sup>3</sup> Jui-Ying Lee<sup>1</sup> Shah-Hwa Chou<sup>1</sup> Chih Jen Yang<sup>2</sup>**

<sup>1</sup>*Division of Thoracic Surgery, Department of Surgery, Kaohsiung Medical University Hospital*

<sup>2</sup>*Division of Pulmonary and Critical Care Medicine, Department of Internal Medicine, Kaohsiung Medical University Hospital* <sup>3</sup>*Department of Pathology, Kaohsiung Medical University Hospital*

### **Purpose**

Non-small cell lung cancer (NSCLC) is the most common form of lung cancer, which remains a leading cause of cancer mortality worldwide. Early detection, particularly at Stage I, is critical for improving survival outcomes. Low-dose computed tomography (LDCT) has increased the detection of small asymptomatic tumors, resulting in an earlier diagnosis and facilitating less invasive surgical approaches such as segmentectomy and wedge resection, which preserve lung function while offering survival outcomes comparable to lobectomy. However, the risk factors for recurrence in Stage I NSCLC remain poorly understood.

### **Materials and Methods**

This retrospective study analyzed 1077 Stage I NSCLC patients treated at Kaohsiung Medical University Hospital from 2010 to 2022. Data including AJCC 7<sup>th</sup> and 8<sup>th</sup> editions staging, surgical interventions, and pathological features were analyzed.

### **Results**

The proportion of Stage I cases increased significantly from 9.3% in 2010 to 33.8% in 2017, with Stage IA cases increasing from 12.1% in 2018 to 38.2% in 2022. Concurrently, the lobectomy rate decreased from 75% in 2010 to 43.6% in 2022, with more sublobar resections performed. Kaplan–Meier analysis found no significant differences in recurrence-free survival between lobectomy and sublobar resection with regional lymph node dissection. Cox regression identified spread through air spaces (STAS) as an independent risk factor for recurrence (hazard ratio 2.87,  $p = 0.006$ ), along with male sex, larger tumor size, and visceral pleural invasion.

### **Conclusions**

These findings highlight the role of LDCT in early detection and the importance of tailored treatment strategies, particularly addressing STAS, to optimize recurrence free survival and improve outcomes of patients with Stage I NSCLC.

## **Real-World Outcomes of Neoadjuvant Treatment in Stage I-III Non-Small Cell Lung Cancer: a Single Medical Center Experience**

**Yi-Wen Chen<sup>1</sup> Cheng-Yen Chuang<sup>1</sup> Chih-Hung Lin<sup>1</sup> Shyh-Sheng Yang<sup>1</sup> Sen-Ei Shai<sup>1</sup> Ming-Ching Lee<sup>1</sup> How-Yun Chen<sup>1</sup>**

*<sup>1</sup>Division of Thoracic Surgery, Department of Surgery, Taichung Veterans General Hospital*

### **Purpose**

This study aimed to evaluate the therapeutic efficacy of neoadjuvant treatments and the complexity of subsequent surgical procedures in patients with stage I–III non-small cell lung cancer (NSCLC).

### **Materials and Methods**

From November 2019 to August 2024, we retrospectively included patients with stage I-III NSCLC who received neoadjuvant treatment at Taichung Veterans General Hospital. The parameters analyzed included major pathological response (MPR), complete pathological response (pCR), duration of surgery, intraoperative blood loss, and the rate of conversion to open surgery.

### **Results**

A total of 54 patients were enrolled and divided into two groups: the immunotherapy (IO) group (n = 23) and the other therapy (OT) group (n = 31). In the IO group, the median age was 59 years, and 74% were male. Most patients (78.3%) were diagnosed with stage III disease, and adenocarcinoma was the most common histology (60.9%). In the OT group, the median age was 61 years, and 50% were male. Adenocarcinoma accounted for 77.4% of cases, and 87.1% were diagnosed at stage III. Most patients in both groups underwent lobectomy as definitive surgery (88.9%). The MPR rate was significantly higher in the IO group compared to the OT group. Similarly, the pCR rate was also higher in the IO group versus in the OT group. There were no significant differences between the groups in terms of surgical blood loss or operative time.

### **Conclusions**

Neoadjuvant therapy in stage I–III NSCLC influences both pathological response and surgical complexity. Immunotherapy-based neoadjuvant treatment demonstrated superior MPR and pCR rates without increasing surgical risk.

## **Impact of Neoadjuvant Treatment Strategies on Surgical Complexity and Perioperative Outcomes in Resectable Non–Small Cell Lung Cancer**

**Hsiang Teng, Hsu-Kai Huang, Kuan-Hsun, Lin, Tsai-Wang Huang**

*Division of Thoracic Surgery, Department of Surgery, Tri-Service General Hospital*

### **Purpose**

Neoadjuvant therapy has become an integral component in the management of resectable non–small cell lung cancer (NSCLC). With the increasing use of immunotherapy and tyrosine kinase inhibitors (TKIs), concerns have been raised that treatment-related fibrosis and hilar inflammation may increase surgical complexity. This study specifically evaluated the impact of different neoadjuvant treatment strategies, with an emphasis on immunotherapy-based regimens, on operative difficulty and perioperative outcomes.

### **Materials and Methods**

We retrospectively reviewed patients with stage IIB–IIIB NSCLC who underwent neoadjuvant therapy followed by curative-intent pulmonary resection at a single tertiary referral center between May 2004 and March 2025. Patients were stratified into three groups: chemotherapy alone ( $n = 49$ ), immunotherapy-based regimens (chemo-immunotherapy or immunotherapy alone;  $n = 33$ ), and targeted therapy-based regimens (TKI alone or combined with chemotherapy;  $n = 20$ ). Surgical complexity and perioperative outcomes—including operative time, intraoperative blood loss, conversion to thoracotomy, extent of resection, length of hospital stay, and R0 resection rate—were analyzed. Pathological responses were assessed using major pathologic response (MPR) and pathologic complete response (pCR).

### **Results**

A total of 102 patients were included. Surgical procedures consisted of lobectomy (71.6%), segmentectomy (19.6%), bilobectomy (4.9%), and pneumonectomy (3.9%). Overall conversion to thoracotomy was 7.8%, and complete resection (R0) was achieved in 93.1% of cases. Neoadjuvant immunotherapy was associated with higher rates of pCR (21.4%) compared with chemotherapy (12.2%) and targeted therapy (0%) ( $p = 0.039$ ). MPR occurred more frequently following immunotherapy-based treatment (32.1%) than chemotherapy (16.3%) or targeted therapy (10.0%), although this did not reach statistical significance ( $p = 0.249$ ). Importantly, operative time, blood loss, conversion rate, and postoperative morbidity did not differ significantly among treatment groups, and no increase in perioperative mortality or severe complications was observed in patients receiving immunotherapy.

### **Conclusions**

Neoadjuvant immunotherapy-based regimens resulted in superior pathological responses without increasing surgical complexity or compromising perioperative safety in patients with resectable NSCLC. Despite theoretical concerns regarding immunotherapy-associated fibrosis and adhesions, immunotherapy-based neoadjuvant regimens did not increase operative time, conversion to thoracotomy, or perioperative morbidity, supporting their surgical feasibility in routine clinical

practice. These findings provide reassuring evidence for thoracic surgeons regarding the integration of immunotherapy into neoadjuvant treatment strategies for resectable NSCLC.

## **Neoadjuvant Immunotherapy Strategies for Resectable Non-Small Cell Lung cancer - Real World Data**

**Pin-Li Chou<sup>1</sup> Shih-Han Huang<sup>1</sup>**

*<sup>1</sup>Chang Gung Memorial Hospital, Linkou branch, Thoracic surgery*

### **Purpose**

To evaluate the feasibility, safety, and early efficacy of neoadjuvant immunotherapy in patients with resectable non-small cell lung cancer (NSCLC).

### **Materials and Methods**

We retrospectively analyzed 15 patients with resectable NSCLC who received neoadjuvant immunotherapy at Linkou Chang Gung Memorial Hospital between 2022 to 2024. All patients subsequently underwent complete surgical resection. Clinical characteristics, treatment regimens, pathological response, surgical outcomes, and survival data were collected.

### **Results**

All 15 patients successfully underwent surgical resection. 66.7% with IO plus chemotherapy and 33.3% with IO alone. Pathological complete response (pCR) was observed in 20%. After a median follow-up of 15 months, the 1-year event-free survival (EFS) rate was 73%, and the overall survival (OS) rate was 87%. Immune related adverse events occurred in 27%, mostly grade 1–2 event.

### **Conclusions**

In this real-world series, neoadjuvant immunotherapy for resectable NSCLC demonstrated good feasibility, acceptable safety, and encouraging pathological responses and survival outcomes, consistent with clinical trial data. Larger cohorts and longer follow-up are warranted.

## Recurrence Patterns and Safety After Extended-Duration Adjuvant Osimertinib in Resected EGFR-Mutant NSCLC

**Yu-Fu Lin<sup>1</sup> Pei-Hsing Chen<sup>1</sup> Mong-Wei Lin<sup>1</sup> Hsao-Hsun Hsu<sup>1,2</sup> Jin-Shing Chen<sup>1</sup>**

<sup>1</sup>*Division of Thoracic Surgery, Department of Surgery, National Taiwan University Hospital, Taipei, Taiwan* <sup>2</sup>*Department of Surgical Oncology, National Taiwan University Cancer Center*

### Purpose

ADAURA established adjuvant osimertinib for up to 3 years, with or without chemotherapy, in resected EGFR-mutant NSCLC. However, the optimal duration beyond 3 years remains uncertain—whether to stop at 3 years or continue longer is a clinically relevant question.

### Materials and Methods

We retrospectively reviewed patients with stage IB–III EGFR-mutant NSCLC who received adjuvant osimertinib after curative-intent resection (January 2019–July 2024). Patients were grouped by treatment duration: standard ( $\leq 3$  years) versus extended ( $> 3$  years). Use of postoperative radiotherapy and chemotherapy was recorded. The primary endpoint was recurrence, categorized as locoregional, distant, brain, and any recurrence. Safety endpoints included dose reductions and interval adjustments, along with standard adverse-event profiling. Survival was analyzed using Kaplan–Meier estimates with log-rank testing.

### Results

A total of 61 patients were included. Recurrence events appeared to increase after treatment interruption, with an observable peak around cessation (“suspension effect”). The extended-duration group showed a numerically longer recurrence free survival compared with the standard-duration group, although the difference was not statistically significant at the current follow-up. Safety was acceptable overall; dose reductions and interval modifications were infrequent.

### Conclusions

Interim data suggest potential clinical benefit to continuing adjuvant osimertinib beyond 3 years, with manageable toxicity. The incremental effect of adding chemotherapy in this setting appeared limited in our cohort. Prospective validation—such as results from trials evaluating 5-year.



## Association Between EGFR-TKI Generations and Oral Microbiota Diversity in Lung Cancer Patients A Comparative Study

**Kuan-Hsun Lin<sup>1,2</sup> Yueh-Hsun Tsai<sup>1,2</sup> Yu-Min Lin<sup>3</sup> Yu-Cheng Lin<sup>3</sup> Chun-Jen Su<sup>4</sup> Hsu Kai Huang<sup>1,2</sup> Lin-Cheng Jung<sup>5</sup> Ying-Shian Chen<sup>6</sup> Tsai-Wang Huang<sup>1,2</sup>**

<sup>1</sup>*Tri-Service General Hospital, Department of Surgery, Division of Thoracic Surgery* <sup>2</sup>*National Defense Medical University* <sup>3</sup>*College of Dentistry, National Yang Ming Chiao Tung University*  
<sup>4</sup>*Institute of Oral Biology, School of Dentistry, National Yang Ming Chiao Tung University*  
<sup>5</sup>*Kaohsiung Armed Forces General Hospital* <sup>6</sup>*Taichung Armed Forces General Hospital*

### Purpose

ADAURA established adjuvant osimertinib for up to 3 years, with or without chemotherapy, in Epidermal growth factor receptor–tyrosine kinase inhibitors (EGFR-TKIs) are standard treatments for patients with EGFR-mutant non-small-cell lung cancer (NSCLC). Despite their therapeutic benefits, these agents often cause adverse effects, including skin rash, diarrhea, and, in some cases, oral symptoms such as mucosal inflammation, stomatitis, and discomfort that compromise quality of life. The underlying mechanisms contributing to these oral manifestations remain unclear, and it is unknown whether alterations in the oral microbiota may be involved.

### Materials and Methods

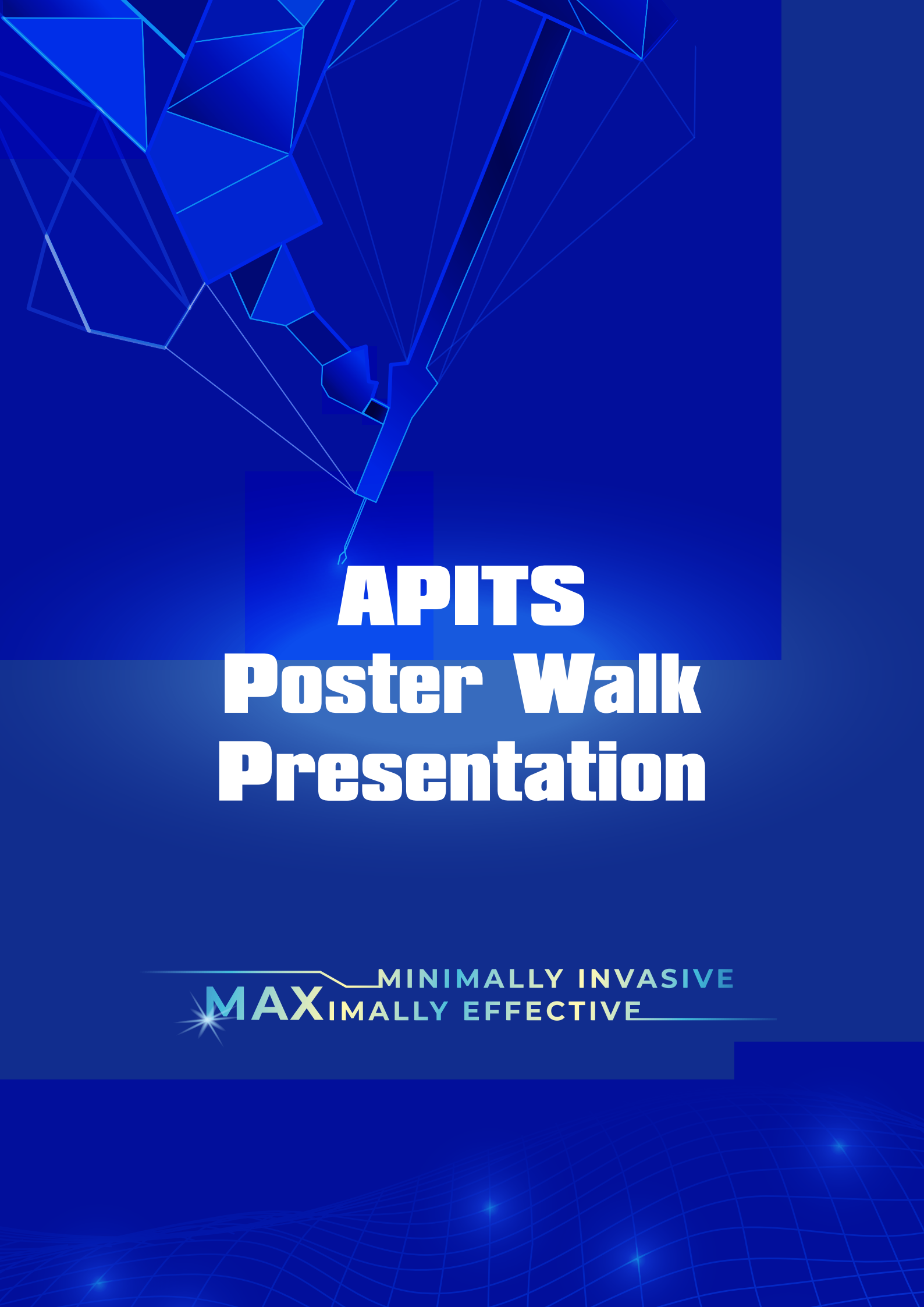
We collected oral samples from lung cancer patients receiving first-, second-, and third-generation EGFR-TKIs. Microbial profiling was performed using 16S rRNA sequencing. Alpha diversity indices and beta diversity analyses were applied to compare microbial communities across treatment groups and disease stages. Differential abundance analysis was conducted to identify taxa associated with specific therapies.

### Results

Alpha diversity did not differ significantly among treatment groups, but beta diversity revealed subtle yet significant shifts in microbial structure. Several genera were differentially enriched in patients receiving different TKI generations. Stage related variations were also observed, suggesting that both drug exposure and disease progression may influence the oral microbiota.

### Conclusions

This study summarizes the overall oral microbiota profiles expressed under different generations of EGFR-TKIs in lung cancer patients. These findings indicate that targeted therapy is associated with distinct microbial changes, and understanding these patterns may provide opportunities to improve oral health management, potentially through microbiota-based interventions.



# **APITS**

# **Poster Walk**

# **Presentation**

**MAX**IMALLY EFFECTIVE MINIMALLY INVASIVE

## Room 101ABD (English) | Saturday, July 11, 2026

### Poster Walk -APITS

Time: 13:00-14:00, July 11th (GMT+8)

|                                                                                              |                                                                                                                                                                                                           |
|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chair(s): Hiroki Ebana (Japan)<br>Mong-Wei Lin (Taiwan)<br>Punnarerk Thongcharoen (Thailand) |                                                                                                                                                                                                           |
| APITS -1                                                                                     | <b>Short-Term Outcomes of Dual-Port Robot-Assisted Thoracic Surgery during the Initial Phase: A Comparison with Multi-Port Approach</b><br>Akihiro Taira (Japan)                                          |
| APITS -2                                                                                     | <b>Preoperative Indocyanine Green-Based Dual Marker Localization Using Microcoil versus Lipiodol for Pulmonary Nodule: A Single-Center Retrospective Study</b><br>Hyeong Hun Song (Republic of Korea)     |
| APITS -3                                                                                     | <b>Precision Lung Wedge Resection for Small Lung Tumors Using RFID or Hybrid CT</b><br>Teppei Hashimoto (Japan)                                                                                           |
| APITS -4                                                                                     | <b>Early Clinical Outcomes of Neo Dual-Port Robotic-Assisted Thoracic Surgery (neoDRATS) for Pulmonary Resection: Initial Experience at a Single Institution</b><br>Jun Suzuki (Japan)                    |
| APITS -5                                                                                     | <b>Clinical Outcomes of Uniportal Thoracoscopic Bullectomy Using a Reinforced Stapler and Oxidized Regenerated Cellulose Sheet Coverage for Primary Spontaneous Pneumothorax</b><br>Mizuki Morota (Japan) |
| APITS -6                                                                                     | <b>Comparison of Short-Term Complications Between Open Esophagectomy and Robot-Assisted Minimally Invasive Esophagectomy (RAMIE): A Large Cohort Study</b><br>Yeong Jeong Jeon (Republic of Korea)        |
| APITS -7                                                                                     | <b>Surgical Management of Tracheal Adenoid Cystic Carcinoma with Thyroid Invasion: A Case Report and Literature Review</b><br>Nhat Ho (Vietnam)                                                           |
| APITS -8                                                                                     | <b>Lessons from Robotic Surgery: Superior Mediastinal Schwannomas with Esophageal Involvement</b><br>Stephanie Koh (Singapore)                                                                            |
| APITS -9                                                                                     | <b>A Study Comparison of Open Versus Minimally Invasive Esophagectomy for Esophageal Cancer at National Cancer Center of Mongolia</b><br>Dashchirev Munkh-Orshikh (Mongolia)                              |

## Short-term Outcomes of Dual-port Robot-assisted Thoracic Surgery during the initial Phase: A Comparison with Multi-port Approach

**Akihiro Taira\*<sup>1</sup>; Seiichi Odate<sup>1</sup>; Kiichiro Beppu<sup>1</sup>**

<sup>1</sup>*thoracic surgery, Miyazaki prefectural Miyazaki Hospital, Miyazaki, Japan*

### Objective

Robot-assisted thoracic surgery (RATS) has been rapidly adopted in Japan. Our institution has performed multi-port RATS (MRATS; 3 or 4 ports + 1 utility incision) since 2020. In pursuit of further minimizing invasiveness, we introduced dual-port RATS (DRATS; 1 utility incision + 1 port) in February 2025. This study aimed to evaluate the safety, feasibility, and surgical outcomes of DRATS in the initial phase compared to the conventional MRATS approach.

### Methods

We retrospectively analyzed 47 patients who underwent RATS lobectomy or segmentectomy between January and December 2025. Patient characteristics and perioperative outcomes were compared between the MRATS and DRATS groups.

### Results

The study included 31 MRATS and 16 DRATS cases. There were no significant differences in patient characteristics between the two groups (MRATS vs. DRATS: median age, 74.0 [67.5-78.5] vs. 72.5 [68.8-78.0] years; sex (male/female), 15/16 vs. 5/11; procedure (segmentectomy/lobectomy), 14/17 vs. 5/11; clinical stage (I / II / other), 24/4/3 vs. 12/1/3). Regarding perioperative outcomes, no significant differences were observed in operative time (245±50.4 vs. 226.9±61.3 min), console time (144.0 [113.0-176.0] vs. 135.0 [94.5-160.5] min), postoperative hospital stay (6.0 [6-9] vs. 6 [5-7] days), or complication rates (8 vs. 1 case). However, significant differences were observed in blood loss (25.0 [5.0-92.5] vs. 2.5 [0.0-6.0] ml,  $p=0.0006$ ) and the duration of regular analgesic use (42.0 [23.0-84.5] vs. 15.5 [11.8-25.5] days,  $p=0.0045$ ). No conversion to thoracotomy was required in either group.

### Conclusions

Our experience in the initial phase indicates that DRATS is a safe and feasible procedure that may offer advantages over conventional MRATS in terms of reduced blood loss and less postoperative pain, without compromising operative efficiency or hospital length of stay.

### Keyword(s)

Reduced Port RATS, Dual Port RATS

## Preoperative Indocyanine Green-Based Dual Marker Localization Using Microcoil versus Lipiodol for Pulmonary Nodule: A Single-Center Retrospective Study

**Jun Hee Lee<sup>\*1</sup>; Hyeong Hun Song<sup>2</sup>; Byung Mo Gu<sup>1</sup>; Hyun Koo Kim<sup>1</sup>**

<sup>1</sup>*Thoracic and Cardiovascular Surgery, Korea University Guro Hospital, Seoul, Republic of Korea*

<sup>2</sup>*Department of Medicine, Korea University College of Medicine, Seoul, Republic of Korea*

### Objective

Preoperative indocyanine green (ICG)-based dual-marker localization, which combines ICG with either lipiodol or a microcoil, offers potential advantages for detecting deeply located small ground-glass nodules. However, comparative clinical evidence regarding different dual-marker strategies remains limited. The present study aimed to evaluate the perioperative outcomes of patients with NSCLC who underwent wedge resection following dual-marker localization using either ICG with lipiodol or ICG with a microcoil.

### Methods

This retrospective study included patients with primary NSCLC who underwent wedge resection following preoperative computed tomography-guided dual-marker localization between May 2016 and December 2025 at Korea University Guro Hospital. Patients were categorized into the ICG–lipiodol or ICG–microcoil groups according to the type of dual marker used. A near-infrared imaging system and a portable C-arm fluoroscopic system were utilized to enable accurate resection.

### Results

A total of 163 patients were included (ICG–lipiodol, n = 75; ICG–microcoil, n = 88). Baseline characteristics, including age, sex, surgical indication, and tumor location, were well balanced between the two groups (all  $p > 0.05$ ). Procedural success rates were high in both groups (93.3% vs. 92.1%,  $p = 0.754$ ), with no significant differences in complication rates, including pneumothorax (4.0% vs. 3.4%,  $p = 1.000$ ) and alveolar hemorrhage (2.7% vs. 3.4%,  $p = 1.000$ ). The median procedural time was significantly shorter in the ICG–microcoil group (9 [7–12] vs. 11 [8–14] minutes,  $p = 0.043$ ). R0 resection was achieved in 97.5% and 100% of patients, respectively ( $p = 0.233$ ), and the median resection margin was similar between groups (17 [12–22] mm vs. 15 [11–22] mm,  $p = 0.583$ ). No significant differences were observed in chest tube duration (2 [1–3] days in both groups,  $p = 0.373$ ) or postoperative hospital stay (3 [3–5] vs. 3 [2–5] days,  $p = 0.575$ ). No 30-day mortality occurred in either group.

### Conclusions

In this study, both dual-marker techniques demonstrated high procedural success rates and low complication rates. These findings indicate that both techniques are safe, feasible, and effective for wedge resection of small subsolid nodules that are difficult to identify.

### Keyword(s)

Indocyanine Green, Preoperative Localization, Dual Marker, Lipiodol, Microcoil, Wedge Resection

Table 1. Patient characteristics and perioperative outcomes

[illegible]

## Precision lung wedge resection for small lung tumors using RFID or Hybrid CT

**Teppe Hashimoto<sup>\*1</sup>; Masaru Takenaka<sup>1</sup>; Fumihiro Tanaka<sup>1</sup>**

<sup>1</sup>*Department of Thoracic surgery, HOSPITAL OF THE UNIVERSITY OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH, JAPAN, Fukuoka, Japan*

### Objective

With advances in computed tomography (CT) technology and an aging population, wedge resection for small lung tumors has become increasingly common. To improve intraoperative localization, our institution has introduced a **radiofrequency identification (RFID) lung-marking system** and **hybrid computed tomography (Hybrid CT; HBCT)**, which are selected or combined according to tumor characteristics.

### Methods

Among 325 patients who underwent wedge resection for small lung tumors between February 2021 and December 2025, cases in which RFID and/or HBCT was used were retrospectively reviewed to evaluate the **safety and clinical utility** of each localization technique.

### Results

The RFID group included 101 patients, and the HBCT group included 9 patients, with 1 patient receiving both modalities. The median tumor diameter and distance from the pleural surface were **10 mm (range, 3–38 mm)** and **9.0 mm (range, 0–28 mm)** in the RFID group, and **10 mm (range, 6–21 mm)** and **4 mm (range, 0–13 mm)** in the HBCT group, respectively. HBCT was preferentially used for **ground-glass opacity (GGO)–dominant tumors** that were expected to be difficult to palpate despite being located near the pleural surface.

Pure GGO lesions on preoperative CT were observed in **54 patients (53.4%)** in the RFID group and **2 patients (22%)** in the HBCT group. The median resection margin was **15 mm (interquartile range [IQR], 10–20 mm)** in the RFID group and **15 mm (IQR, 8.5–20 mm)** in the HBCT group. In the RFID group, adequate margins exceeding the tumor diameter were achieved even for tumors located **up to 28 mm from the pleural surface** by utilizing energy devices. Complete resection by wedge resection was achieved in all HBCT cases. Surgeons evaluated the RFID and HBCT systems as useful in **95%** and **100%** of cases, respectively.

### Conclusions

**RFID-guided marking and Hybrid CT** enhance reliable intraoperative localization and adequate margin acquisition during **precision wedge resection** for small, non-palpable lung tumors, enabling **safe and complete resection** in clinical practice.

### Keyword(s)

Precision Lung Wedge Resection, Small Lung Tumors, Sure-Find, Hybrid CT



## Early clinical outcomes of neo dual-port robotic-assisted thoracic surgery (neoDRATS) for pulmonary resection: initial experience at a single institution

**Jun Suzuki\*<sup>1</sup>; Hikaru Watanabe<sup>1</sup>; Satoshi Takamori<sup>1</sup>; Takayuki Sasage<sup>1</sup>; Kohei Abe<sup>1</sup>; Kazumasa Hoshijima<sup>1</sup>; Hiroki Ebana<sup>2</sup>; Tetsuro Uchida<sup>1</sup>; Satoshi Shiono<sup>1</sup>**

<sup>1</sup>*Department of Surgery 2, Yamagata University Faculty of Medicine, Yamagata, Japan*

<sup>2</sup>*Department of Thoracic Surgery, Tokyo Metropolitan Bokutoh Hospital, Tokyo, Japan*

### Objective

neo dual-port robotic-assisted thoracic surgery (neoDRATS) is a dual-port RATS technique that uses all robotic arms without arm cancellation, thereby preserving key technical advantages of robotic surgery while reducing the number of access ports. Although its technical concept has been reported, early clinical outcome data after implementation in routine practice remain limited. We evaluated the feasibility and short-term perioperative outcomes of neo DRATS in our initial clinical experience.

### Methods

We retrospectively reviewed consecutive patients who underwent planned neoDRATS anatomical lung resection at a single institution between September 2024 and February 2026. Patient characteristics, procedure type, operative variables, and short-term postoperative outcomes were analyzed. Feasibility endpoints included completion of the planned neoDRATS approach and conversion to thoracotomy. Safety endpoints included 30-day mortality and postoperative complications within 30 days. Continuous variables are presented as median (interquartile range [IQR]), and categorical variables as number (%).

### Results

A total of 22 patients underwent planned neoDRATS anatomical lung resection. Median age was 73 years (IQR, 63.8-75.8), and 11 patients (50.0%) were women. Lesions were located on the left in 12 patients and on the right in 10. Procedures included 11 lobectomies and 11 segmentectomies. Median operative time was 150 minutes (IQR, 126-189), median console time was 117.5 minutes (IQR, 105.5-159.3), and median intraoperative blood loss was 2 g (IQR, 2-2). Median stapler use was 8 (IQR, 5.3-10). Median length of hospital stay was 5 days (IQR, 4-6), and median postoperative stay was 4 days (IQR, 3-5). No case required conversion to thoracotomy, and all planned neoDRATS procedures were completed. There were no 30-day mortality and no postoperative complication within 30 days. Favorable outcomes were observed across both lobectomy and segmentectomy cases.

### Conclusions

In this initial single-center experience, neoDRATS was feasible and safe for anatomical lung resection, with complete procedural success, no thoracotomy conversion, no 30-day mortality, and no 30-day postoperative complications. The technique was applicable to both lobectomy and segmentectomy while maintaining full robotic arm utilization. Further evaluation in larger comparative cohorts is warranted.

**Keyword(s)**

Robotic-Assisted Thoracic Surgery, Reduced-Port Surgery, Lung Resection, Lobectomy, Segmentectomy, Perioperative Outcomes

## **Clinical outcomes of uniportal thoracoscopic bullectomy using a reinforced stapler and oxidized regenerated cellulose sheet coverage for primary spontaneous pneumothorax**

**Mizuki Morota\*<sup>1</sup>; Takahiro Negi<sup>1</sup>; Daisuke Tochii<sup>1</sup>; Sachiko Tochii<sup>1</sup>; Takashi Suda<sup>1</sup>**

<sup>1</sup>*Thoracic surgery, Fujita Health University Okazaki Medical Center, Aichi, Japan*

### **Objective**

Thoracoscopic surgery has become the standard surgical approach for spontaneous pneumothorax; however, postoperative recurrence remains a clinically relevant issue.

At our institution, uniportal video-assisted thoracoscopic surgery (U-VATS) bullectomy using a stapler with the reinforcement-equipped cartridge, and covering by an oxidized regenerated cellulose sheet has been routinely performed with favorable outcomes. We herein report our surgical results.

### **Methods**

A retrospective analysis was conducted of 106 patients aged  $\leq 50$  years who underwent pulmonary resection for spontaneous pneumothorax between April 2020 and 2025.

### **Results**

All patients underwent U-VATS bullectomy using a stapler with the reinforcement-equipped cartridge and followed by coverage with an oxidized regenerated cellulose sheet. The median operative time was 51 minutes, median blood loss was 5 mL, median duration of chest drainage was 1 day, and median postoperative hospital stay was 2 days. The median numerical rating scale (NRS) score for pain at the first outpatient visit after discharge was 0.

The overall ipsilateral recurrence rate was 3.8% (4 cases), while the contralateral recurrence rate was 12.3% (13 cases). All ipsilateral recurrences occurred in patients aged  $\leq 18$  years.

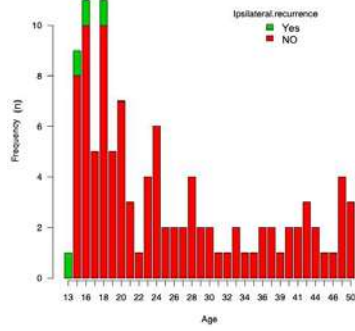
Univariate analysis demonstrated that age was significantly associated with both ipsilateral and contralateral recurrence ( $p = 0.008$  and  $p = 0.012$ , respectively). Multivariate analysis identified younger age as an independent risk factor for ipsilateral recurrence (95% confidence interval: 0.16–0.98,  $p = 0.045$ ).

### **Conclusions**

U-VATS with reinforced stapled bullectomy and oxidized cellulose sheet coverage was associated with minimal postoperative pain and favorable surgical outcomes. Consistent with previous studies, a higher tendency for postoperative recurrence was observed in younger patients.

### **Keyword(s)**

Uniportal VATS, Pneumothorax, Bullectomy, Oxidized Regenerated Cellulose Sheet, Reinforced Stapler



## Comparison of Short-Term Complications Between Open Esophagectomy and Robot-Assisted Minimally Invasive Esophagectomy (RAMIE): A Large Cohort Study

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<sup>1</sup>*Thoracic Surgery, Samsung Medical Center, Seoul, Republic of Korea*

### Objective

Robot-assisted minimally invasive esophagectomy (RAMIE) has been increasingly adopted as an alternative to open esophagectomy (OE). However, the complication profile of RAMIE compared with OE remains incompletely characterized, particularly regarding specific morbidity categories. This study aimed to compare 30-day postoperative complications between the two approaches.

### Methods

This retrospective cohort study included 1,920 patients with esophageal cancer who underwent curative-intent esophagectomy: OE 1,488 (77.5%) and RAMIE 432 (22.5%). The primary outcome was the overall 30-day complication rate. Secondary outcomes included pulmonary complications, pleural effusion, recurrent laryngeal nerve-related vocal cord palsy (VCP), anastomotic leak, and infectious complications. Adjusted odds ratios (aOR) with 95% confidence intervals were calculated using multivariable logistic regression adjusting for age, sex, clinical stage, smoking, and neoadjuvant therapy.

### Results

The overall 30-day complication rate was comparable between the two groups (OE 71.0% vs. RAMIE 73.3%; aOR 1.24, 95% CI 0.84–1.81;  $p = 0.275$ ). RAMIE was associated with significantly lower pulmonary complications (9.4% vs. 37.0%; aOR 0.18, 95% CI 0.12–0.29;  $p < 0.001$ ) and infectious complications (9.9% vs. 23.9%; aOR 0.37, 95% CI 0.23–0.59;  $p < 0.001$ ). In contrast, recurrent laryngeal nerve-related vocal cord palsy was significantly more frequent in the RAMIE group (33.7% vs. 16.4%; aOR 2.52, 95% CI 1.64–3.86;  $p < 0.001$ ). Pleural effusion rates did not differ significantly (12.5% vs. 16.0%; aOR 0.82, 95% CI 0.50–1.34;  $p = 0.434$ ). Anastomotic leak tended to be higher in the RAMIE group, though this did not reach statistical significance (10.4% vs. 7.1%; aOR 1.89, 95% CI 0.98–3.65;  $p = 0.056$ ).

### Conclusions

Although overall 30-day complication rates were similar, RAMIE demonstrated a markedly favorable profile in pulmonary and infectious complications compared with OE. However, the higher incidence of recurrent laryngeal nerve palsy following RAMIE warrants attention. These findings suggest that the complication spectrum shifts rather than simply decreases with the robotic approach, highlighting the need for targeted strategies to mitigate RAMIE-specific morbidities.

## **SURGICAL MANAGEMENT OF TRACHEAL ADENOID CYSTIC CARCINOMA WITH THYROID INVASION: A CASE REPORT AND LITERATURE REVIEW**

**Nhat Ho<sup>\*1</sup>; Nguyen Kha Dang<sup>1</sup>**

<sup>1</sup>*General Oncology Department, Da Nang Oncology Hospital, Da Nang, Vietnam*

### **Objective**

Primary malignant tumors of the trachea are rare, accounting for approximately 0.2% of all respiratory tract tumors. Adenoid cystic carcinoma (ACC) represents the second most common histological type of malignancy of the trachea after squamous cell carcinoma (SCC). Thyroid gland invasion by tracheal adenoid cystic carcinoma (TACC) is extremely uncommon but poses significant therapeutic challenges due to the proximity of critical airway and vascular structures.

### **Results**

This report details a case of advanced TACC with direct thyroid invasion successfully treated by radical surgery with tracheal tumor resection, total thyroidectomy, and 5cm primary tracheal anastomosis by combined incisions (cervico-mediastinal incision), achieving free margins and favorable postoperative outcomes. Some important notes: The optimal treatment approach for ACC consists of radical surgical resection with negative margins achievement and reconstruction / Resection should be done at least 1 cm beyond the gross tumor margin / Airway security during anesthesia in patients with tracheal tumors that nearly completely occlude the airway is very important / Total thyroidectomy with invasive tumor tissue is necessary to ensure oncological principles. Preserving the two recurrent laryngeal nerves is extremely important to limit complications related to this nerve, reducing pressure on the anastomosis after surgery / Reconstruction techniques (end-to-end tracheal anastomosis) after such surgical resection techniques are used when the tension on the anastomosis is excessive and include release maneuvers / Five to six centimeters is usually the maximal length that can be safely resected with a primary anastomosis

### **Conclusions**

Tracheal adenoid cystic carcinoma (TACC) with thyroid invasion is exceedingly rare and poses many challenges in diagnosis and treatment. The optimal treatment approach for these cases consists of radical surgical resection and adjuvant radiotherapy when indicated. Surgery offers definite cure for primary tumor of the trachea and should be performed by an experienced team and high technical expertise at an experienced center

### **Keyword(s)**

Trachea, Adenoid Cystic Carcinoma, Thyroid, Tracheal Anastomosis





## LESSONS FROM ROBOTIC SURGERY: SUPERIOR MEDIASTINAL SCHWANNOMAS WITH ESOPHAGEAL INVOLVEMENT

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<sup>1</sup>*Cardiac, Thoracic and Vascular Surgery, National University Hospital, Singapore, Singapore*

### Objective

Superior mediastinal tumours are rare and present significant operative challenges due to the restricted working surgical field and its close proximity to vital structures. Robotic-assisted thoracic surgery has expanded minimally invasive options for resection in this region by enhancing visualization and instrument dexterity. However, tumours that are closely adherent to the esophagus are associated with increased risk of esophageal injury. This study aims to describe two cases of anatomically similar superior mediastinal schwannomas resected with robotic assistance, highlighting intraoperative esophageal injury repair strategies and key technical lessons.

### Methods

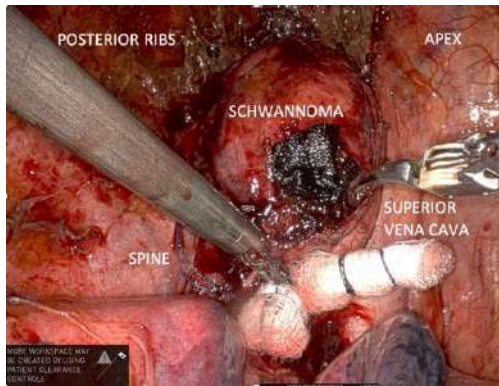
Both patients underwent preoperative computed tomography to delineate mediastinal anatomy. Robotic-assisted thoracoscopic resections were performed by the same surgeon using the Da Vinci Xi system with a multiport approach and carbon dioxide insufflation. Intra-operative esophagogastroduodenoscopy was routinely performed to assess esophageal integrity, and primary repair was undertaken when injury was identified.

### Results

The first patient, a 77-year-old male presenting with acute dyspnea, had a 7.3 cm superior mediastinal mass causing significant tracheoesophageal compression. Intra-operatively, the tumour was found to originate from the esophageal wall, resulting in two mucosal tears during dissection. Both were repaired, with a negative intra-operative leak test. The right vagus and recurrent laryngeal nerves were sacrificed due to tumour invasion, resulting in postoperative vocal cord palsy. The second patient, a 77-year-old female presenting with dysphagia, had a 7.5 cm mediastinal mass arising from the esophageal muscular layer. Three mucosal tears occurred intra-operatively and were successfully repaired. Postoperative contrast studies in both patients demonstrated no esophageal leak. Histopathology confirmed schwannoma in both cases.

### Conclusions

Esophageal injury remains an important consideration during resection of superior mediastinal tumours, particularly when the tumour originates from or closely involves the esophagus. Robotic-assisted surgery allows enhanced visualisation and precise dissection in this anatomically complex region. Careful preoperative imaging, routine intra-operative endoscopy, and readiness to manage esophageal injury are essential to achieving favourable surgical outcomes.



## **A study comparison of open versus minimally invasive esophagectomy for esophageal cancer at National Cancer Center of Mongolia**

**Dashchirev Munkh-Orshikh<sup>\*1</sup>; Baatar Ganzorig<sup>1</sup>; Badamkhand Azjargal<sup>1</sup>; Dugarsuren Mergen<sup>1</sup>; Purevdorj Zunduidorj<sup>1</sup>**

*<sup>1</sup>Thoracic surgery department, National cancer center of Mongolia, Ulaanbaatar, Mongolia*

### **Objective**

Minimally invasive esophagectomy is increasingly performed for esophageal or gastroesophageal junction cancer (EGJ), with the advantages of improved peri-operative outcomes in comparison with open esophagectomy. In NCCM (National Cancer Center of Mongolia), the thoracic surgery department responsible for esophageal cancer surgery, even though esophageal cancer surgery is most complicated and has a high incidence of mortality, our team uses the Minimally invasive technique. In two (Ivor Lewis esophagectomy ) and Three fields (Mc Keown esophagectomy) of surgeries we do open esophagectomy, hybrid and pure MIE (minimally Invasive Esophagectomy) techniques. In this study, we compare between two different methods of esophageal surgery by three techniques.

### **Methods**

Data was collected from E-Health program, statistical analysis were performed on SPSS 25 software program. Retrospective study evaluating short-term outcomes of open, MIE and hybrid MIE in patients with resectable esophageal and EGJ cancer. Main parameters included 30-day in hospital mortality and R classification.

### **Results**

Data was collected from 209 patients who underwent esophageal surgery, but information from 101 patients was excluded due to the different types of surgeries performed and other reasons. Age, sex, and the cancer stage between the 3 groups were not statistically different. Among 108 patients included, 73 underwent MIE and Hybrid MIE. Compared with propensity-matched patients who underwent OE and MIE , patients who underwent Hybrid MIE had a significantly higher incidence of complications, longer hospital stays and higher incidence of 30-day mortality. McKeown esophagectomy was associated 100% resection margin negativity. Compared with OE, MIE and Hybrid MIE was not associated with any significant differences in peri-operative outcomes.

### **Conclusions**

This study suggests that OE, MIE and Hybrid MIE are comparable with the respect to clinical safety. Pure MIE may be a better option when clinically suitable but McKeown esophagectomy would be a better oncologically safe technique.

### **Keyword(s)**

MIE /Minimally Invasive Esophagectomy/, Gastroesophageal Junction Cancer (EGJ)



# **TSTS**

## **Poster Walk Presentation**

**MAX**IMALLY EFFECTIVE MINIMALLY INVASIVE



## Room 101ABD (English) | Saturday, July 11, 2026

### Poster Walk -TSTS

**Time: 13:00-14:00, July 11th (GMT+8)**

Po-Chih Chang (Taiwan)  
 Chair(s): Cheau-Feng Lin (Taiwan)  
 Yi-Ting Yen (Taiwan)

- |        |                                                                                                                                                                                           |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TSTS-1 | <b>Advancing Benign Esophageal Tumor Management: The Robotic Enucleation Paradigm</b><br>Tzu-Yi Yang (Taiwan)                                                                             |
| TSTS-2 | <b>Health-Related Quality of Life and Long-Term Survival after Subcostal Uniportal Robot-Assisted Lung Resection: A Secondary Analysis of a Clinical Trial</b><br>Chuan Cheng (Taiwan)    |
| TSTS-3 | <b>Evaluating Trisegmentectomy and Lingulectomy Versus Lobectomy in Stage I Left Upper Lobe Non-Small Cell Lung Cancer</b><br>Tzu-Ning Kao (Taiwan)                                       |
| TSTS-4 | <b>Comparing the Prognostic Outcomes of Neoadjuvant CCRT Followed by Definite CCRT vs Direct Definite CCRT in Esophageal Cancer: Role of Treatment Interval</b><br>Chih-Lun Chen (Taiwan) |
| TSTS-5 | <b>Hyaluronan-Coated Gold Nanoshells for Enhanced Synergistic Effect and Immunogenic Cell Response of Chemo-Photothermal Therapy on Lung Cancer</b><br>Ke-Cheng Chen (Taiwan)             |
| TSTS-6 | <b>Intraoperative Tumor Assessment of Lung Cancer with Surgical Specimens: Advancing Precision Surgery through Rapid Fresh Digital Pathology</b><br>Min-Shu Hsieh (Taiwan)                |
| TSTS-7 | <b>Surgical Treatment of Thymoma and Myasthenia Gravis in a Patient with Situs Inversus Totalis: A Rare Case Report</b><br>Chieh-Kuo Lin (Taiwan)                                         |
| TSTS-8 | <b>Video-assisted Left Cardiac Sympathetic Denervation for Refractory Ventricular Tachycardia: A Report of Two Cases</b><br>Ying-Che Ting (Taiwan)                                        |
| TSTS-9 | <b>Traumatic Diaphragmatic Rupture: A Case Series from a Medical Center</b><br>Chien-Yu Lee (Taiwan)                                                                                      |

## Advancing Benign Esophageal Tumor Management: The Robotic Enucleation Paradigm

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<sup>1</sup>thoracic department, Chang Gung Memorial Hospital, Taichung, Taiwan <sup>2</sup>thoracic department, Chang Gung Memorial Hospital, Taoyuan, Taiwan

### Objective

Leiomyoma is the most common benign esophageal tumor. Although most leiomyomas are asymptomatic, some patients present with symptoms such as dysphagia, reflux, or chest pain. Surgical intervention remains the definitive treatment for esophageal leiomyoma. Previous studies have demonstrated that minimally invasive surgery offers greater benefits to patients compared with open surgery. However, limited evidence is available regarding the advantages of robotic-assisted thoracoscopic surgery (RATS) versus video-assisted thoracoscopic surgery (VATS). This study aims to compare the outcomes of these two minimally invasive approaches.

### Methods

This was a multi-center retrospective study conducted between January 2010 and July 2025. Patients who underwent enucleation of esophageal tumors were included. After applying exclusion criteria and grouping, 10 patients were assigned to the RATS group and 12 to the VATS group. Perioperative outcomes were analyzed as the primary endpoints.

### Results

Baseline characteristics were comparable between the two groups. Overall, 45.8% of tumors were located in the middle third of the esophagus. Endoscopic ultrasound revealed that 76.4% of leiomyomas originated from the muscularis propria. No significant differences were observed in operative time, intraoperative blood loss, or complication rates. Three patients did not require chest tube drainage postoperatively in the RATS group. Regarding hospitalization, the RATS group had a shorter mean duration of chest tube drainage ( $4.4 \pm 2.1$  vs.  $3.3 \pm 1.9$  days,  $p = 0.214$ ) and a shorter hospital stay ( $6.2 \pm 2.4$  vs.  $5.3 \pm 2.2$  days,  $p = 0.387$ ), though these differences were not statistically significant.

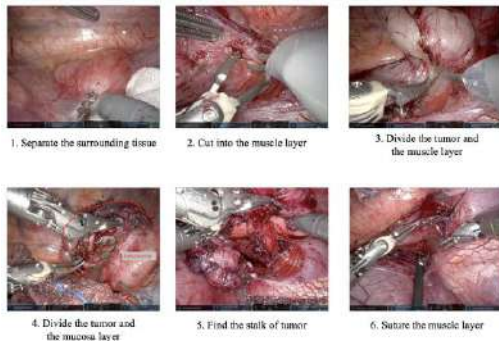
### Conclusions

The robotic approach may provide advantages in the enucleation of esophageal leiomyoma, particularly for more challenging tumors. In addition, RATS may offer a trend toward faster postoperative recovery. Further prospective studies are warranted to validate these findings.

### Keyword(s)

Esophageal Leiomyoma Enucleation, Robotic Surgery

Figure 1-6. Steps of robotic approach of esophageal leiomyoma enucleation



## Health-related quality of life and long-term survival after Subcostal Uniportal Robot-Assisted Lung Resection: A Secondary Analysis of a Clinical Trial

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<sup>1</sup>*Division of Thoracic Surgery, New Taipei Municipal Tu-Cheng Hospital, New Taipei City, Taiwan*

<sup>2</sup>*Division of Thoracic Surgery, Chang Gung Memorial Hospital, College of Medicine, Chang Gung University, Taoyuan, Taiwan, taoyuan, Taiwan*

### Objective

Subcostal uniportal robot-assisted thoracic surgery (URATS) using the da Vinci Single-Port (SP) system employs a single-incision, non-intercostal approach designed to minimize chest wall trauma. This study evaluated mid-term health-related quality of life (HRQOL) and long-term oncological outcome after subcostal URATS for early-stage lung cancer.

### Methods

In this prespecified secondary analysis of a clinical trial (NCT05535712), patients undergoing subcostal uniportal robotic anatomical lung resection were followed longitudinally. Chronic pain – defined as pain persisting beyond 90 days postoperatively – was evaluated at 3, 6, and 12 months using the Numerical Rating Scale (NRS) for pain intensity and the painDETECT Questionnaire (PDQ) for neuropathic characteristics. HRQOL was measured using the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire (EORTC QLQ-C30) summary score.

### Results

Among 33 patients undergoing subcostal URATS, the prevalence of chronic pain progressively decreased over time (30.3% at 3 months, 21.2% at 6 months, and 6.1% at 12 months). Pain intensity remained consistently mild (NRS ≤ 2), and PDQ scores confirmed the absence of neuropathic features in all patients. Median EORTC QLQ-C30 summary scores were uniformly high (≥ 98.7), reflecting minimal symptom burden and well-preserved HRQOL. With a median follow-up of 36 months, one patient developed bilateral pulmonary recurrence 15 months after surgery, and all patients remained alive.

### Conclusions

Subcostal URATS represents a promising non-intercostal strategy that preserves postoperative quality of life while maintaining acceptable oncological durability.

### Keyword(s)

Uniportal Robotic Surgery, Subcostal Approach, Health-Related Quality Of Life, Robotic Lung Resection, Chronic Pain, Neuropathic Pain



## Evaluating Trisegmentectomy and Lingulectomy Versus Lobectomy in Stage I Left Upper Lobe Non-Small Cell Lung Cancer

**Tzu-Ning Kao<sup>\*1</sup>; Xu-Heng Chiang<sup>2</sup>; Shuenn-Wen Kuo<sup>1</sup>; Pei-Ming Huang<sup>1</sup>; Hsao-Hsun Hsu<sup>1</sup>; Mong-Wei Lin<sup>1</sup>; Jin-Shing Chen<sup>1</sup>**

<sup>1</sup>*Department of Surgery, National Taiwan University Hospital, Taipei, Taiwan* <sup>2</sup>*Department of Medical Education, National taiwan, Taipei, Taiwan*

### Objective

While removing a full lobe remains the conventional approach for early-stage pulmonary malignancies, sublobar techniques are gaining traction for localized lesions. However, the comparative efficacy of resecting the left upper lobe (LUL) versus performing anatomical lung-sparing surgery via trisegmentectomy or lingulectomy is not fully established. We sought to contrast the operative metrics and oncological efficacies of these approaches in patients presenting with clinical stage I LUL non-small cell lung cancer (NSCLC).

### Methods

We conducted a retrospective evaluation spanning ten years (2011–2021) encompassing 377 individuals diagnosed with clinical stage I NSCLC localized to the LUL in National Taiwan University Hospital. Subjects underwent either comprehensive LUL removal or targeted sublobar excision (trisegmentectomy/lingulectomy). Cohorts were stratified by maximal nodule dimension (0–2 cm and 2–4 cm). To mitigate selection bias and balance baseline characteristics, 1:1 propensity-score matching (PSM) was implemented.

### Results

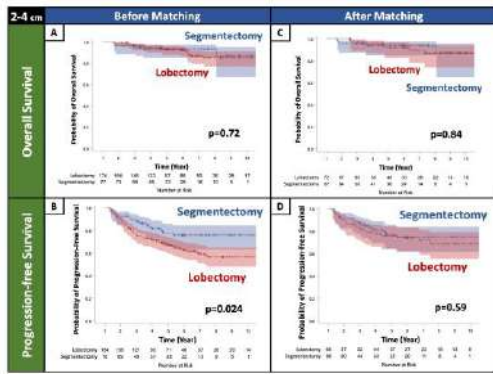
Following PSM, with a primary focus on the 2–4 cm subset, the lung-sparing cohort demonstrated markedly reduced operative durations alongside decreased intensive care and overall hospitalization days. Following matching, the two surgical groups demonstrated comparable progression-free survival (PFS) and overall survival (OS) across both the 0–2 cm and 2–4 cm tumor categories. Furthermore, multivariate evaluations confirmed that the chosen extent of resection did not independently influence long-term oncological prognosis.

### Conclusions

For early-stage (clinical stage I) NSCLC within the left upper lobe, anatomical sublobar resection serves as a highly viable alternative to traditional lobectomy. This approach enhances short-term postoperative recovery while achieving equivalent long-term oncological outcomes.

### Keyword(s)

Sublobar Resection, Segmentectomy, Early Lung Cancer, Non-Small Cell Lung Cancer



## Comparing the Prognostic Outcomes of Neoadjuvant CCRT Followed by Definite CCRT vs Direct Definite CCRT in Esophageal Cancer: Role of Treatment Interval

**Chih Lun Chen<sup>\*1</sup>; Chih-Hung Lin<sup>1</sup>**

<sup>1</sup>*Surgery, Taichung Veterans General Hospital, Taichung, Taiwan*

### Objective

For patients with resectable esophageal squamous cell carcinoma (ESCC) who decline surgery after neoadjuvant concurrent chemoradiotherapy (nCCRT), conversion to definitive concurrent chemoradiotherapy (dCCRT) is a common alternative. However, the impact of treatment timing on oncological outcomes in this setting remains unknown.

### Methods

Patients with ESCC (cT2–T4 or N1–3 M0; stage II–IVa; AJCC 8e) who received chemoradiotherapy without surgery between 2013 and 2020 were retrospectively analyzed. These included patients who converted from nCCRT to dCCRT after declining surgery (neoadjuvant group) and those who received upfront dCCRT (definitive group). The conversion interval and treatment duration were evaluated for their impact on survival. Propensity score matching (PSM) was performed, and overall survival (OS) and event-free survival (EFS) were assessed.

### Results

After PSM, 74 patients (neoadjuvant group, n=37; definitive group, n=37) were analyzed. The conversion interval ranged from 3 to 9 weeks (median, 5 weeks), with 77.0% resuming treatment within 3–5 weeks. Neither conversion interval ( $\leq 4$  vs.  $> 4$  weeks) nor treatment duration ( $\leq 12$  vs.  $> 12$  weeks) significantly affected OS or EFS (all  $p > 0.05$ ), and between-group survival differences were also non-significant (OS,  $p = 0.112$ ; EFS,  $p = 0.208$ ). On multivariable analysis, neither timing variable was an independent prognostic factor; definitive group treatment and hypertension were independent adverse prognostic factors for OS, and betel nut use and hypertension for EFS.

### Conclusions

The conversion interval does not significantly influence survival outcomes in ESCC patients who convert from nCCRT to dCCRT after declining surgery. Moderate delays during surgical decision-making are clinically acceptable without compromising prognosis.

### Keyword(s)

Esophageal Squamous Cell Carcinoma, Neoadjuvant Chemoradiotherapy, Definitive Chemoradiotherapy, Treatment Timing, Survival Analysis

## **Hyaluronan-coated gold nanoshells for enhanced synergistic effect and immunogenic cell response of chemo-photothermal therapy on lung cancer**

**Ke-Cheng Chen<sup>1,2</sup> Shu-Jyuan Yang<sup>2</sup> Ming-Jium Shieh<sup>2</sup>**

*<sup>1</sup>National Taiwan University Hospital, Yunlin Branch <sup>2</sup>Department of Biomedical Engineering,  
National Taiwan University, Taipei, Taiwan*

### **Purpose:**

Lung cancer (LC) is the predominant cause of cancer-related fatalities globally, with the highest death rates in both genders, primarily attributed to smoking. The non-kinase transmembrane cell surface glycoprotein, CD44, enhances LC cell migration and invasion, leading to drug resistance and an unfavorable prognosis.

### **Materials and Methods:**

This research formulated a cisplatin-loaded gold nanoshell (HCP@GNS) integrated with hyaluronan (HCP@GNS@HA) to enhance targeting capability and realize a synergistic effect of chemo-photothermal therapy (chemo-PTT) against LC.

### **Results:**

The coating of hyaluronic acid (HA) facilitated the uptake of HCP@GNS@HA into CD44-rich cancer cells, maintaining the superior photothermal conversion capacity of HCP@GNS nanoparticles for hyperthermia and photothermal eradication of tumor tissues under near-infrared exposure. As a nanocarrier, HCP@GNS@HA exhibited high biocompatibility and hemocompatibility, showing stronger cytotoxicity than either the free drug or photothermal therapy alone when combined with NIR irradiation, especially at high cis-diamminedichloroplatinum (II) (CDDP) concentrations. The chemo-PTT mediated by HCP@GNS@HA effectively curtailed tumor growth without adverse effects, significantly mobilizing B cells, DC cells, macrophages, natural killer (NK) cells, and NKT cells in the distal tumor against tumor growth.

### **Conclusion:**

In conclusion, the developed hyaluronic acid (HA)-coated gold nanoshells could potentially serve as a promising candidate for nanomedicine, tackling both primary and distal LC growth.

## **Intraoperative Tumor Assessment of Lung Cancer with Surgical Specimens: Advancing Precision Surgery through Rapid Fresh Digital Pathology**

**Min-Shu Hsieh<sup>1</sup> Yao-Chen Tseng<sup>2</sup> Yuan-Te Lu<sup>2</sup> Pei-Hsing Chen<sup>3</sup> Jen-Hao Chuang<sup>3</sup> Tung-Ming Tsai<sup>3</sup> Hsao-Hsun Hsu<sup>3</sup> Chi-Kuang Sun<sup>2</sup> Jin-Shing Chen<sup>3</sup>**

<sup>1</sup>*Department of Pathology, National Taiwan University Hospital Cancer Center, Taipei, Taiwan*

<sup>2</sup>*Graduate Institute of Photonics and Optoelectronics and Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan* <sup>3</sup>*Department of Surgery, National Taiwan University Hospital, Taipei, Taiwan*

### **Purpose:**

Lung cancer is the leading cause of cancer-related mortality worldwide, and non small cell lung cancer (NSCLC) represents the majority of these cases.[1] Despite advances in targeted therapies and immunotherapies, surgical resection remains the cornerstone of treatment for early-stage disease.[2] As a result, intraoperative pathological diagnosis has assumed a vital role in determining the extent of resection, providing guidance that can balance oncologic safety with preservation of lung function. Adenocarcinoma, the most common NSCLC subtype, displays distinct growth patterns that correlate with prognosis. Lepidic-predominant adenocarcinomas generally confer excellent survival and lend themselves to parenchyma-sparing procedures such as segmentectomy. By contrast, micropapillary and solid subtypes are aggressive and associated with early recurrence, guiding the surgeon toward a more extensive lobectomy. [3] The presence of spread through air spaces (STAS) has also emerged as a critical pathological feature that alters operative planning. Consequently, accurate intraoperative classification of lung cancer is not only desirable but often decisive for the course of surgery. [3-4] Historically, frozen section (FS) has been the method of choice for intraoperative consultation. While indispensable, FS is hampered by obvious limitations, including freezing artifacts, inconsistent diagnostic accuracy in fragile lung tissue, and significant demands on time. [5-6] In recent years, rapid fresh digital pathology (RFP) has emerged as a promising alternative. [7] By enabling high-quality digital imaging of fresh tissue without freezing, RFP offers improved morphological preservation, faster turnaround, and compatibility with digital workflows and artificial intelligence. The present article aims to apply RFP to one hundred lung surgical specimens, with results that demonstrate its potential as a new standard.

### **Materials and Methods:**

Lung tissue specimens were collected immediately after surgical resection. Each sample was subjected to a rapid hematoxylin and eosin (H&E) whole-mount tissue staining protocol. Following staining, the specimens were digitized using the PATHOscope (mesoView Co. Ltd.) system, which captures high-resolution pseudo color remapped images across the entire tissue section. The workflow was designed to minimize processing delays, and high-quality pathological images suitable for intraoperative review were consistently obtained within ten minutes.

In total, one hundred surgical specimens were examined using this protocol. The cohort included malignant tumors, such as adenocarcinoma, squamous cell carcinoma, and small cell carcinoma, as well as benign lesions including granulomas and inflammatory nodules. All rapid fresh digital pathology (RFP) diagnoses were subsequently compared against reference diagnoses established from standard formalin-fixed paraffin-embedded (FFPE) sections. This comparison allowed for validation of both the diagnostic accuracy and the technical feasibility of the RFP workflow.

## Results:

We validated our pipeline using the cohort of lung surgical specimens, rapid fresh digital pathology (RFP) demonstrated excellent diagnostic performance. The generated digital pathology images exhibited clear nuclear and cytoplasmic contrast, with preservation of key histological features required for distinguishing between normal alveolar structures and malignant patterns. The approach achieved a one hundred percent success rate in distinguishing malignant from benign lesions when validated against standard FFPE histology. Among the malignant cases, RFP enabled accurate classification into adenocarcinoma, squamous cell carcinoma, and small cell carcinoma. Within the adenocarcinoma subset, the method further allowed reliable recognition of major growth patterns, including lepidic, acinar, papillary, micropapillary, and solid, supporting surgical decision-making at the time of operation.

## Conclusion:

Our institutional study demonstrates that rapid fresh digital pathology (RFP) provides accurate and efficient intraoperative assessment of lung cancer. In one hundred surgical specimens, RFP achieved 100% accuracy in distinguishing malignant from benign disease and showed the ability to subtyping adenocarcinoma. High-quality digital images were consistently generated within ten minutes, enabling real-time communication between surgeons and pathologists. These results confirm RFP as a reliable tool for guiding surgical decisions and preserving functional lung parenchyma. With future integration of artificial intelligence to detect prognostic features such as aggressive subtypes, STAS, and nodal involvement, RFP has the potential to redefine intraoperative pathology and improve outcomes for patients with lung cancer.

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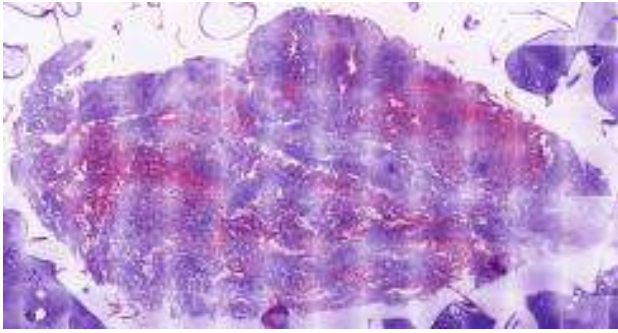


Fig. 1 Representative rapid fresh pathology image of lung cancer specimen.



## **Surgical Treatment of Thymoma and Myasthenia Gravis in a Patient with Situs Inversus Totalis: A Rare Case Report**

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<sup>2</sup>*Department of Neurology, Far East Memorial Hospital*

Situs inversus totalis is a rare congenital condition characterized by complete mirror-image transposition of thoracic and abdominal organs. Although often asymptomatic, it may pose challenges for surgical management due to anatomical variations. The coexistence of thymoma and myasthenia gravis in such patients is very rare.

The 46-year-old man with a history of chronic obstructive pulmonary disease and situs inversus totalis. He presented with fluctuating bilateral ptosis since December 2024, without diplopia, bulbar symptoms, or limb weakness. Anti-acetylcholine receptor antibody was positive (8.2 nmol/L), and chest computed tomography revealed a 4.9 cm anterior mediastinal mass consistent with thymoma, compatible with thymoma-associated myasthenia gravis.

The patient underwent video-assisted thoracoscopic surgery extensive thymectomy. Intraoperative findings were consistent with situs inversus anatomy, with the thymic drainage vein directed to the superior vena cava. However, pericardial invasion was noted, and partial pericardial resection was performed. The operation was completed uneventfully. The patient was extubated on postoperative day one and discharged under stable condition on postoperative day four, with ongoing pyridostigmine therapy and scheduled follow-up.

This case highlights the importance of careful perioperative planning in patients with rare anatomical variations.



Thymoma and situs inversus totalis



Thymic drainage vein to the superior vena cava



## **Video-assisted left cardiac sympathetic denervation for refractory ventricular tachycardia: A report of two cases**

**Ting, Ying-Che<sup>1</sup> Hsu, Po-Kuei<sup>1,2</sup>**

*<sup>1</sup>Division of thoracic surgery, Department of surgery, Taipei Veterans General Hospital <sup>2</sup>Institute of Clinical Medicine, National Yang Ming Chiao Tung University*

Left cardiac sympathetic denervation (LCSD), achieved by resecting the stellate ganglion and the T2–T4 thoracic ganglia to reduce noradrenergic input to the heart, has been recognized for its potential to effectively manage life-threatening cardiac arrhythmias such as long QT syndrome and ventricular tachycardia. (Ref: 2016 QoL) However, despite the introduction of thoroscopic techniques in the early 2000s, the procedure remains underutilized among cardiologists. (Ref: 2023 Unlocking the potential of LCSD) We present two cases of LCSD performed via left video-assisted thoroscopic surgery (VATS), indicated for refractory ventricular tachycardia secondary to ischemic heart disease. The first patient experienced multiple episodes of ventricular tachycardia requiring cardiopulmonary resuscitation (CPR), while the second patient received multiple implantable cardioverter-defibrillator (ICD) shocks due to recurrent VT. No further VT episodes occurred during a 7-month follow-up in the first case and a 1-month follow-up in the second case. Both patients remained clinically stable with ICDs in place for secondary prevention.

## Traumatic Diaphragmatic Rupture: A Case Series from a Medical Center

Chien-Yu Lee<sup>1</sup> Ching-Yuan Cheng<sup>1</sup>

<sup>1</sup>*Division of General Thoracic Surgery, Changhua Christian Hospital*

### Background:

Traumatic diaphragmatic rupture (TDR) is an uncommon but potentially life threatening injury, often associated with high-energy blunt or penetrating trauma and multiple concomitant injuries. Early diagnosis and prompt surgical repair are crucial to prevent morbidity and mortality. This study aimed to analyze the clinical characteristics, management, and outcomes of patients with TDR treated at our institution.

### Methods:

We retrospectively reviewed medical records of patients diagnosed with TDR between August 2020 and September 2025. Demographic data, injury mechanism, associated injuries, diagnostic methods, surgical approaches, and clinical outcomes were collected and analyzed. Injury Severity Score (ISS) was used to assess trauma severity.

### Results:

The cohort included 12 males and 5 females, with a mean age of  $55.6 \pm 15.0$  years (range 18–78). Blunt trauma accounted for 82.4% of cases, while 17.6% were penetrating injuries caused by rib fracture fragments. The most common mechanism was motor vehicle collision (64.7%), followed by falls (29.4%). Left sided ruptures occurred in 47.1% and right-sided in 52.9%. The median ISS was 26 (IQR 16–34). Associated injuries included thoracic trauma, abdominal injuries, orthopedic injuries, head injuries and spinal injuries. Diagnosis was made by computed tomography in 70.6% and intraoperatively in 29.4%. Time to diagnosis was immediate in 64.7% and delayed ( $> 24$  h) in 35.3%. Surgical repair was performed via laparotomy (35.3%), thoracotomy (23.5%), or minimally invasive approaches including laparoscopy and thoracoscopy (41.2%), with primary suture repair in all cases. The median ICU stay was 10 days (IQR 6–13) and hospital stay 15 days (IQR 10–21). Postoperative complications occurred in 35.3% of patients, and in-hospital mortality was 5.9%.

### Conclusions:

TDR is frequently associated with severe multisystem trauma and high ISS score. Computed tomography remains the mainstay of diagnosis, but a significant proportion of cases are identified intraoperatively. Early recognition and prompt surgical repair, often in conjunction with management of concomitant injuries, are essential to optimize outcomes. Multidisciplinary trauma care is critical in reducing morbidity and mortality in this patient population.



# Poster Presentation

MINIMALLY INVASIVE  
**MAX**IMALLY EFFECTIVE

Poster Mounting Time: **July 11, 07:30–09:00** | Poster Removal Time: **July 12, 15:30–16:00**

Poster Area: **Room 101ABD**

|     |                                                                                                                                                                                                                             |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P01 | <b>Repeated Metastasectomy for Symptom Control in Metastatic Thymoma with Ocular Myasthenia Gravis: A Case Report</b><br>Li-Chun Chen (Taiwan)                                                                              |
| P02 | <b>Thoracic Duct Embolization for Chylothorax Refractory to Surgical Ligation: A Case Report</b><br>Wen Chiang (Taiwan)                                                                                                     |
| P03 | <b>Multiple Diaphragmatic Fenestration (or Porous Diaphragm Syndromes??) as Incidental Finding in Recurrent Female Pneumothorax - 2 Case Reports</b><br>Chao-kun Chen (Taiwan)                                              |
| P04 | <b>Primary Pulmonary Meningioma with Poor Prognosis - A Case Report and Literature Review</b><br>Ssu-Chia Chao (Taiwan)                                                                                                     |
| P05 | <b>Feasibility and Clinical Benefits of Gel-port Tenting Combined with Single-Port Thoracoscopic Rib Fixation in Multiple Rib Fractures Complicated by Hemopneumothorax</b><br>Po-Chun Chang (Taiwan)                       |
| P06 | <b>Empyema Thoracis Secondary to Splenothoracic Fistula from Splenic Abscess: A Rare but Fatal Etiology</b><br>Ching-Yun Chou (Taiwan)                                                                                      |
| P07 | <b>Chest Wall Metastasis from Hepatocellular Carcinoma in the Absence of a Primary Liver Cancer</b><br>Chao-kun Chen (Taiwan)                                                                                               |
| P08 | <b>Uniportal Video-Assisted Thoracoscopic Surgery Is Associated with Earlier Resolution of Subjective Symptoms Following Anatomical Lung Resection: A Prospective Randomized Controlled Trial</b><br>Takahiro Homma (Japan) |
| P09 | <b>Functional Preservation after Lung Segmentectomy with Unidirectional Stapling for Intersegmental Division Evaluated by 3D-Volumetry</b><br>Akio Hara (Japan)                                                             |
| P10 | <b>CUSUM Analysis of Surgical Proficiency in Uniportal Video-Assisted Thoracic Surgery: A Single-Surgeon Experience</b><br>Fumiaki Kato (Japan)                                                                             |
| P11 | <b>Feasibility and Safety of Same-Day Chest Drain Removal Following Minimally Invasive Minor Thoracic Surgery</b><br>Akinobu Ida (Japan)                                                                                    |
| P12 | <b>Anatomical Segmentectomy and Wedge Resections Are Associated with Comparable Outcomes for Patients with cT1bN0 Non-Small Cell Lung Cancer</b><br>Chia-Hui Lin (Taiwan)                                                   |

Poster Mounting Time: **July 11, 07:30–09:00** | Poster Removal Time: **July 12, 15:30–16:00**  
 Poster Area: **The hallway outside Room 103**

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| P13 | <b>A Dual Minimally Invasive Strategy for a Patient with Severe Aortic Stenosis and Non-Small Cell Lung Cancer: Transcatheter Aortic Valve Implantation Enabling Curative Robotic Lobectomy</b><br>Hiroki Watanabe (Japan) |
| P14 | <b>Persistent Air Leak from a Supernumerary Fissure after Lobectomy</b><br>Kenji Miura (Japan)                                                                                                                             |
| P15 | <b>Computed Tomography-Guided Ablation for Lung Cancer: A Real-World Experience</b><br>Hao-Wen Chen (Taiwan)                                                                                                               |
| P16 | <b>Simultaneous Bi-Lobar Torsions after Video-Assisted Thoracoscopic Right Upper Lobe Lobectomy</b><br>Chung-Yun Kuan (Taiwan)                                                                                             |
| P17 | <b>Considerations on Bronchial Stump Leakage in Uniportal Thoracoscopic Pulmonary Resection; three case series</b><br>Naoko Ose (Japan)                                                                                    |
| P18 | <b>Esophageal Tumor Stage Determines Survival after Surgical Treatment of Synchronous Head and Neck and Esophageal Cancer</b><br>Chi Cheng (Taiwan)                                                                        |
| P19 | <b>Clinicopathological Features and Significance of Epidermal Growth Factor Receptor Mutation in Surgically Resected Early-Stage Lung Adenocarcinoma</b><br>Chao-Wen Lu (Taiwan)                                           |
| P20 | <b>Is Consolidation-to-Tumor Ratio Redundant When Solid Diameter Is Known? Incremental Value Analysis in Part-Solid Lung Adenocarcinoma</b><br>Takuya Tokunaga (Japan)                                                     |
| P21 | <b>Reframing Nodal Staging in Non-Small Cell Lung Cancer: Development and External Validation of Metastatic Node Count versus the 9th Edition N descriptor</b><br>Ji Yong Kim (Republic of Korea)                          |
| P22 | <b>Margin Distance as a Tumor Biology Surrogate for Risk Stratification after Lobectomy in Stage I NSCLC: A Retrospective Multi-Institutional Externally Validated Analysis</b><br>Shia Kim (Republic of Korea)            |
| P23 | <b>Thoracic SMARCA4-Deficient Undifferentiated Tumor: A Case Report</b><br>Chih-Hao Yu (Taiwan)                                                                                                                            |
| P24 | <b>Surgical Management of Anterior Mediastinal Tumor in a High-Risk Elderly Patient with Myasthenic Crisis</b><br>Han-Yu Kuo (Taiwan)                                                                                      |
| P25 | <b>Elevated Neuregulin-1 Expression Modulates Tumor Malignancy and Autophagy in Esophageal Squamous Cell Carcinoma</b><br>Yen-Chiang Tseng (Taiwan)                                                                        |
| P26 | <b>Unexpected Bronchopleural Fistula Following Tyrosine Kinase Inhibitor Therapy in Lung Adenocarcinoma: A Case Report</b><br>Shih-Hung Chou (Taiwan)                                                                      |

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| P27 | <b>Combined Small Cell Lung Carcinoma Presenting as a Slowly Enlarging Part-Solid Pulmonary Nodule Successfully Treated with Surgery and Adjuvant Chemotherapy: A Case Report</b><br>Chi-Hung Chiang (Taiwan) |
| P28 | <b>Robotic Approach Can Remove More Lymph Nodes Than VATS Approach in Anatomical Lung Resection Surgeries for Lung Cancer</b><br>Yap Zhen Yu (Singapore)                                                      |
| P29 | <b>Perioperative Outcomes of Robotic-Assisted Thoracic Surgery Segmentectomy for Primary Lung Cancer: A Propensity Score-Matched Comparison with Video-Assisted Thoracic Surgery</b><br>Akinobu Ida (Japan)   |
| P30 | <b>Subxiphoid Uniportal Robotic Thymectomy Using the Da Vinci Xi System; Initial Outcomes</b><br>Daisuke Tochii (Japan)                                                                                       |
| P31 | <b>Feasibility and Early Outcomes of Robotic-Assisted Thoracic Surgery Using Single Port System through intercostal approach</b><br>Amber Chao (Taiwan)                                                       |
| P32 | <b>Initial Experience of D-RATS Using Japanese Robotic Surgical System Hinotori</b><br>Shinya Tane (Japan)                                                                                                    |
| P33 | <b>Robotic Thymectomy for Anterior Mediastinal Tumors: Lateral Versus Subxiphoid Approach</b><br>Shia Kim (Republic of Korea)                                                                                 |
| P34 | <b>Clinical Evaluation of "Fusion D-RATS": Robotic-Assisted Anatomical Lung Resection Using Assistant-Side Staplers</b><br>Hikaru Watanabe (Japan)                                                            |
| P35 | <b>Single-Stage Hybrid Operating Room Localization and Robotic-Assisted Resection for Non-Palpable Intrathoracic Tumors: A Prospective Case Series</b><br>Jui-Yu Weng (Taiwan)                                |
| P36 | <b>Transitioning from Multi-Port to Single-Port Robotic Lobectomy: Initial Experience and Perioperative Outcomes</b><br>Junghee Lee (Republic of Korea)                                                       |
| P37 | <b>Learning Signals in Robotic Assisted Bronchoscopy-Guided Ablation: Session and Per Nodule Time Based Cumulative Sum Analysis</b><br>Wei Liu (Hong Kong)                                                    |
| P38 | <b>Preparation for the Safe Initiation of Single-Port Robotic-Assisted Thoracic Surgery (SP-RATS): Initial 20 Procedures</b><br>Shota Nakamura (Japan)                                                        |
| P39 | <b>Intercostal Robotic Lung Resection Using the Da Vinci SP System</b><br>Junghee Lee (Republic of Korea)                                                                                                     |
| P40 | <b>From Trial to Routine Practice: Single-Surgeon Outcomes of Single Port Robotic Lung Resection for Lung Cancer</b><br>Chia-Wei Chang (Taiwan)                                                               |
| P41 | <b>Intrathoracic Robotic Resection of a Rare Chest Wall Hibernoma: A Novel Single-Stage Paradigm Leveraging Hybrid OR Localization</b><br>Kai-Hua Chen (Taiwan)                                               |

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| P42 | <b>Perioperative Outcomes of Robot-Assisted Thoracoscopic Surgery and Open Surgery for Large Anterior Mediastinal Tumors</b><br>Yoshitaka Kitamura (Japan)                                                                  |
| P43 | <b>Combined Esophageal Endoscopic Submucosal Dissection and Robotic Mediastinal Lymphadenectomy: A Novel Hybrid Approach in Esophageal Cancer, Case Report</b><br>Tzu-Wei Kuo (Taiwan)                                      |
| P44 | <b>Clinical Outcomes of Subxiphoid Extended Thymectomy in Patients with Myasthenia Gravis</b><br>Mizuki Morota (Japan)                                                                                                      |
| P45 | <b>Comparison of Median Sternotomy and Subxiphoid VATS in Extended Thymectomy</b><br>Hiroyuki Kaneda (Japan)                                                                                                                |
| P46 | <b>Building a Multi-Institutional Database for Thymoma and Thymic Carcinoma in Taiwan: A Collaborative Study from Nine Medical Centers</b><br>Ying-An Chou (Taiwan)                                                         |
| P47 | <b>Efficacy of Tracheobronchial Stenting for Central Airway Stenosis During Rigid Bronchoscopy with Extracorporeal Membrane Oxygenation Support</b><br>Tzu-Wei Kuo (Taiwan)                                                 |
| P48 | <b>The Pulsating Handle: Surgical Management of a Penetrating Chest Injury with Cardiac-Synchronous Movements and Minimal Pneumothorax</b><br>Chia Liu (Taiwan)                                                             |
| P49 | <b>Chronic Traumatic Diaphragmatic Hernia Masked for 8 Years: A Case Report of Complex Thoraco-abdominal Adhesion and Mesh Repair</b><br>Ying-Che Ting (Taiwan)                                                             |
| P50 | <b>Postoperative ICU Nursing Management Following Video-Assisted Thoracoscopic Decortication for Empyema</b><br>Yi-Peng Chen (Taiwan)                                                                                       |
| P51 | <b>Thoracic Endometriosis Syndrome with Catamenial Pneumothorax among Patients who Underwent Surgery at the Lung Center of the Philippines</b><br>Richard Briones (Philippines)                                             |
| P52 | <b>Intraoperative Lung Cancer Diagnosis Using Three Dimensional (3D) Optical Coherence Tomography (OCT) with Deep Learning</b><br>Aloysius Niko (Indonesia)                                                                 |
| P53 | <b>Development of a Prediction Model Incorporating Radiomic Features from Longitudinal Lung CT Images to Distinguish Invasiveness in Early-Stage Lung Adenocarcinomas: A Retrospective Study</b><br>Shan-Jang Chen (Taiwan) |
| P54 | <b>CT-Based Deep Learning for Prediction of Visceral Pleural Invasion in Lung Adenocarcinoma</b><br>Hsueh-Ching Lin (Taiwan)                                                                                                |

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| P55 | <b>Survival Outcomes of Patients with Esophageal Cancer and Post-chemoradiotherapy Surgical T4b Disease: Is Palliative Resection Justified?</b><br>Tzu-Yi Yang (Taiwan) |
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| P56 | <b>Prognostic Value of Tumor Length in Clinical T1-2N0M0 Esophageal Squamous Cell Carcinoma</b><br>Yohan Bae (Republic of Korea) |
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| P57 | <b>Delayed Gastric Conduit Emptying after Esophagectomy: Effects of Botox Injection over Pylorus</b><br>Yu-Hsuan Tsai (Taiwan) |
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| P58 | <b>Two Cases of Intraoperative ICG Fluorescence Imaging for Thoracic Duct Visualization for Postoperative Chyle Leak After Esophagectomy</b><br>Himeko Mori (Japan) |
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| P59 | <b>Synchronous Esophageal SCC and Lung Adenocarcinoma with Post Esophagectomy Gastric Tube Adenocarcinoma: A Case Report</b><br>Chieh-Ju Liao (Taiwan) |
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## **Repeated Metastasectomy for Symptom Control in Metastatic Thymoma with Ocular Myasthenia Gravis: A Case Report**

**Li-Chun Chen<sup>1,2</sup> Ying-Chieh Su<sup>1,2,3</sup> Chao-Kun Chen<sup>1,2</sup>**

<sup>1</sup>*Department of Thoracic Surgery, Chi Mei Medical Center, Tainan, Taiwan*

<sup>2</sup>*Department of Surgery, Chi Mei Medical Center, Tainan, Taiwan* <sup>3</sup>*Department of Biotechnology and Bioindustry Sciences, National Cheng Kung University*

### **Background:**

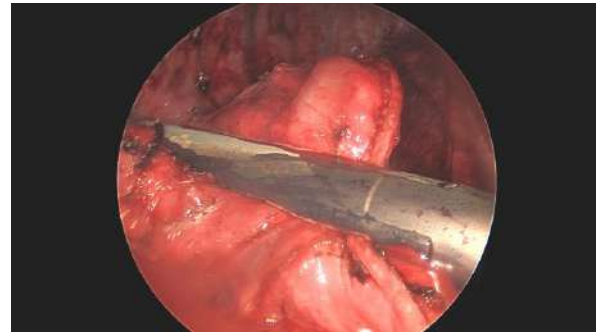
Thymoma is frequently associated with myasthenia gravis (MG), and recurrent disease may trigger MG exacerbations. Management of metastatic thymoma remains challenging, especially when ocular manifestations of MG recur with each episode of tumor progression.

### **Case Presentation:**

We report the case of a 39-year-old male initially diagnosed with type B2/B3 thymoma, stage IVA, with invasion of the right lung, pleura, superior vena cava, and left innominate vein. He underwent total thymectomy with superior vena cava reconstruction followed by concurrent chemoradiotherapy. Despite multimodality therapy, he developed multiple recurrences involving the bilateral pleura, diaphragm, and lungs from 2022 to 2025. Each recurrence was accompanied by ocular MG symptoms, including bilateral ptosis and diplopia, which responded poorly to steroids, pyridostigmine, or intravenous immunoglobulin. The patient underwent repeated video-assisted thoracoscopic surgeries, including wedge resections, pleural and diaphragmatic metastasectomies, pneumolysis, and diffuse argon plasma coagulation. Pathology consistently confirmed metastatic thymoma. After each operation, ocular symptoms improved, and postoperative imaging showed satisfactory lung expansion.

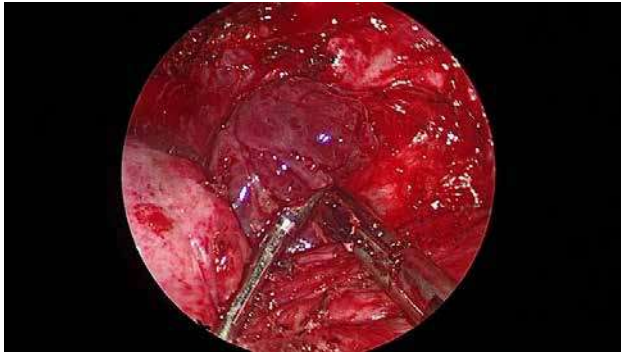
### **Conclusion:**

This case highlights the close association between metastatic thymoma and ocular MG relapse. Although repeated metastasectomy cannot provide cure, it offered meaningful symptomatic relief and temporary disease control. For selected patients with good performance status, repeated surgical intervention may serve as a valuable strategy for managing metastatic thymoma with refractory ocular MG.

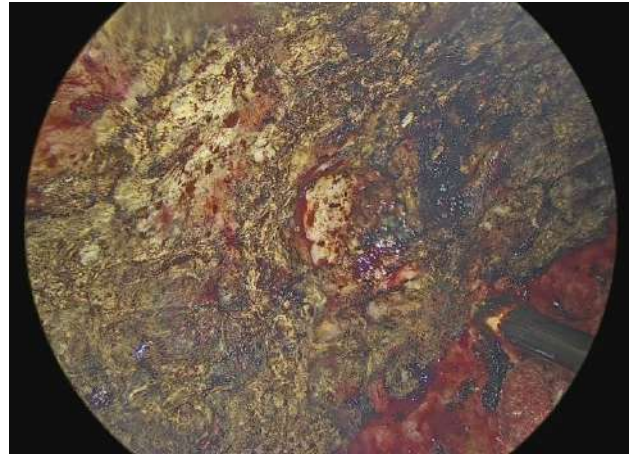


Lung metastasis: Wedge resection of right lung; pathology revealed metastatic thymoma.

Initial specimen (2021): Thymoma, combined B2/B3 type (T3), following total thymectomy.



Pleural metastasis: Surgical removal of pleural tumor; pathology confirmed metastatic thymoma.



Pleural surface: Diffuse argon plasma coagulation (APC) applied to ablate possible residual tumors.



Diaphragm metastasis: Tumor resection and local ablation; pathology confirmed metastatic thymoma.

## Thoracic Duct Embolization for Chylothorax Refractory to Surgical Ligation: A Case Report

**Wen Chiang<sup>1</sup> Po-Kuei Hsu<sup>2,3</sup>**

*<sup>1</sup>Department of Surgery, Taipei Veterans General Hospital <sup>2</sup>Division of Thoracic Surgery, Department of Surgery, Taipei Veterans General Hospital, Taipei, Taiwan <sup>3</sup>School of Medicine, National Yang-Ming Chiao Tung University, Taipei, Taiwan*

### Background

Chylothorax is a rare but critical complication after pulmonary lobectomy and mediastinal lymph node dissection. Both surgical duct ligation and thoracic duct embolization have been reported to be efficacious treatment methods.

### Case Presentation

A 61-year-old woman had been operated with right lower lobectomy and mediastinal lymph node dissection for lung adenocarcinoma. During the procedure, a clear watery discharge was observed following subcarinal lymph node dissection. Suspecting chyle leakage, thoracic duct ligation was performed at the level of inferior pulmonary vein. Postoperatively, the patient was placed on a low-fat diet. Despite this, chylothorax with drainage volume remained approximately 600 mL per day. Furthermore, somatostatin infusion and diet modifications with a fat-free diet or nil per os (NPO) did not result in significant improvement. On postoperative day seven, thoracic duct lymphangiography and embolization were performed. Lymphangiography revealed active extravasation at the carinal level of the mediastinum. Microcatheter was injected into the retroperitoneal lymphatic duct. Contrast injection confirmed a collateral lymphatic duct arose from the proximal thoracic duct at the T10 level, bypassing the surgical ligation site, ascending and then connecting to a transverse lymphatic plexus at the carinal level. Diluted N-Butyl Cyanoacrylate (NBCA) was injected into the collateral lymphatic duct for embolization. Following the procedure, the drainage amount decreased, and the drainage tube was successfully removed on postoperative day nine.

### Key Learning Points

Mediastinal lymph node dissection is one of the risk factors for postoperative chylothorax. Chyle leakage after subcarinal lymph node dissection is very rare. For conditions refractory to surgical duct ligation, anatomic variations should be considered. Our report highlighted that lymphangiography and thoracic duct embolization may be helpful to identify and address cases with collateral lymphatic pathways.

## Multiple diaphragmatic fenestration ( or Porous diaphragm syndromes ?? ) as incidental finding in recurrent female pneumothorax - 2 case reports

**Chao-Kun Chen<sup>1</sup> Ying-Jie Su<sup>1</sup> Li-Chun Chen<sup>1</sup>**

<sup>1</sup>*Division of thoracic surgery, Department of surgery, Chi Mei medical center*

The most famous diagnosed pneumothorax in female patients is Catamenial pneumothorax. Catamenial pneumothorax is defined as episodes of pneumothorax appear 48 to 72 hours after menstruation. The mechanism is proposed to be hormonal influence (ectopic endometrial tissue), diaphragmatic fistula, air migration. One term, Porous diaphragm syndromes, may be another interpretation of our patients. However, they usually present with thoracic symptomatology--pleural effusions, hemothorax, or empyema--mediated by this defect. Could Catamenial pneumothorax be explained ?

Here, we present 2 female case of recurrent pneumothorax without definite relationship to menstrual cycle. Due to recurrent pneumothorax with persistent air leak, video-thoracic surgery was performed. During the procedure, small pulmonary fistula / small bleb of right lung was found. No evident endometriosis tissue found, even biopsy of pleura. The most conspicuous lesions were multiple diaphragmatic fenestrations, large enough to expose subdiaphragmatic liver surface. The therapeutic policy included diaphragmatic repair / plication and wedge resection of pulmonary parenchyma. Afterthen, there was no recurrence of pneumothorax until now.



right diaphragm fenetration



Right sub-diaphragmatic liver surface

## **Primary pulmonary meningioma with poor prognosis — a case report and literature review**

**Ssu-Chia Chao<sup>2</sup> Jui-Yu Weng<sup>1</sup> Hsien-pin Li<sup>1</sup> Yu-Ting Lo<sup>1</sup> Yu-Wei Liu<sup>1</sup> Shah-Hwa Chou<sup>1</sup>**

<sup>1</sup>*Division of Thoracic Surgery, Department of Surgery, Kaohsiung Medical University Hospital, Kaohsiung Medical University, No. 100, Tzyou 1st Road, Kaohsiung, 80756, Taiwan.* <sup>2</sup>*Division of Surgery, Department of Surgery, Kaohsiung Medical University Hospital, Kaohsiung Medical University, No. 100, Tzyou 1st Road, Kaohsiung, 80756, Taiwan*

Primary Pulmonary Meningioma is an extremely rare pathological finding among lung tumors, with fewer than 60 cases reported since Kemnitz's initial description in 1982. Most reported cases have had favorable postoperative outcomes, and recurrence within the same hemithorax or distant metastasis to the contralateral lung is exceedingly rare.

We present a case of primary pulmonary meningioma, which initially presented as a well-circumscribed, homogeneous tumor in the left lower lobe. A transthoracic CT(Computed Tomography)-guided biopsy revealed a low-grade epithelioid tumor, which was negative for SSTR2A staining. Thoracoscopic left lower lobectomy was performed uneventfully with both macroscopic and pathological free margins. Focal positive staining for SSTR2A, along with additional immunohistochemical stains in the pathological report after the operation, confirmed the diagnosis of meningioma. Central nervous system imaging, including brain CT(Computed Tomography) and MRI(Magnetic Resonance Imaging), did not reveal any intracranial abnormalities, confirming the diagnosis of primary pulmonary meningioma.

The first postoperative follow-up CT(Computed Tomography) scan was performed 6 months later and revealed a newly developed solid lesion in the left upper lobe. A more conservative approach was adopted, with interval CT(Computed Tomography) follow-ups. Over time, multiple small nodules were observed on subsequent CT(Computed Tomography) scans. After thorough discussion with the patient, a second surgical biopsy was performed, and the pathological findings remained consistent with primary pulmonary meningioma.

Oral Hydroxyurea was attempted as adjuvant chemotherapy for nine months, but it was ineffective, with metastatic lesions continuing to grow and increase in number. Despite this, the patient remains alive three years post-diagnosis and continues to maintain an acceptable quality of life.



## **Feasibility and Clinical Benefits of Gel-port Tenting Combined with Single-Port Thoracoscopic Rib Fixation in Multiple Rib Fractures Complicated by Hemopneumothorax**

**Po-chun Chang<sup>1</sup> Chia-yu Chang<sup>1</sup> Tzu-ping Chen<sup>1</sup> Yin-Kai Chao<sup>2</sup> Chi-hsiao Yeh<sup>2</sup> Yun-hen Liu<sup>2</sup>**

<sup>1</sup>*Department of Thoracic and Cardiovascular Surgery, Chang-Gung Memorial Hospital, Keelung*

<sup>2</sup>*Division of Thoracic and Cardiovascular Surgery, Chang-Gung Memorial Hospital, Linkou*

Rib fractures complicated by hemopneumothorax often require surgical stabilization to improve pain control and pulmonary recovery. We present preliminary results of four patients who underwent gel-port tenting–assisted single-port thoracoscopic rib fixation. All patients sustained multiple rib fractures with concomitant hemopneumothorax and were stabilized prior to surgery. The mean operative time was  $125 \pm 34$  minutes. Mechanisms of injury included falls ( $n = 1$ ), traffic accidents ( $n = 2$ ), and crush injury ( $n = 1$ ). The average number of rib fractures was  $4.9 \pm 2.5$ , with three patients having unilateral and one bilateral chest wall involvement. The mean Injury Severity Score was 18.3. No intraoperative complications occurred, and postoperative recovery was uneventful in all cases. Early outcomes demonstrated effective fracture fixation, adequate pleural drainage, and satisfactory pain control. These preliminary findings suggest that gel-port tenting combined with single-port thoracoscopic rib fixation is a feasible and safe minimally invasive approach for selected patients with multiple rib fractures and hemopneumothorax, meriting further validation in larger studies.

## Empyema Thoracis Secondary to Splenothoracic Fistula from Splenic Abscess: A Rare but Fatal Etiology

Chia Liu<sup>1</sup> Ching-Yun Chou<sup>1</sup>

<sup>1</sup>Taipei Veterans General Hospital

Splenic abscess is an uncommon but life-threatening condition with incidence of 0.1–0.7%, with mortality rates approaching 100% in untreated patients and ranging from 10–47% despite appropriate therapy. It is a rare cause of empyema thoracis. We report the case of a 70-year-old man with a history of colon adenocarcinoma who presented with one week of persistent hiccups, one day of fever, and acute-onset dyspnea, without cough or sputum production. CT and serial chest radiographs demonstrated a rapidly progressing massive left pleural effusion and multiple hypodense splenic lesions, the largest measuring 7.1 cm (Fig. 1). Thoracocentesis yielded purulent fluid, and thoracoscopic decortication exposed purulent discharge through a diaphragmatic opening (Fig. 2). Laparoscopic inspection showed no ascites, suggesting a direct fistulous tract between the spleen and thorax resulted from the abscess with proteolytic agents in it. Two 28 Fr chest tubes were positioned toward the diaphragm and apex for drainage. Cultures from the pleural peels and fluid grew *Streptococcus anginosus*. MRI excluded tumor growth. On postoperative day 10 and 17, three pigtail catheters were sequentially inserted into separate loculated splenic abscess chambers and retained for 15, 24, and 17 days respectively. The patient completed a two-week course of intravenous antibiotics, followed by a 12-week regimen of oral antimicrobial therapy. This case highlights the importance of recognizing splenic abscess as a rare etiology of empyema thoracis and emphasizes the value of early diagnosis, timely surgical intervention, and coordinated multidisciplinary care.



Fig. 1 Chest CT reveals a massive loculated left pleural effusion with hypodense splenic lesions.

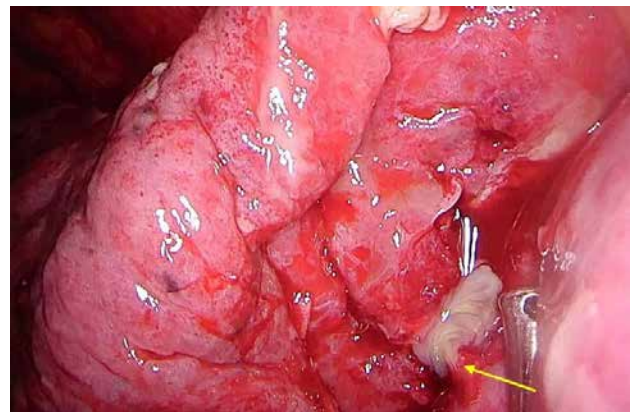


Fig. 2 Intraoperative image shows a diaphragmatic opening with thick purulent discharge (arrow).



## **Chest wall metastasis from hepatocellular carcinoma in the absence of a primary liver cancer**

**Chao-Kun Chen<sup>1</sup> Ying-Jie Su<sup>1</sup> Li-Chun Chen<sup>1</sup>**

*<sup>1</sup>Division of thoracic surgery, Department of surgery, Chi Mei medical center*

Metastatic hepatocellular carcinoma (HCC) has an aggressive course with a very poor outcome. The common hematogenous metastatic sites are the lungs, bones, and adrenal glands. The chest wall is an extremely rare site of metastasis from HCC. We report a case of left chest wall and rib metastasis without evidence of detectable primary HCC.

Ectopic liver is a rare developmental error where liver tissue grew at sites, like omentum, retroperitoneum, and the thorax, etc. An extrahepatic HCC without a primary intrahepatic lesion has been explained as being either due to ectopic liver carcinogenesis or hepatoid adenocarcinoma.

The survival rate of this disease is low, and the prognosis is usually poor. As the treatment options, surgical excision followed by chemotherapy in localized metastasis may be reasonable control.

## **Uniportal video-assisted thoracoscopic surgery is associated with earlier resolution of subjective symptoms following anatomical lung resection: a prospective randomized controlled trial**

**Takahiro Homma**

*St. Marianna University School of Medicine*

### **Objective**

While uniportal video-assisted thoracoscopic surgery (U-VATS) is reported to reduce postoperative pain and complications compared to multiportal VATS (M-VATS), few studies have compared postoperative subjective symptoms. We previously demonstrated that the COPD Assessment Test (CAT) score is a useful tool for evaluating subjective symptoms after thoracic surgery. This study aimed to compare postoperative subjective symptoms, as measured by the CAT score, between patients undergoing U-VATS and M-VATS for anatomical lung resection.

### **Methods**

This single-center, prospective randomized trial included patients undergoing anatomical lung resection via U-VATS or M-VATS. Exclusion criteria were conversion to thoracotomy, robot-assisted thoracic surgery, emergency surgery, re-operation, age <15 years, simultaneous resection of other organs, and postoperative complications (Clavien-Dindo Grade III) or adjuvant therapy that could influence CAT scores. The primary endpoint was the CAT score, measured preoperatively and at 1 week, 2 weeks, 1 month, 2 months, and 3 months postoperatively.

### **Results**

Of the 110 patients enrolled, 94 were analyzed (57 U-VATS [60.6%] and 37 M-VATS [39.4%]). There were no significant differences in clinical background (including COPD) or perioperative factors between the groups. While no significant differences in median CAT scores were observed from the preoperative period through 1 month postoperatively, the U-VATS group showed significantly lower scores at 2 months (7 vs. 8;  $P=0.046$ ) and 3 months (4 vs. 9;  $P=0.0015$ ).

### **Conclusion**

Compared with M-VATS, U-VATS resulted in lower CAT scores starting from 2 months postoperatively, suggesting earlier resolution of subjective symptoms and faster recovery of quality of life. These findings support the clinical benefit of U-VATS as a less invasive approach for anatomical lung resection.

## Functional Preservation after Lung Segmentectomy with Unidirectional Stapling for Intersegmental Division Evaluated by 3D-Volumetry

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<sup>1</sup>*Surgery, Suita Municipal Hospital, Osaka, Japan* <sup>2</sup>*Thoracic Surgery, Kawanishi City General Medical Center, Hyogo, Japan*

### Objective

Multidirectional stapling—such as the "Mercedes-Benz" technique—has been widely used to promote lung re-expansion after segmentectomy. Yet whether unidirectional stapling leads to inferior functional outcomes has never been clearly demonstrated. We sought to test this assumption using 3D-volumetry-based predictions as a reference standard.

### Methods

Thirty-one patients underwent segmentectomy with unidirectional stapling applied to all intersegmental planes (VATS: 19, RATS: 11, open: 1). Preoperative 3D-volumetry provided resection volume ratios and predicted postoperative (ppo) values for Vital Capacity (VC) and FEV1. Perioperative data and pulmonary function tests at 6 and 12 months were reviewed.

### Results

Median operative time was 238 minutes (range: 164–351); blood loss was minimal (median 10 mL). A median of 7 staplers were used (range: 5–11), and median chest drain duration was 1 day (range: 0–6). Two complications were noted: one prolonged air leak and one pneumonia. Median resection volume ratio was 7.7%. At 12 months (n=25), VC reached 2,670 mL against a ppoVC of 2,644 mL, recovering to 94.0% of baseline. FEV1 was 1,730 mL versus a ppoFEV1 of 1,789 mL—a difference that was not statistically significant (p=0.7). At 6 months (n=31), FEV1 had already exceeded the ppoFEV1 at 1,820 mL.

### Conclusions

Contrary to common concern, unidirectional stapling did not restrict postoperative pulmonary function. Outcomes at 12 months met or exceeded 3D-volumetry predictions, with low complication rates and short drainage times. These findings support unidirectional stapling as a straightforward and lung-preserving approach to intersegmental division.

### Keyword(s)

Anatomic Sublobar Resection, Segmentectomy, Intersegmental Plane, Unidirectional Dissection

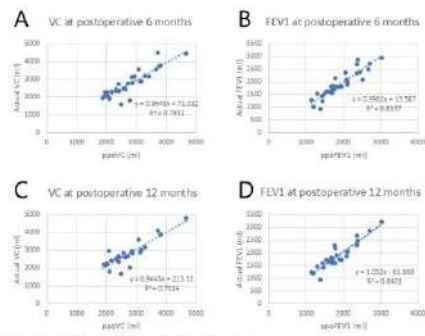


**Figure 1. Correlation between ppo- and actual values.**  
(A, B) at 6 months (n=31); (C, D) at 12 months (n=25). Dotted lines indicate linear regression.

## ***CUSUM Analysis of Surgical Proficiency in Uniportal Video-Assisted Thoracic Surgery: A Single-Surgeon Experience***

**Fumiaki Kato<sup>\*1</sup>; Masaki Tomita<sup>1</sup>; Toshihiko Sato<sup>2</sup>**

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### **Objective**

Although uniportal video-assisted thoracic surgery (U-VATS) is increasingly performed, data regarding its learning curve based on consecutive cases by a single surgeon are limited. This study aimed to evaluate the learning curve of U-VATS and determine the number of cases required to achieve proficiency.

### **Methods**

We retrospectively analyzed 270 consecutive U-VATS procedures performed by a single surgeon at our institution. Operative time was recorded for each case, and the learning curve was evaluated using cumulative sum (CUSUM) analysis to identify the case at which proficiency was achieved.

### **Results**

CUSUM analysis demonstrated an initial peak at case 68, including the point at which surgical proficiency was achieved. The cases were divided into Group A (the first 68 cases) and Group B (the subsequent cases). The mean operative time in Group B was significantly shorter than in Group A (170±46 vs. 139±52 min. respectively,  $p<0.0001$ ).

### **Conclusions**

The learning curve analysis revealed that proficiency in U-VATS was achieved after approximately 68 cases, with a notable decrease in operative time thereafter.

### **Keyword(s)**

Uniportal VATS, Learning Curves, Single Surgeon

## Feasibility and Safety of Same-Day Chest Drain Removal Following Minimally Invasive Minor Thoracic Surgery

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<sup>1</sup>*General Thoracic Surgery, Japanese Red Cross Maebashi Hospital, Gunma, Japan*

### Objective

Early removal of postoperative chest drains reduces pain and facilitates early ambulation, but concerns remain regarding bleeding and air leakage. We evaluated the feasibility, safety, and determinants of same-day chest drain removal after minimally invasive minor thoracic surgery.

### Methods

We retrospectively reviewed 232 consecutive patients who underwent minimally invasive non-anatomical lung resection (Cohort 1, n=190) or non-pulmonary tumor resection (Cohort 2, n=42) between December 2021 and April 2025 at a single center. In Cohort 1, drains were removed in the operating room when three criteria were satisfied: (1) absence of air leak on the first or second intraoperative sealing test, (2) no air leak in the postoperative drainage system, and (3) satisfactory lung expansion on chest radiography. When postoperative bleeding was a concern, drains were removed after 2–3 hours of observation. In Cohort 2, sealing tests were omitted, and the remaining criteria were identical. Cohort 1 patients were stratified into same-day removal (Group D) and removal on postoperative day (POD)  $\geq 1$  (Group P). Perioperative outcomes were compared, and predictors of delayed removal were analyzed using multivariate logistic regression.

### Results

Same-day drain removal was achieved in 84.2% of Cohort 1 and 92.9% of Cohort 2. Re-drainage rates were 3.2% (6/190) and 2.4% (1/42), respectively; all cases in Cohort 1 resulted from delayed pulmonary fistula. Within Cohort 1, Group P patients were significantly older (median 73 vs. 35 years), had heavier smoking history (Brinkman Index 600 vs. 0), longer operative time (76 vs. 40 minutes), greater stapler use (5 vs. 3), and higher incidence of initial air leak (53.3% vs. 8.1%) (all  $p < 0.05$ ). Postoperative hospital stay was longer in Group P (2 vs. 1 days,  $p < 0.001$ ), while re-drainage rates were comparable (3.3% vs. 3.1%,  $p > 0.99$ ). Use of  $\geq 4$  staplers independently predicted delayed removal (OR 2.95, 95% CI 1.03–8.47,  $p = 0.045$ ), whereas absence of initial air leak strongly favored same-day removal (OR 0.14, 95% CI 0.05–0.38,  $p < 0.001$ ).

### Conclusions

Same-day chest drain removal after minimally invasive minor thoracic surgery is feasible and safe, with low re-drainage rates. These findings support incorporation of same-day removal into enhanced recovery pathways, while careful consideration is warranted in cases requiring multiple stapler firings.

## **Anatomical Segmentectomy and Wedge Resections Are Associated with Comparable Outcomes for Patients with cT1bN0 Non–Small Cell Lung Cancer**

**Chia-Hui Lin<sup>\*1</sup>; Pin-Li Chou<sup>1</sup>; Chien-Hong Chiu<sup>1</sup>; Wei-Hsun Chen<sup>1</sup>; Yun-Hen Liu<sup>1</sup>; Yi-Cheng Wu<sup>1</sup>; Yin-Kai Chao<sup>1</sup>**

<sup>1</sup>*Division of Thoracic Surgery, Chang Gung Memorial Hospital-Linkou, Taoyuan, Taiwan*

### **Objective**

The optimal surgical extent of sublobar resection for clinical T1bN0 non–small cell lung cancer (NSCLC) remains a matter of ongoing debate. We aimed to compare the oncologic efficacy of wedge resection (WR) and anatomical segmentectomy (AS) in this patient population.

### **Methods**

A retrospective review of a prospective single institution database was performed (2010 – 2023) for cT1bN0 patients, excluding patients with multiple primary tumors, carcinoid tumors, adenocarcinoma in situ, and minimally invasive adenocarcinoma. Demographic, clinical, and pathological data were reviewed. Overall survival (OS) and disease-free survival (DFS) were estimated using the Kaplan-Meier method and differences compared using log-rank test.

### **Results**

A total of 1051 eligible patients were identified, of whom 742 underwent sublobar resection: 386 received WR and 356 received AS. Compared with WR, AS was associated with a higher number of lymph nodes retrieved (14.76 vs. 10.59,  $p < 0.001$ ) and a higher rate of nodal upstaging (cN0→pN1/2) (3.1% vs. 1.0%,  $p = 0.047$ ). Despite more extensive nodal evaluation, recurrence rates were similar between WR and AS (3.4% vs. 3.7%,  $p = 0.834$ ). Five-year DFS was comparable (81.6% vs. 84.3%,  $p = 0.879$ ), as was five-year OS (81.9% vs. 86.7%,  $p = 0.737$ ).

### **Conclusions**

WR and AS provide comparable oncologic outcomes for patients with cT1bN0 NSCLC. Although AS yields more thorough lymph node assessment and higher nodal upstaging rates, this did not translate into a survival advantage in this low-risk population. Careful patient selection may allow WR to remain an acceptable surgical option in selected cT1bN0 cases.

### **Keyword(s)**

Clinical T1bn0 Non–Small Cell Lung Cancer, Sublobar Resection, Recurrence, Disease-Free Survival, Overall Survival



## **A Dual Minimally Invasive Strategy for a Patient with Severe Aortic Stenosis and Non–Small Cell Lung Cancer: Transcatheter Aortic Valve Implantation Enabling Curative Robotic Lobectomy**

**Hiroki Watanabe<sup>\*1</sup>; Shota Nakamura<sup>1</sup>; Yoshiyuki Tokuda<sup>2</sup>; Hirofumi Takenaka<sup>1</sup>; Yuka Kadomatsu<sup>1</sup>; Harushi Ueno<sup>1</sup>; Taketo Kato<sup>1</sup>; Tetsuya Mizuno<sup>1</sup>; Masato Mutsuga<sup>2</sup>; Toyofumi Yoshikawa<sup>1</sup>**

<sup>1</sup>*Thoracic Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan* <sup>2</sup>*Cardiac Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan*

### **Objective**

Aortic stenosis (AS) is a life-threatening condition with a prognosis as poor as that of locally advanced non–small cell lung cancer (NSCLC). In such patients, treatment sequencing can substantially influence prognosis. Lung cancer surgery under untreated severe AS carries a high risk of perioperative cardiac events, whereas surgical aortic valve replacement may delay oncologic treatment because of postoperative recovery and may increase bleeding risk related to anticoagulation therapy. We report a strategic treatment approach in which transcatheter aortic valve implantation (TAVI) was performed prior to robotic-assisted thoracic surgery (RATS) for locally advanced NSCLC complicated by severe AS.

### **Results**

A 77-year-old male was referred with a rapidly enlarging mass in the right upper lobe detected during treatment for heart failure. The tumor increased from 3.5 to 4.8 cm over two months. Transbronchial biopsy confirmed NSCLC, clinically staged as T2bN0M0 stage IIA. Systemic evaluation revealed heart failure, chronic kidney disease (serum creatinine; 2.39 mg/dL), and severe AS. Transthoracic echocardiography demonstrated a peak transaortic velocity of 4.5 m/s, a mean systolic pressure gradient of 55 mmHg, a stroke volume index of 55 mL/m<sup>2</sup>, and an aortic valve area of 0.71 cm<sup>2</sup>. Following discussion at an expanded multidisciplinary team (MDT) meeting involving the thoracic oncology tumor board and the heart team, it was concluded that prioritizing TAVI would enable subsequent curative-intent RATS, allowing safe, minimally invasive, and curative treatment of both conditions. A balloon-expandable bioprosthetic valve was implanted. Twelve days after TAVI, right upper lobectomy was performed via RATS. The postoperative course was uneventful, and he was discharged on postoperative day five. Pathological examination revealed large cell carcinoma, pathological stage T2bN0M0 stage IIA. He remains free of recurrence five months after surgery.

### **Conclusions**

In this case, TAVI improved cardiac function in a minimally invasive manner and enabled lung cancer surgery without delay, with a favorable outcome. In recent years, therapeutic modalities for both heart disease and lung cancer have evolved toward less invasive yet curative approaches. Through strategic planning within an expanded MDT, we were able to integrate these advances and implement a dual minimally invasive treatment strategy.

### **Keyword(s)**

Lung Cancer, Robotic-Assisted Thoracic Surgery, Transcatheter Aortic Valve Implantation, Aortic Stenosis, Multidisciplinary Team

## **Persistent Air Leak from a Supernumerary Fissure after lobectomy**

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<sup>1</sup>*Thoracic surgery, Kakogawa central city hospital, Hyogo, Japan*

### **Objective**

To highlight a supernumerary fissure as an underrecognized source of persistent postoperative air leakage after lobectomy and emphasize the importance of tissue-based reinforcement in situations involving high postoperative mechanical stress.

### **Results**

A 58-year-old man with lung adenocarcinoma (cT2aN0M0 stage IB) underwent uniportal video-assisted thoracic surgery for right upper lobectomy. Intraoperatively, more than half of the right upper lobe was firmly adherent to the chest wall and mediastinum, likely related to a history of pneumothorax. A supernumerary fissure of the lower lobe was identified and appeared intact on gross inspection, and no air leakage was detected at the end of the procedure. On postoperative day 1, a massive air leak developed following forceful coughing. A blood patch was ineffective, and reoperation was performed. Intraoperative exploration revealed an air leak originating from a torn supernumerary fissure of the lower lobe. The leak point was repaired using a mediastinal fat pad secured with sutures, and air leakage was eliminated. During emergence from anesthesia, bucking caused recurrent bleeding and massive air leakage, necessitating immediate reoperation. After evacuation of approximately 100 mL of blood, a tear at the repaired site was identified and resutured. The post operative course was uneventful, and the patient was discharged on postoperative day 4.

### **Conclusions**

Supernumerary fissures represent a potential but often overlooked source of persistent postoperative air leakage, particularly under dynamic mechanical stress such as coughing. In such high-risk anatomical situations, tissue-based reinforcement providing bulk and elasticity, including mediastinal fat attachment, may offer a durable and practical solution for air leak control.

## Computed Tomography–Guided Ablation for Lung Cancer: A Real-World Experience

**Hao Wen Chen<sup>\*1</sup>; Sun Nou Chung<sup>2</sup>; Ning Chien<sup>3</sup>; Tzu Ning Kao<sup>4</sup>; Hsien Neng Huang<sup>5</sup>; Min Shu Hsieh<sup>6</sup>; Ling Kai Chang<sup>7,8</sup>; Mong Wei Lin<sup>4</sup>; Shun Mao Yang<sup>8</sup>**

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### Objective

To present the procedural safety and long-term oncological outcomes of treating lung malignancies with cone-beam computed tomography (CBCT)-guided microwave ablation (MWA) in a hybrid operating room (HOR) setting across National Taiwan University Hospital (NTUH) branches. Our goal was to evaluate whether this minimally invasive, lung-sparing technique could offer a safe and effective alternative for patients who are not good candidates for standard surgical resection.

### Methods

We retrospectively reviewed 70 patients with 88 lung nodules treated with CBCT-guided percutaneous MWA in HOR across NTUH branches between September 2020 and December 2024. The study evaluated overall survival (OS), progression-free survival (PFS), local tumor control, and procedure-related complications.

### Results

The procedure proved to be both safe and highly effective, with zero 30-day mortalities and no distant metastases observed during the follow-up period. At 1, 2, and 3 years, OS rates remained remarkably stable at 100%, while PFS rates were 91.8%, 88.8%, and 88.8%, respectively. Local tumor control was achieved in 94.3% of treated nodules at 1 and 2 years, and 93.2% at 3 years. Only six patients (8.6%) experienced local failure, which was successfully managed with salvage therapies such as repeat ablation or surgical resection. The overall complication rate was low and predominantly minor. Pneumothorax was the most common adverse event (11.4%), yet only two cases (2.9%) were classified as major complications requiring interventions. The mean hospital stay was exceptionally brief at 2.34 days.

### Conclusions

The NTUH experience demonstrates that CBCT-guided MWA performed in a HOR is a highly effective, lung-sparing, and safe therapeutic option for patients with lung cancer. It provides outstanding long-term survival and excellent local control with minimal perioperative morbidity.

**Keyword(s)**

Microwave Ablation, CBCT-Guided

## Simultaneous bi-lobar torsions after video-assisted thoracoscopic right upper lobe lobectomy

**Chung-Yun Kuan<sup>\*1</sup>**

<sup>1</sup>*Chest surgery, Taipei veteran general hospital, Taipei, Taiwan*

### Objective

Right middle lobe (RML) torsion was usually observed during the acute postoperative period of right upper lobe (RUL) lobectomy due to the completeness of the fissures. However, RML and right lower lobe (RLL) “bi-lobar” torsion after right upper lobe lobectomy has seldom reported. We herein present an exceptionally rare case of bi-lobar torsion that developed following RUL lobectomy with a literature review.

### Results

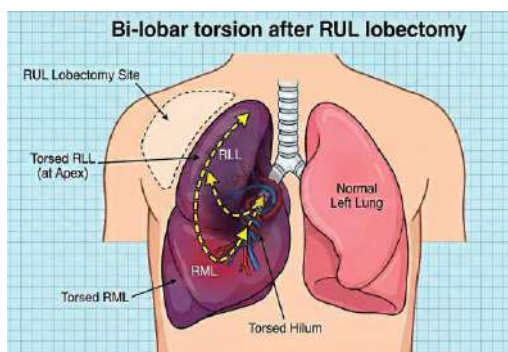
A 71-year-old male patient underwent RUL lobectomy due to adenocarcinoma of the lung. RML and RLL were well inflated and did not rotate before wound closure, so prophylactic pneumopexy was not performed. The patient developed progressive shortness of breath on postoperative day 2. The bronchoscopy revealed obliteration of the RML and RLL orifices. The chest computed tomography showed twisting bronchovascular pedicles of RML and RLL. Emergent VATS revealed clockwise torsion of the RML and RLL. Reduction and pneumopexy were performed. The patient was doing well and discharged on postoperative day 6.

### Conclusions

Bi-lobar torsion is a fatal complication requiring a high index of awareness of postoperative clinical symptoms and radiographic findings. Given the low incidence, making a clinical diagnosis can be challenging. We shared this case to establish a timely diagnosis and arrange prompt surgical intervention.

### Keyword(s)

Bi-Lobar Torsion, RUL Lobectomy, Complication



## Considerations on Bronchial Stump Leakage in Uniportal Thoracoscopic Pulmonary Resection; three case series

**Naoko Ose<sup>\*1</sup>; Takashi Kanou<sup>1</sup>; Toru Kimura<sup>1</sup>; Eriko Fukui<sup>1</sup>; Kenji Kimura<sup>1</sup>; Hideki Nagata<sup>1</sup>; Yasushi Shintani<sup>1</sup>**

<sup>1</sup>*General Thoracic Surgery, The University of Osaka, Osaka, Japan*

### Objective

The incidence of broncho-pleural fistula (BPF) following pulmonary resection using minimally invasive approaches in our department is low (0.4%). Among 190 patients who underwent uniportal video-assisted thoracoscopic surgery (UVATS), only one case developed postoperative BPF. All bronchial stumps are closed using staplers in UVATS. Bronchial stump-related complications were observed in three cases: two intraoperative air leaks and one postoperative BPF. These cases are presented, and potential risk factors and preventive measures are discussed.

### Results

#### Case presentations:

**Case 1:** A woman in her 70s underwent right upper lobectomy for lung cancer. Intraoperative air leakage was detected from the membranous portion at the center of the bronchial stump. The leak was repaired by mattress sutures with artificial pledget and covered with free mediastinal fat using fibrin glue. The postoperative course was uneventful.

**Case 2:** A man in his 60s underwent right lower lobectomy. A similar intraoperative air leak from the central membranous portion was identified and repaired using the same technique as in Case 1. No perioperative complications occurred.

**Case 3:** A man in his late 60s underwent right lower lobectomy. No intraoperative air leak was noted. Postoperatively, pleural effusion developed due to pleuritis, requiring drainage on postoperative day 21. After drain removal, pneumothorax occurred on postoperative day 29. Surgical exploration revealed a bronchial stump fistula. As no intrathoracic infection was present, the closure of fistula with thoracoscopic intercostal muscle flap reinforcement was performed, and the patient recovered without recurrence.

### Conclusions

#### Discussion and Conclusion:

In all three cases, air leakage originated from the central membranous portion of the bronchial stump. Each case exhibited early branching of the segmental bronchus, resulting in a near double-barrel configuration during stapling. Such anatomical variations may lead to insufficient closure at the central portion compared with the edges. When early bronchial branching is present, division at a more proximal single-lumen site should be considered. In addition, prophylactic reinforcement using autologous tissue coverage may help prevent bronchial stump complications.

### Keyword(s)

Bronchial Stump Leakage, Broncho-Pleural Fistula, Single Port VATS

## **Esophageal Tumor Stage Determines Survival After Surgical Treatment of Synchronous Head and Neck and Esophageal Cancer**

**Chi Cheng<sup>\*1</sup>; Fang Hsin-Yuan<sup>1</sup>; Lin Yu-Sen<sup>1</sup>; Lien Ming-Yu<sup>2</sup>; Shen Yu-Cheng<sup>1</sup>**

<sup>1</sup>surgery, China medical university hospital, Taichung, Taiwan <sup>2</sup>internal medicine, China medical university hospital, Taichung, Taiwan

### **Objective**

Synchronous head and neck cancer (HNC) and esophageal cancer (EC) in upper aerodigestive tract are due to “field-cancerization”. The prevalence of patients with HNC may have 15-20% developing a secondary EC in Taiwan and vice versa. The clinical outcome of synchronous diseases was not well understood. Operation is meditative but often complicated requiring multiple specialties. The relative prognostic impact of tumor stage at each site in surgically treated patients remain unclear.

### **Methods**

We retrospectively reviewed 24 patients from 2015 to 2017 with different stages of synchronous HNC and EC treated in China medical university hospital. Overall survival (OS) was identified as the time from surgery to death from any cause or last follow-up. Kaplan-Meier survival curves were generated and compared using the log-rank test. Cox proportional hazards regression was performed to evaluate the independent effects of HNC stage and EC stage, with adjustment for age, ECOG performance status, postoperative complications, and adjuvant therapy. An interaction term between HNC and EC stage was included to assess potential synergistic effects.

### **Results**

A total of 24 patients were included. Kaplan–Meier analysis showed no significant difference in OS among the four groups stratified by combined HNC and EC stage (log-rank  $p = 0.471$ ), although patients with advanced EC demonstrated a trend toward worse survival. In multivariable Cox analysis, advanced EC stage showed a strong trend toward increased mortality (HR 34.4, 95% CI 0.98–1207.7,  $p = 0.051$ ), whereas HNC stage was not associated with OS (HR 1.24,  $p = 0.83$ ). ECOG performance status, postoperative complications, and adjuvant therapy were not independently associated with survival. No significant interaction between HNC and EC stage was observed (HR 0.53, 95% CI 0.03–9.05,  $p = 0.659$ ).

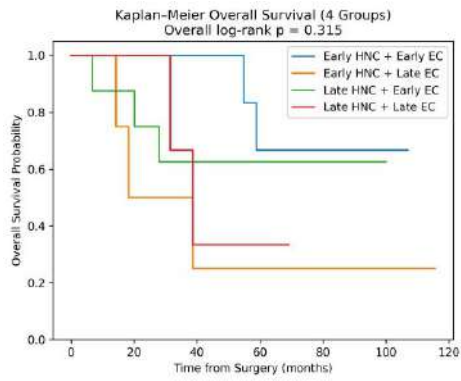
### **Conclusions**

In surgically treated patients with synchronous HNC and EC, esophageal tumor stage appears to be the primary determinant of overall survival, while HNC stage has limited prognostic impact. No synergistic effect between HNC and EC stage was identified. Larger studies are warranted to confirm these findings and refine risk stratification.

### **Keyword(s)**

Synchronous Cancer, Esophageal Cancer, Head And Neck Cancer, Overall Survival After Operation





## **Clinicopathological Features and Significance of Epidermal Growth Factor Receptor Mutation in Surgically Resected Early-Stage Lung Adenocarcinoma**

**Chao-Wen Lu<sup>\*1</sup>; Mong-Wei Lin<sup>1</sup>; Xu-Heng Chiang<sup>2</sup>; Hsao-Hsun Hsu<sup>3</sup>; Min-Shu Hsieh<sup>4</sup>; Jin-Shing Chen<sup>1</sup>**

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### **Objective**

The study aimed to analyze the postoperative prognosis and clinicopathological characteristics associated with epidermal growth factor receptor (EGFR) mutations in patients with surgically resected stage I and II lung adenocarcinoma. It also examined the specific impacts of common drug-treatable mutations, namely Exon 19 deletion and Exon 21 L858R.

### **Methods**

**Study Population:** A retrospective review of 1034 patients with pathological stage I or II lung adenocarcinoma who underwent pulmonary resection at National Taiwan University Hospital between January 2014 and December 2017.

**Mutation Analysis:** DNA was extracted from formalin-fixed, paraffin-embedded (FFPE) tumor samples and analyzed for EGFR mutations using MassARRAY genotyping.

**Statistical Analysis:** Clinicopathological features were compared using chi-squared and Student's t-tests. Survival outcomes (Disease-Free Survival [DFS] and Overall Survival [OS]) were evaluated via the Kaplan-Meier method, log-rank tests, and Cox regression models for multivariate analysis.

### **Results**

**Mutation Prevalence:** EGFR mutations were identified in 622 (60%) of the 1034 patients.

**Clinicopathological Features:** The EGFR-mutant group was significantly associated with older age (>65), higher CEA levels, non-lepidic histological subtypes, higher histological grade, more advanced pathological stage, and increased rates of pleural and lymphovascular invasion.

**Subtype Analysis:** Patients with the L858R mutation exhibited a more lepidic predominant histological type and less lymphovascular invasion compared to those with the Exon 19 deletion.

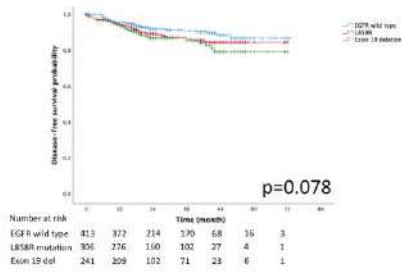
**Survival Outcomes:** In multivariate analysis, EGFR mutation status was not an independent predictor of DFS or OS. Key independent factors for poor prognosis included tumor size, lymphovascular invasion, and N1 lymph node metastasis. No significant survival differences were found between Exon 19 deletion and L858R subtypes.

### **Conclusions**

In early-stage (stage I and II) operable lung adenocarcinoma, EGFR mutation status is associated with several aggressive pathological features but does not significantly impact clinical prognosis (DFS or OS). Consequently, EGFR mutation status in this population should be viewed primarily as a predictor for response to tyrosine kinase inhibitor (TKI) therapy rather than a prognostic marker.

## Keyword(s)

Lung Adenocarcinoma, EGFR Mutation



## **Is Consolidation-to-Tumor Ratio Redundant When Solid Diameter Is Known? Incremental Value Analysis in Part-Solid Lung Adenocarcinoma**

**Takuya Tokunaga<sup>\*1</sup>; Shoichiro Morizono<sup>1</sup>; Yuto Nonaka<sup>1</sup>; Aya Takeda<sup>1</sup>; Go Kamimura<sup>1</sup>; Koki Maeda<sup>1</sup>; Junichi Murakami<sup>2</sup>; Toshiyuki Nagata<sup>1</sup>; Toshiki Tanaka<sup>2</sup>; Kazuhiro Ueda<sup>1</sup>**

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### **Objective**

The consolidation-to-tumor ratio (CTR) is widely used as a prognostic imaging marker in part-solid lung adenocarcinoma. However, because CTR is mathematically derived from solid tumor diameter, its incremental prognostic value beyond solid diameter remains uncertain. This study aimed to determine whether CTR provides additional prognostic information when solid tumor diameter is already considered.

### **Methods**

We retrospectively analyzed 1090 patients with resected lung adenocarcinoma presenting as part-solid nodules on thin-section computed tomography. Solid tumor diameter, total tumor diameter, and CTR were measured using standardized criteria. Recurrence-free survival (RFS) was evaluated using Cox proportional hazards models. Model discrimination was assessed using concordance indices (C-index), and incremental value was examined using likelihood ratio testing and Akaike information criterion (AIC).

### **Results**

During a median follow-up of 63.7 months, 120 RFS events were observed. Solid tumor diameter provided the largest improvement in model discrimination ( $\Delta$ C-index = 0.052) compared with tumor diameter ( $\Delta$ C = 0.022) and CTR ( $\Delta$ C = 0.032). The solid-only model demonstrated the lowest AIC. Likelihood ratio testing showed that neither tumor diameter nor CTR significantly improved model fit once solid diameter was included ( $p = 0.39$  and  $p = 0.79$ , respectively).

### **Conclusions**

Solid tumor diameter captures the majority of prognostic information conveyed by both total tumor diameter and CTR. Once solid diameter is incorporated, CTR provides minimal incremental value. These findings suggest that solid diameter alone may be sufficient for prognostic stratification in part-solid lung adenocarcinoma.

### **Keyword(s)**

Lung Cancer, Ground-Glass Nodule, Solid Diameter, Tumor Diameter, Consolidation-To-Tumor Ratio

## **Reframing Nodal Staging in Non-Small Cell Lung Cancer: Development and External Validation of Metastatic Node Count versus the 9th Edition N descriptor**

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### **Objective**

The 9th edition TNM system for non-small cell lung cancer (NSCLC) subdivides N2 disease. The number-based nodal (nN) classification has shown prognostic performance similar to the 8th N descriptor, but comparisons with the 9th N descriptor are limited. This study aimed to identify statistically valid cutoffs for the nN classification and to compare its prognostic discrimination with the 9th N descriptor.

### **Methods**

Patients with NSCLC who underwent lobectomy or more extensive resection were included. The SEER database (2010–2022) served as the training cohort, and an institutional dataset (2005–2022) as the validation cohort. These two cohorts were not merging and analyzed independently. Optimal cutoffs for nN classification were identified using pairwise log-rank tests and multivariable Cox models in validation cohort. Prognostic performance for overall survival (OS) was assessed in the validation cohort.

### **Results**

A total of 18,294 training cohort patients and 7,386 validation cohort patients were analyzed. In training cohort, Cutoffs of 1 and 4 metastatic lymph nodes were identified, defining four nN classes (0, 1, 2–4,  $\geq 5$ ). In the validation cohort, 5-year OS rates by nN class were 85.6%, 68.7%, 61.2%, and 44.4%, and all adjacent class comparisons were significant in multivariable Cox models ( $p < 0.001$ ). Prognostic discrimination was similar between the nN classification and the 9th N descriptor (5-year Net Reclassification Improvement = 0.000;  $p = 0.893$ ). The two systems had moderate correlation ( $\rho = 0.601$ ;  $p < 0.001$ ). In the single-node metastasis subgroup, survival did not differ between N1 and N2a ( $p = 0.440$ ), whereas patients with  $\geq 5$  metastatic lymph nodes showed worse survival in N2a and N2b ( $p < 0.001$  and  $p = 0.043$ ).

### **Conclusions**

The nN classification provides prognostic discrimination equivalent to the 9th N descriptor and may serve as a complementary tool.

### **Keyword(s)**

Non-Small Cell Lung Carcinoma, Metastatic Lymph Node Count, Prognostic Discrimination, SEER Database

## **Margin Distance as a Tumor Biology Surrogate for Risk Stratification After Lobectomy in Stage I NSCLC: A Retrospective Multi-Institutional Externally Validated Analysis**

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### **Objective**

The prognostic implications of resection margin distance after lobectomy for stage I non–small cell lung cancer (NSCLC) remain uncertain, as most prior studies have focused on sublobar resections where margin adequacy is surgically modifiable. Therefore, we evaluated whether margin distance and the margin-to-tumor ratio (MTR) are independent predictors of recurrence after lobectomy for stage I NSCLC and validated these findings in an external cohort.

### **Methods**

Between 2011 and 2021, we retrospectively analyzed data from 3,727 patients with pathologic stage I NSCLC who underwent lobectomy and validated findings in an independent cohort of 1,597 patients. Margin distance was defined as the shortest pathologic distance from the tumor edge to the bronchial resection margin, and the MTR indicated the distance divided by tumor diameter. Optimal cutoff values were identified using maximally selected log-rank statistics. Prognostic significance was assessed through multivariable Cox models, restricted cubic splines, and propensity score matching (PSM).

### **Results**

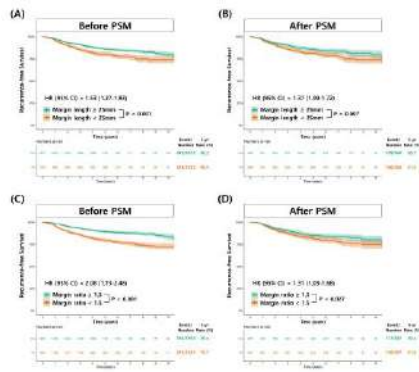
Cutoffs of 25 mm for distance and 1.5 for MTR provided the best discrimination of prognosis. In the multivariable analysis, margins < 25 mm and ratios < 1.5 were associated with inferior RFS (hazard ratio [HR], 1.34; p=0.002; and HR, 1.40; p<0.001, respectively), independent of tumor size, grade, and lymphovascular invasion. Propensity-matched analyses confirmed these associations, which were reproduced in the independent validation cohort.

### **Conclusions**

Margin distance and MTR were confirmed as independent, externally validated predictors of recurrence after lobectomy for stage I NSCLC. Quantitative margin assessment may improve postoperative risk stratification and help optimize surveillance strategies in early-stage disease.

### **Keyword(s)**

Lobectomy, Recurrence, Non-Small Cell Lung Cancer, Resection Margin, Thoracic Surgery



## Thoracic SMARCA4-Deficient Undifferentiated Tumor: A Case Report

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### Objective

Thoracic SMARCA4-deficient undifferentiated tumor (SMARCA4-UT) is a rare and highly aggressive malignancy strongly associated with heavy smoking. It is characterized by rapid progression and poor responsiveness to conventional chemotherapy. In recent years, emerging evidence has suggested a potential role for immunotherapy in its management. Here we report a case of primary pulmonary SMARCA4-UT.

### Results

A 57-year-old man with a 30-pack-year smoking history presented with blood-tinged sputum for two months. Chest computed tomography revealed a 6-cm mass in the right upper lobe (RUL) accompanied by severe emphysema and large bullae. Bronchoscopic biopsy failed to yield diagnostic malignant tissue, and CT-guided percutaneous biopsy was considered high risk due to underlying emphysematous changes. Therefore, the patient underwent video-assisted thoracoscopic surgery (VATS) right upper lobectomy for diagnostic and therapeutic purposes. Intraoperative frozen section analysis was inconclusive for malignancy. Final histopathological examination demonstrated diffuse sheets of poorly differentiated rhabdoid cells with extensive tumor necrosis. Immunohistochemical studies revealed complete loss of BRG1 (SMARCA4) expression and focal positivity for SALL4, confirming the diagnosis of SMARCA4-UT. The tumor was staged as IIIA (pT4N0M0). Programmed death-ligand 1 (PD-L1) expression was 5–10%. The postoperative course was uneventful. The patient subsequently received adjuvant chemoimmunotherapy consisting of paclitaxel, cisplatin, and pembrolizumab.

### Conclusions

SMARCA4-UT is a rare and highly aggressive thoracic malignancy that often presents significant diagnostic challenges due to extensive tumor necrosis and nonspecific biopsy findings. This case highlights the role of upfront surgical resection in selected patients and suggests that adjuvant chemoimmunotherapy may be a feasible therapeutic strategy.

### Keyword(s)

SMARCA4-UT



## **Surgical Management of Anterior Mediastinal Tumor in a High-Risk Elderly Patient with Myasthenic Crisis**

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### **Objective**

Anterior mediastinal tumors in elderly patients are often associated with significant perioperative risk, particularly when complicated by myasthenic crisis and cardiovascular comorbidities. Optimal surgical timing and multidisciplinary management remain crucial to improve outcomes.

### **Results**

The patient underwent surgical resection under carefully optimized hemodynamic and respiratory conditions. Postoperative neurological and respiratory status improved gradually. No perioperative catastrophic complications occurred. The patient was successfully managed in the ICU and transferred to the ward in stable condition.

### **Conclusions**

Anterior mediastinal tumor resection in elderly patients with myasthenic crisis and multiple comorbidities requires meticulous perioperative optimization and multidisciplinary coordination. Careful timing and structured critical care support can facilitate safe surgical intervention in high-risk patients.

### **Keyword(s)**

Anterior Mediastinal Tumor, Thymoma, Myasthenic Crisis

## **Elevated neuregulin-1 expression modulates tumor malignancy and autophagy in esophageal squamous cell carcinoma**

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### **Objective**

Esophageal squamous cell carcinoma (ESCC) has a poor prognosis, with a 5-year survival rate of <20%, underscoring the urgent need for novel therapeutic targets. Neuregulin-1 (NRG1), a transmembrane protein involved in cell proliferation and survival signaling, has an unclear biological role and clinical significance in ESCC. This study aimed to investigate the expression, biological function, and prognostic value of NRG1 in ESCC.

### **Methods**

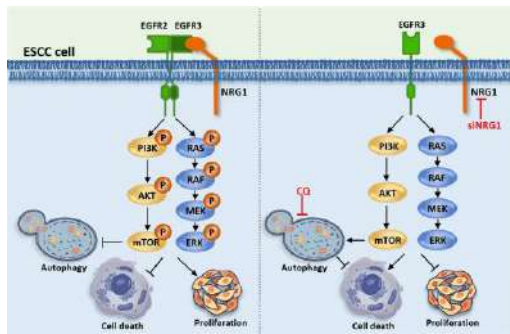
NRG1 expression was analyzed in ESCC patient samples and data from The Cancer Genome Atlas (TCGA). Reverse transcription-quantitative PCR and immunohistochemistry were used to assess NRG1 gene and protein expression in tumor and normal tissues. Functional assays were conducted following NRG1 silencing to evaluate changes in signaling pathways, including phosphorylated AKT and cRAF, as well as effects on cancer cell proliferation, migration, tumor sphere formation, and cell death. Autophagy-related changes were examined by assessing autophagosome and autolysosome formation, LC3B levels, and the effects of the autophagy inhibitor chloroquine.

### **Results**

NRG1 gene and protein expression levels were significantly higher in ESCC tumor tissues compared with normal tissues and were associated with poor clinical outcomes, particularly in advanced ESCC. Silencing NRG1 reduced mRNA and protein expression, disrupted p-AKT and p-cRAF signaling, and resulted in decreased cell proliferation, migration, and tumor sphere formation, alongside increased cell death. High expression levels of NRG1 and cRAF were significantly correlated with poor prognosis. NRG1 silencing promoted autophagosome and autolysosome formation and decreased LC3B levels. Inhibition of autophagy with chloroquine significantly enhanced cell death induced by NRG1 silencing, indicating that autophagy acts as a survival mechanism in ESCC cells. Moreover, high co-expression of NRG1 and LC3B was associated with worse prognosis.

### **Conclusions**

This study demonstrates that NRG1 plays a critical role in ESCC progression and survival by regulating oncogenic signaling pathways and autophagy. Targeting NRG1 in combination with autophagy inhibitors may represent a promising therapeutic strategy for the treatment of ESCC.



## **Unexpected Bronchopleural Fistula Following Tyrosine Kinase Inhibitor Therapy in Lung Adenocarcinoma: A Case Report**

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The 59-year-old man with a history of hypertension and diabetes mellitus presented with one month of vertigo. Chest radiography incidentally revealed a right upper lobe (RUL) mass. Subsequent staging workup and biopsy confirmed lung adenocarcinoma (cT4N2aM1b) with brain metastasis. The patient underwent whole-brain radiotherapy, followed by targeted therapy with osimertinib (Tagrisso) due to the detection of an epidermal growth factor receptor (EGFR) exon 21 L858R mutation.

One week after initiating osimertinib, he developed acute dyspnea and was admitted to the emergency department, where right pneumothorax with right lung total collapse was diagnosed. Despite pigtail drainage for 24 hours, persistent air leakage was observed. Chest computed tomography demonstrated a right upper lobe bronchopleural fistula. Emergent thoracotomy with right upper lobectomy, empyema debridement, and bronchial stump repair was performed. Surgical management successfully achieved lung re-expansion and marked clinical improvement.

Tumor necrosis resulting from good response to targeted therapy may precipitate life-threatening complications, particularly in patients with bulky tumors. Early recognition and timely surgical intervention are crucial for optimizing patient outcomes.

## **Combined Small Cell Lung Carcinoma Presenting as a Slowly Enlarging Part-Solid Pulmonary Nodule Successfully Treated with Surgery and Adjuvant Chemotherapy: A Case Report**

**Chiang, Chi-Hung<sup>1</sup> Li Lo<sup>1</sup> Tseng, Po-Wen<sup>1</sup> Chiu, Hsin-Yi<sup>1</sup> Chung, Cheng-Chin<sup>1</sup> Wu, Yu-Chung<sup>1</sup>**

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### **Background:**

Small cell lung carcinoma (SCLC) usually presents as a central mass with rapid growth and early dissemination. Combined SCLC is uncommon and may display atypical radiologic features.

### **Case Presentation:**

A 63-year-old man, heavy former smoker with multiple comorbidities, was incidentally found to have a part-solid nodule in the left upper lobe that increased in size from 1.2 cm to 1.5 cm within three months. He underwent video-assisted thoracoscopic wedge resection with mediastinal lymph node dissection. Pathology revealed poorly differentiated carcinoma with neuroendocrine features, positive for TTF-1, synaptophysin, chromogranin A, and INSM1, consistent with combined small cell carcinoma (type P). The patient subsequently received four cycles of adjuvant carboplatin and etoposide. At 18 months of follow-up, he remains disease-free without recurrence.

### **Conclusion:**

This case demonstrates an unusual presentation of combined SCLC as a part-solid pulmonary nodule and highlights the importance of integrating surgery and adjuvant chemotherapy in selected early-stage cases.

## **Robotic approach can remove more lymph nodes than VATS approach in anatomical lung resection surgeries for lung cancer**

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### **Objective:**

Systematic lymph node dissection is essential for accurate staging and optimal management of lung cancer. Although video-assisted thoracoscopic surgery (VATS) is the standard minimally invasive approach, robotic-assisted thoracic surgery (RATS) has been increasingly adopted. However, whether the technical advantages of the robotic platform translate into improved lymph node dissection remains uncertain. In patients undergoing lung resection for primary lung cancer, we compared lymph node dissection outcomes between RATS and VATS.

### **Methods:**

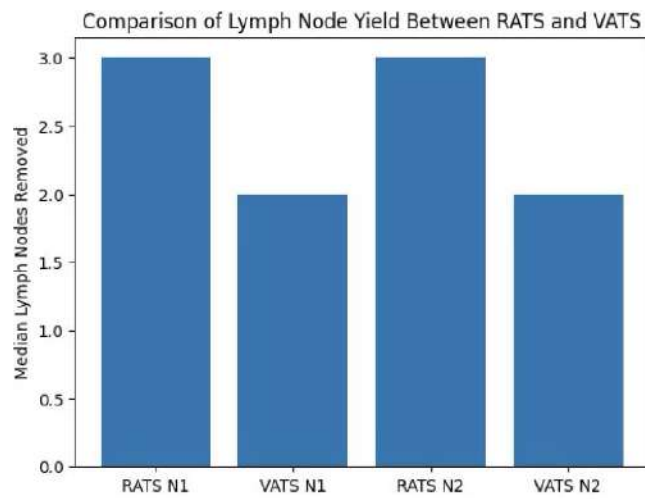
We conducted a retrospective cohort study of patients who underwent anatomical lung resection with systematic lymph node dissection for lung cancer at a single tertiary thoracic surgery centre between 2023 and 2025. Procedures were performed using either RATS or uniportal VATS by three experienced thoracic surgeons proficient in both techniques. The primary outcomes were the number of N1 and N2 lymph nodes removed. Comparisons between groups were performed using the Mann-Whitney U test, with statistical significance defined as  $p < 0.05$ .

### **Results:**

A total of 488 patients were included, of whom 75 underwent RATS and 413 underwent VATS. The median number of N1 lymph nodes removed was 3 with RATS and 2 with VATS. Although the RATS group demonstrated a numerically higher N1 lymph node yield, this difference did not reach statistical significance ( $p = 0.066$ ). In contrast, N2 lymph node yield was significantly higher with RATS. The median number of N2 lymph nodes removed was 3 with RATS compared to 2 with VATS (mean 3.23 vs 2.61), demonstrating a statistically significant difference between approaches ( $p = 0.005$ ).

### **Conclusions:**

RATS was associated with significantly greater mediastinal (N2) lymph node yield compared to VATS, while N1 lymph node harvest remained comparable. These findings suggest that the enhanced visualization and instrument dexterity of the RATS may facilitate more thorough mediastinal lymph node dissection and potentially improve nodal staging in lung cancer surgery.



## **Perioperative outcomes of robotic-assisted thoracic surgery segmentectomy for primary lung cancer: A Propensity Score-Matched Comparison with Video-Assisted Thoracic Surgery**

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### **Objective**

We compared perioperative outcomes of RATS lung segment resection in our department with VATS to verify its safety and efficacy.

### **Methods**

We reviewed 285 patients who underwent segmentectomy for primary lung cancer (Apr 2017–Dec 2025): RATS (n=116) and VATS (n=169). After propensity score matching, 98 pairs were analyzed. Surgical margin (SM) was assessed in cases measured since Feb 2021. As sensitivity analysis, inverse probability of treatment weighting (IPTW) was applied.

### **Results**

RATS had a higher rate of drain removal by postoperative day 1, shorter length of stay, and less blood loss (all  $p < 0.01$ ). Operative time, conversion to thoracotomy, vascular injury, major postoperative complications, and 30-day readmission were comparable; IPTW showed consistent results. No surgery-related mortality occurred. Median SM did not differ (2.5 vs 2.8 cm,  $p = 0.19$ ).

### **Conclusions**

RATS segmentectomy was associated with earlier drain removal and shorter hospitalization than VATS, with similar perioperative safety and comparable SM.

### **Keyword(s)**

RATS, Segmentectomy, Lung Cancer



## Subxiphoid uniportal robotic thymectomy using the da Vinci Xi system; initial outcomes

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### Objective

While multiportal subxiphoid robotic thymectomy facilitates complex procedures requiring combined resection of adjacent organs, conventional methods involve intercostal port placements, inevitably leading to postoperative intercostal neuralgia. To overcome this limitation, subxiphoid uniportal robotic thymectomy (SURT) utilizing the da Vinci Xi surgical system was developed.

### Methods

This retrospective study included 18 patients who underwent SURT at Fujita Health University Okazaki Medical Center between August 2023 and September 2025. SURT was executed using a dedicated "cross-arm technique." Three robotic arms were inserted through a single subxiphoid wound and strategically crossed to optimize the surgical workspace and avoid arm collision within the mediastinum.

### Results

The cohort comprised 10 males and 8 females (median age, 61.5 years; interquartile range [IQR], 48.5–75.8). Median operative and console times were 120 minutes (IQR, 106–168.8) and 80.5 minutes (IQR, 62.5–116.8), respectively. Median estimated blood loss was 5 g (IQR, 5–6.5). Postoperative drainage duration was remarkably short: 0 days (13 patients), 1 day (4 patients), and 2 days (1 patient). Median postoperative hospital stay was 3 days (IQR, 3–4). Combined resection (left lung and pericardium) was safely achieved in one case. Pathological diagnoses revealed thymoma (9 cases), thymic cyst (8 cases), and thymic carcinoma (1 case). There were zero postoperative complications and no in-hospital mortalities. Two surgeons performed the procedures, reflecting procedural reproducibility.

### Conclusions

SURT provides a favorable midline operative view, profound minimal invasiveness, and excellent surgical operability, safely avoiding intercostal nerve injury through careful subxiphoid port positioning. However, a limitation of this procedure is the absence of a dedicated retraction arm. Consequently, the assistant must expose the surgical field using long cotton swabs or a suction device through the narrow wound space. Additionally, interference between the left and right arms may occasionally occur. The key to preventing this interference is to move the camera while keeping both arms centered within its field of view.

### Keyword(s)

Robotic Thymectomy, Uniportal, Subxiphoid

## **Feasibility and Early Outcomes of Robotic-assisted Thoracic Surgery using Single Port System through intercostal approach**

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### **Objective**

Since its introduction into robotic-assisted thoracic surgery, the single-port robotic system has been applied almost exclusively through the outside-the-cage approach, as the 2.5-cm cannula diameter exceeds the typical width of the intercostal space. However, while the outside-the-cage approach provides broad access to the thoracic cavity from its most caudal aspect, it presents two potential limitations. First, for apical pathologies, the instrument length may be insufficient to comfortably reach the target area. Second, and more critically, in the event of major pulmonary vessel bleeding, the outside-the-cage incision trajectory may hinder timely proximal vascular control due to its longer and more tangential path to the hilum. Building upon these considerations, we explored the feasibility of an intercostal single-port robotic approach for thoracic procedures.

### **Methods**

Between 2025/6 and 2025/9, a total of 33 patients underwent robotic-assisted thoracic surgery using the single port robotic system and 12 patients were through intercostal approach. Clinical data of these patients were retrospectively reviewed to assess procedural feasibility and perioperative safety.

### **Results**

Using the float docking technique, the three instrument arms were fully deployed before entry and then positioned at the extreme right, left, and inferior margins of the intercostal site. This configuration provided sufficient clearance for insertion of the 1.6-cm camera while minimizing instrument crowding at the chest wall and reducing torque at the access site. Procedures included lung resection (lobectomy or segmentectomy) in four patients, esophagectomy in three, posterior mediastinal disease in five. All operations were successfully completed without conversion to thoracotomy or the addition of ports. Two patients experienced postoperative complications of Clavien–Dindo grade  $\geq$  II. There was no operative mortality, and the median length of postoperative stay was 4 days.

### **Conclusions**

Robotic-assisted thoracic surgery using single port system through an intercostal approach is feasible and safe across a spectrum of thoracic procedures. Strategic instrument alignment achieved through the float docking technique allows atraumatic insertion of the robotic arms and camera through the intercostal space while maintaining adequate intrathoracic working volume.

### **Keyword(s)**

Single Port Robotic Surgery, Intercostal Approach

## Initial experience of D-RATS Using Japanese Robotic Surgical System Hinotori

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### Objective

At our institution, we have been performing Uniportal RATS using the Da Vinci Xi system. However, due to setup constraints with the Japanese robotic surgical system Hinotori developed at our university, we have introduced Dual port RATS (D-RATS), and we report the initial outcomes.

### Methods

We began performing D-RATS using Hinotori in November 2025, and we present case examples. The setup involves placing a window of approximately three finger-widths at the 5th or 6th intercostal space on the anterior axillary line, inserting one arm and a 0-degree camera scope. Additionally, a port is created at the axillary line three intercostal spaces below, and another arm is inserted. The assistant is responsible for stapling, energy device operation, and surgical field exposure through the window.

### Results

We performed 5 lobectomies and 1 segmentectomy. The mean operative time was 155 minutes, and the median blood loss was 10 ml. There were no cases requiring additional ports, conversion to multiport approach, or conversion to open thoracotomy. One case developed postoperative chylothorax, but no other perioperative complications were observed. Since Hinotori is a docking-free system, sufficient working space at the bedside was secured, facilitating the assistant's surgical field exposure and stapling procedures. Additionally, while Uniportal RATS is difficult because the safety mechanism stops the system when arms interfere with each other, D-RATS proved useful as interference within the thoracic cavity becomes more easily recognizable.

### Conclusions

D-RATS using the domestic robot Hinotori demonstrated good operability for the assistant due to the docking-free system and could be performed safely in combination with fusion surgery. Further case accumulation and technical improvement are necessary to clarify its clinical utility.

### Keyword(s)

Robotic Surgery, Dual Port, Lung Resection

## **Robotic Thymectomy for Anterior Mediastinal Tumors: Lateral versus Subxiphoid Approach**

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*<sup>1</sup>Thoracic and Cardiovascular surgery, Asan Medical Center, Seoul, Republic of Korea*

### **Objective**

Robotic-assisted thoracic surgery (RATS) thymectomy has been increasingly adopted for the management of anterior mediastinal tumors. Various surgical approaches and port configurations are currently used, including lateral and subxiphoid approaches, with expanding application across different robotic platforms. However, comparative evidence between these approaches remains limited. This study aimed to compare perioperative outcomes between the lateral and subxiphoid approaches in RATS thymectomy.

### **Methods**

We retrospectively reviewed consecutive patients who underwent RATS thymectomy for anterior mediastinal tumors between October 2020 and December 2025 at a single institution. Demographic characteristics, operative details, and postoperative outcomes were compared between the lateral and subxiphoid approach groups.

### **Results**

A total of 236 patients were included: 109 (46.2%) underwent the lateral approach and 127 (53.8%) the subxiphoid approach. The subxiphoid group was older than the lateral group ( $55.6 \pm 12.9$  vs.  $51.4 \pm 12.5$  years,  $P = 0.013$ ). There were no significant differences in sex, body mass index, presence of myasthenia gravis, number of comorbidities, ECOG performance status, pulmonary function, or clinical tumor size between the groups. Operative time was similar ( $113.8 \pm 35.7$  vs.  $110.0 \pm 44.2$  minutes,  $P = 0.474$ ). Rates of combined resection ( $11.9\%$  vs.  $8.7\%$ ,  $P = 0.541$ ) and complete resection ( $98.2\%$  vs.  $97.6\%$ ,  $P = 0.99$ ).

### **Conclusions**

The lateral and subxiphoid approaches for RATS thymectomy demonstrated similar perioperative outcomes. These findings suggest either approach may be selected without compromising short-term surgical results.

### **Keyword(s)**

Robotic-Assisted Thoracic Surgery, Thymectomy

## **Clinical Evaluation of "Fusion D-RATS": Robotic-Assisted Anatomical Lung Resection Using Assistant-Side Staplers**

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### **Objective**

In dual-portal robotic-assisted thoracic surgery (D-RATS), the use of robotic staplers (RS) has made surgery easier and safer. However, anatomical constraints or intraoperative requirements occasionally necessitate the concurrent use of assistant-side staplers (AS). This study evaluated the perioperative outcomes of our "Fusion D-RATS" approach defined by the intraoperative utilization of AS.

### **Methods**

Between May 2023 and December 2025, 148 patients underwent D-RATS anatomical lung resection at our institution. We retrospectively analyzed 29 cases (19.6%) categorized into the Fusion group where AS was utilized.

### **Results**

A total of 29 patients were included in this study. Median age was 71 years (interquartile range (IQR), 63-78), and 19 patients (65.5%) were men. The Fusion group comprised 17 lobectomies and 12 segmentectomies. The primary reason for employing AS was the difficulty of maneuvering the RS in narrow spaces during vascular and bronchial procedures, due to limited range of motion. The median operative and console times were 122 minutes (IQR: 90-142) and 100 minutes (IQR: 70-118), respectively. The median intraoperative blood loss was 0 g (IQR: 0-6). Postoperative outcomes were favorable, with a median drainage duration of 1 day (IQR: 1-1) and a median hospital stay of 3 days (IQR: 3-4). Three patients (10.3%) developed Clavien-Dindo grade I-II postoperative complications consisting of prolonged air leak (n=2) and atrial fibrillation (n=1), while no grade III-IV complications were observed. There was no conversion to thoracotomy and additional ports were required in no patient. No perioperative deaths or complications directly attributable to the robotic procedure were observed.

### **Conclusions**

While RS provides high precision, AS remains a versatile and essential option in scenarios involving restricted intraoperative space or diagnostic uncertainty. Our findings suggest that the "Fusion D-RATS" approach is a safe and effective strategy for successfully completing anatomical lung resection via D-RATS, representing a viable surgical option.

### **Keyword(s)**

Dual-Portal Robotic-Assisted Thoracic Surgery (D-RATS), Fusion D-RATS

## **Single-Stage Hybrid Operating Room Localization and Robotic-Assisted Resection for Non-palpable Intrathoracic Tumors: A Prospective Case Series**

**Jui-Yu Weng<sup>\*1</sup>; Yu-Wei Liu<sup>1</sup>; Shah-Hwa Chou<sup>1</sup>; Po-Chih Chang<sup>1</sup>; Jui-Ying Lee<sup>1</sup>; Yu-Ting Lo<sup>1</sup>; Kai-Hua Chen<sup>1</sup>; Ting-Wei Chang<sup>1</sup>**

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### **Objective**

Robotic-assisted thoracic surgery (RATS) offers superior visualization and dexterity for anatomical resections. However, the inherent lack of tactile feedback poses a significant challenge in identifying small, non-palpable pulmonary nodules (SPNs). Traditional two-stage workflows—involving localization in a radiology suite followed by transfer to the operating room—carry risks of marker dislodgement and transport-related complications. This study evaluates the clinical feasibility and safety of a streamlined, single-stage paradigm utilizing hybrid operating room (HOR) localization followed immediately by robotic resection.

### **Methods**

We prospectively analyzed 12 consecutive patients who underwent single-stage HOR localization using the ARTIS pheno system and da Vinci Xi robotic resection between November 2025 and February 2026. Under general anesthesia, target lesions were localized via robotic C-arm-guided percutaneous patent blue dye injection, followed immediately by RATS in the same surgical setting. Data were extracted from a prospectively maintained institutional database.

### **Results**

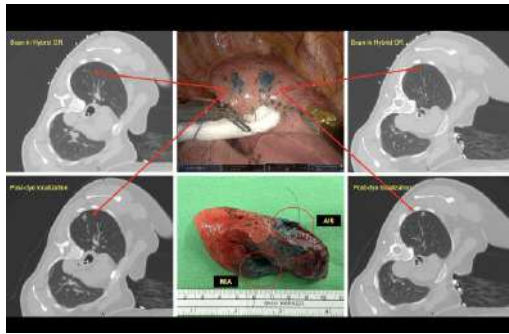
The cohort included four wedge resections, seven segmentectomies for early-stage lung cancer, and one excision of an extrapleural tumor. The success rate for both localization and resection was 100%. No intraoperative or postoperative complications occurred, and R0 resection was achieved in all cases without the need for re-resection. While median operative time and hospital length of stay were comparable to a control group undergoing standard robotic lung resections, the localization-to-resection interval was significantly reduced.

### **Conclusions**

A single-stage HOR workflow integrating image-guided localization with robotic resection is a safe, efficient, and reproducible strategy for managing occult pulmonary nodules and deep intrathoracic lesions. By eliminating the "time-at-risk" between localization and incision, this approach effectively overcomes the inherent sensory limitations of the robotic platform while maintaining surgical outcomes equivalent to conventional multi-stage procedures.

### **Keyword(s)**

Robotic-Assisted Thoracic Surgery, Hybrid Operating Room Localization



## Transitioning from Multi-port to Single-Port Robotic Lobectomy: Initial Experience and Perioperative Outcomes

**Junghee Lee\***<sup>1</sup>

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### Objective

The Da Vinci SP system enables complex maneuvers through a single 2.5-cm incision, potentially reducing surgical trauma compared to multi-port systems. While robotic-assisted thoracoscopic surgery (RATS) is well-established, clinical data for the SP platform in major pulmonary resections are still evolving. This study evaluates the initial experience and safety of robotic SP lobectomy by comparing its perioperative outcomes with the conventional multi-port Xi system.

### Methods

We retrospectively reviewed 205 patients (Multiport including Xi and dV5: n=186, SP: n=19) who underwent robotic lobectomy for lung cancer (Nov. 2023 - Oct.2025). Baseline characteristics, including clinical stage and tumor size, and perioperative outcomes, such as total operation time, console time, total lymph node (LN) count, and hospital stay, were analyzed to assess the feasibility of the SP platform.

### Results

The mean age was 54.6 years in the SP group and 63.8 years in the Multiport group. Clinical stage I was predominant in both groups (63% in SP vs. 76% in Multiport). Regarding surgical outcomes, the SP group achieved acceptable efficiency despite the initial adoption phase: total operation time was  $133 \pm 42.0$  min (SP) vs.  $117 \pm 44.5$  min (Xi), and console time was  $101 \pm 33.8$  min (SP) vs.  $82.6 \pm 31.1$  min (Xi). The total LN count confirmed oncological radicality in both groups (19.7 in SP vs. 23.2 in Multiport). Postoperative hospital stay showed no significant difference ( $5.0 \pm 2.65$  days vs.  $4.74 \pm 2.56$  days,  $p=0.223$ ). Notably, there were no conversions to open surgery or major complications (Clavien-Dindo Grade  $\geq$  III) in the SP cohort.

### Conclusions

Robotic SP lobectomy is a safe and feasible alternative to the conventional multi-port system for lung cancer treatment. Even during the initial learning curve, the SP system achieved comparable oncological and recovery outcomes, demonstrating its potential as a promising minimally invasive platform for major pulmonary resection.



## **Learning signals in robotic assisted bronchoscopy-guided ablation: session and per nodule time based cumulative sum analysis**

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### **Objective**

Robotic assisted bronchoscopy (RAB)-guided ablation is increasingly used for minimally invasive local treatment of lung lesions, yet its learning curve is poorly defined and can be confounded by multi nodule sessions. This feasibility study aimed to describe operator learning and to compare session level versus per nodule learning signals when multi nodule sessions are present.

### **Methods**

We conducted a single-center retrospective study of consecutive RAB-guided microwave ablations performed by one operator without prior RAB-guided ablation experience at Prince of Wales Hospital from December 2021 to June 2025. The efficiency metric was navigation plus ablation time. Learning phase transitions were explored using two approaches. First, traditional cumulative sum (CUSUM) of time was constructed at the session level and modelled with a three-segment piecewise linear fit to identify two breakpoints. Second, a per nodule CUSUM monitoring curve was constructed as CUSUM of time minus a target, where the target was the median per nodule time of the latest 30 percent of nodules. Two breakpoints were identified on the monitoring curve using a piecewise approach.

### **Results**

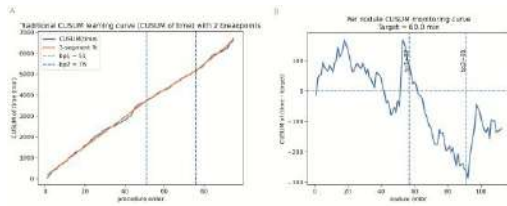
The cohort comprised 112 nodules. Median navigation plus ablation time decreased from 68.5 minutes in the earliest 30 percent of sessions to 63.0 minutes in the latest 30 percent, an 8.0 percent relative reduction. Mean session time changed little, reflecting substantial variability. Traditional CUSUM of time suggested two phase transitions at procedure orders 51 and 76 (Figure 1A). The per nodule CUSUM monitoring curve identified two breakpoints at nodule orders 57 and 91 (Figure 1B), with an overall downward trajectory after the first breakpoint indicating improved efficiency relative to the target.

### **Conclusions**

Using a per-nodule, novel CUSUM framework, RAB-guided microwave ablation demonstrated a reproducible three-phase learning pattern. Session level cumulative sum of time is smooth and may be less sensitive, whereas per nodule target centred monitoring better highlights phase transitions in multi nodule practice, supporting prospective capture of nodule level timing for future risk adjusted modelling.

### **Keyword(s)**

## Robotic Assisted Bronchoscopy, Microwave Ablation, Learning Curve, Cumulative Sum



## Preparation for the Safe Initiation of Single-Port Robotic-Assisted Thoracic Surgery (SP-RATS): Initial 20 Procedures

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### Objective

In our hospital, over 300 robot-assisted thoracic surgeries (RATS) were performed annually. In 2025, we introduced single-port (SP) RATS. Safe initiation requires meticulous preparation, given the limited number of high-volume centers and the resulting scarcity of guidance. Prior to launch, we visited Mie University, Japan, where six surgeons, nurses, and clinical engineers participated in 11 lung resections and 3 thymectomies. We also visited Korea University Gro Hospital, observing two anatomical lung resections and one thymectomy. Best practices from both centers were integrated into our manual. SP-RATS was initiated simultaneously by three experienced Xi proctors, in line with our policy of team-based RATS performed collaboratively by all department members. This team-oriented approach not only ensures safety during the learning phase but also facilitates the secure expansion of operators in the future, allowing us to pursue and expand this collaborative model for SP-RATS as well. This study was aimed to evaluate our initial cases and assess the effectiveness of our preparation.

### Methods

We retrospectively reviewed 20 consecutive SP-RATS cases. Patient characteristics and perioperative outcomes were analyzed.

### Results

Lung Resections (n=11): Median age 69 years; 4 males; 10 primary lung cancers, 1 metastasis; median tumor size 24 mm; all cN0; median SUVmax 2.3; emphysema in 2 cases; incomplete fissure in 3 cases. Procedures: 9 lobectomies, 2 segmentectomies. Median operative time 169 min; blood loss 5 g. Complications: 1 grade 3 cerebral infarction. Median hospital stay 5 days. Thymectomies (n=9): Median age 62 years; 4 females; 8 thymic epithelial tumors, 1 cyst; median tumor size 38 mm; median SUVmax 3.0; no myasthenia gravis. All total thymectomies. Median operative time 177 min; blood loss 0 g. Complications: 1 grade 3 pleuritis requiring readmission/drainage. Median hospital stay 4 days. All procedures were completed successfully with no conversions to open thoracotomy.

### Conclusions

SP-RATS presents unique challenges compared to Xi, including a distinctive SP access and more constrained manipulation. Even with experience in Xi, these differences make SP-RATS far from straightforward to initiate. Through meticulous preparation, we safely introduced SP-RATS in our department. We plan to increase the number of operators, adhering to our institutional policy of team-based RATS involving all department members.

**Keyword(s)**

Single-Port Robotic-Assisted Thoracic Surgery, Da Vinci SP, Robotic-Assisted Thoracic Surgery,  
Minimally Invasive Approach, SP-RATS

## INTERCOSTAL ROBOTIC LUNG RESECTION USING THE DA VINCI SP SYSTEM

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### Objective

The da Vinci SP system has had limited adoption for intercostal thoracic approaches because of concerns regarding port placement and instrument maneuverability, while subcostal access may be constrained by patient habitus. We report our initial clinical experience with intercostal SP robotic lung resection for non-small cell lung cancer (NSCLC).

### Methods

Between October 2024 and December 2025, 28 consecutive patients with NSCLC underwent intercostal SP robotic lung resection, including lobectomy (n=20) and segmentectomy (n=8). All patients underwent systematic node dissection. The SP robotic port was placed through the fifth or sixth intercostal space. Procedures were performed using a uniportal approach without CO<sub>2</sub> insufflation or a biportal approach with an assistant access port in the eighth intercostal space and CO<sub>2</sub> insufflation.

### Results

The median tumor size and consolidation-to-tumor ratio were 28 mm (range, 10–45) and 1.0 (0.3–1.0), respectively. Clinical stages were IA1 (n=6), IA2 (n=5), IA3 (n=12), IB (n=3), and IIA (n=2). All intercostal SP robotic lung resections were completed without conversion. R0 resection was achieved in all cases, with a median of 17 lymph nodes harvested (3–33). The median docking and console times were 7 (2–28) and 88 (46–183) minutes, respectively. Median operative time was 120 (70–222) minutes for lobectomy and 105 (80–141) minutes for segmentectomy, with stabilization after approximately 10 cases. There were no major complications (Clavien–Dindo ≥ III). Minor complications (Clavien–Dindo II) occurred in three patients. Median postoperative hospital stay was 4 days (2–13).

### Conclusions

Intercostal robotic lung resection using the da Vinci SP system is feasible and safe in patients with NSCLC, achieving complete oncologic resection with early stabilization of operative performance. The intercostal approach constitutes a viable alternative to subcostal access for SP robotic lung surgery.

## **From Trial to Routine Practice: Single-Surgeon Outcomes of single port robotic lung resection for lung cancer**

**Chia-Wei Chang<sup>\*1</sup>; Chuan Cheng<sup>2</sup>; Yin-Kai Chao<sup>1</sup>**

<sup>1</sup>*Division of Thoracic Surgery, Chang Gung Memorial Hospital-Linkou, Taoyuan, Taiwan* <sup>2</sup>*Division of Thoracic Surgery, New Taipei Municipal Tu-Cheng Hospital, New Taipei City, Taiwan*

### **Objective**

Single-port (SP) robotic lung resection has demonstrated promising perioperative outcomes in clinical trials; however, the reproducibility of these results after regulatory approval and broader clinical adoption remains unclear. We aimed to compare outcomes between the clinical trial phase and subsequent real-world implementation in a single-surgeon series.

### **Methods**

We conducted a retrospective comparative study of consecutive patients undergoing SP robotic lung resection by a single surgeon. The initial 33 cases were performed under a prospective clinical trial protocol between August 2022 and May 2023 (trial phase). Following regulatory approval for routine clinical use, the subsequent 28 consecutive cases performed between June 2025 and January 2026 constituted the real-world phase. Patient characteristics, procedural profiles, and perioperative outcomes were compared.

### **Results**

The real-world cohort demonstrated comparable baseline characteristics but a higher adoption of segmentectomy (15.2% vs. 28.6%). The real-world phase achieved a higher lymph node yield (21.4 vs. 15.6,  $p=0.019$ ) and a shorter console time (135 vs. 163 minutes,  $p=0.024$ ). Overall complication rates were similar between groups; however, the real-world cohort had a significantly shorter length of hospital stay (2.7 vs. 4.0 days,  $p=0.013$ ).

### **Conclusions**

Transition of SP robotic lung resection from a controlled trial environment to routine clinical practice was associated with maintained safety and enhanced procedural efficiency. These findings support the procedural maturity, scalability, and real-world generalizability of the SP robotic platform.

### **Keyword(s)**

Single-Port Robotic Lung Surgery, Lung Cancer, Real-World Implementation, Single-Surgeon Outcomes, Segmentectomy, Lymph Node Yield

## **Intrathoracic Robotic Resection of a Rare Chest Wall Hibernoma: A Novel Single-Stage Paradigm Leveraging Hybrid OR Localization**

**Kai-Hua Chen<sup>\*1</sup>; Yu-Wei Liu<sup>1</sup>; Shah-Hwa Chou<sup>1</sup>; Po-Chih Chang<sup>1</sup>; Jui-Ying Lee<sup>1</sup>; Jui-Yu Weng<sup>1</sup>**

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### **Objective**

Hibernoma is a rare benign soft tissue tumor originating from residual brown adipose tissue. It occurs predominantly in adults and is most commonly found in the thigh, accounting for less than 2% of benign lipomatous tumors. Although typically slow-growing and asymptomatic, hibernomas are characteristically hypermetabolic on FDG-PET/CT due to the high mitochondrial content of brown fat. This intense metabolic activity often leads to a false-positive suspicion of malignancy, particularly in patients with a known history of cancer. In the thoracic region, identifying and resecting small or deep-seated lesions can be technically demanding. Leveraging advanced platforms like the ARTIS pheno for localization and the da Vinci Xi for resection allows for a more streamlined and accurate surgical intervention.

### **Results**

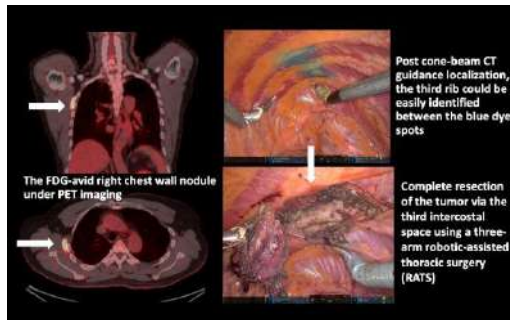
A 57-year-old male with a history of acral melanoma underwent a surveillance PET/CT, which revealed a solitary, intensely FDG-avid (SUVmax 12.4) nodule in the right chest wall. Physical examination revealed no palpable mass. To ensure accurate identification of this small, non-palpable lesion and to minimize surgical trauma, a single-stage hybrid OR workflow was utilized. After the induction of general anesthesia, the patient was positioned for a robotic C-arm CBCT scan. The lesion was localized with percutaneous patent blue dye under real-time guidance. Immediately following localization, the da Vinci Xi robotic system was docked. Using a three-arm configuration, the tumor—located adjacent to the third intercostal space—was excised with clear margins. The patient was discharged on postoperative day two without complications. Final pathology revealed multivacuolated adipocytes with granular eosinophilic cytoplasm, confirming a hibernoma.

### **Conclusions**

To our knowledge, this case may represent the first reported instance of a chest wall hibernoma resected via an intrathoracic robotic-assisted approach following hybrid operating room (HOR) localization. The integration of HOR-guided blue dye localization is the linchpin of this workflow. It provides the surgeon with a definitive "target" in a platform that otherwise lacks tactile feedback, ensuring that the robotic resection is both minimally invasive and oncologically sound. This combined strategy is not only safe and effective for anatomically challenging deep chest wall tumors but also represents a valuable, reproducible paradigm for the future management of occult thoracic lesions.

### **Keyword(s)**

RATS, Hybrid OR Localization, Chest Wall Hibernoma





## Perioperative outcomes of robot-assisted thoracoscopic surgery and open surgery for large anterior mediastinal tumors

**Yoshitaka Kitamura<sup>\*1</sup>; Ryosuke Izawa<sup>1</sup>; Takefumi Doi<sup>1</sup>; Hiroyuki Ogawa<sup>1</sup>; Daisuke Hokka<sup>1</sup>;  
Shinya Tane<sup>1</sup>; Yoshimasa Maniwa<sup>1</sup>**

*<sup>1</sup>Division of Thoracic Surgery, Kobe University Graduate School of Medicine, Kobe, Japan*

### Objective

The aim of this study was to evaluate perioperative outcomes of robot-assisted thoracoscopic surgery (RATS) in patients with large anterior mediastinal tumors ( $\geq 5$  cm) compared with open surgery.

### Methods

We retrospectively reviewed patients with anterior mediastinal tumors measuring  $\geq 5$  cm on preoperative imaging who underwent either open surgery or RATS at our institution between January 2010 and July 2025. RATS was introduced at our institution in June 2018 and has been applied to anterior mediastinal tumors  $\geq 5$  cm since April 2021. Perioperative outcomes were compared between the two groups.

### Results

Among 114 eligible patients, 26 (22.8%) underwent RATS and 88 (77.2%) underwent open surgery. The pathological diagnoses were as follows: thymic epithelial tumors (9 vs. 55), malignant anterior mediastinal tumors (2 vs. 15), and benign tumors (15 vs. 18) in the RATS and open surgery groups, respectively. There was no significant difference in the median preoperative tumor size between the RATS and open surgery groups (68.5 mm vs. 65.5 mm,  $p=0.55$ ). The median operative time was significantly shorter in the RATS group than in the open surgery group (116.0 min vs. 216.5 min,  $p<0.001$ ). No patient required conversion from RATS to open surgery. Combined resection of adjacent organs was performed more frequently in the open surgery group than in the RATS group (49/88 vs. 4/26,  $p=0.01$ ). The incidence of postoperative complications was comparable between the two groups ( $p=0.746$ ).

## **Conclusions**

Open surgery remains an indispensable approach for selected patients with large anterior mediastinal tumors. However, RATS may be a safe and feasible alternative to open surgery in appropriately selected patients.

## **Keyword(s)**

Mediastinal Tumor, Robot-Assisted Thoracoscopic Surgery

## **Combined Esophageal Endoscopic Submucosal Dissection and Robotic Mediastinal Lymphadenectomy: A Novel Hybrid Approach in Esophageal Cancer, Case Report**

**Tzu-wei Kuo<sup>2</sup> Po-chun Chang<sup>1</sup> Tzu-ping Chen<sup>1</sup> Yin-Kai Chao<sup>2</sup> Chi-hsiao Yeh<sup>2</sup> Yun-hen Liu<sup>2</sup>**

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We report the first case of synchronous esophageal endoscopic submucosal dissection (ESD) and robotic mediastinal lymphadenectomy for salvage treatment of esophageal cancer. A 61-year-old male with esophageal squamous cell carcinoma (initial stage T3N3M1a) underwent definitive concurrent chemoradiotherapy (CCRT). Post-CCRT evaluation revealed two lesions: complete remission at 35–40 cm and a partially regressed lesion at 25 cm from the incisors. Restaging showed T1N1M0 disease with a positive right upper paratracheal node. The patient underwent combined esophageal ESD and robotic lymphadenectomy in a single session. The metastatic node was firmly adherent to the right recurrent laryngeal nerve, which was sacrificed during dissection. The postoperative course was uneventful except for hoarseness and temporary nasogastric feeding for 5 days. Pathology confirmed T1b carcinoma at the esophageal lesion. The patient recovered well without further complications. This case highlights the feasibility and potential advantages of a novel hybrid minimally invasive approach that integrates endoscopic resection with robotic lymphadenectomy, enabling curative salvage management of residual esophageal cancer with nodal involvement.

## Clinical Outcomes of Subxiphoid Extended Thymectomy in Patients with Myasthenia Gravis

**Mizuki Morota<sup>\*1</sup>; Takahiro Negi<sup>1</sup>; Daisuke Tochii<sup>1</sup>; Sachiko Tochii<sup>1</sup>; Takashi Suda<sup>1</sup>**

*<sup>1</sup>Thoracic surgery, Fujita Health University Okazaki Medical Center, Aichi, Japan*

### Objective

Video-assisted thoracoscopic surgery (VATS) has increasingly been adopted worldwide for extended thymectomy in patients with myasthenia gravis (MG). In our department, subxiphoid uniportal VATS or subxiphoid uniportal robotic-assisted thoracic surgery (RATS) is the standard approach for anterior mediastinal tumors. When the primary lesion extends cranially beyond the left brachiocephalic vein, a combined subxiphoid and bilateral intercostal multiport RATS approach is selected. The same strategy has been applied to MG, aiming to minimize surgical invasiveness and prevent postoperative myasthenic crisis.

### Methods

We retrospectively analyzed 10 consecutive patients who underwent extended thymectomy for MG between April 2020 and June 2025.

### Results

The cohort consisted of 7 patients with thymoma-associated MG, 2 with early-onset MG, and 1 with late-onset MG. The median preoperative anti-acetylcholine receptor antibody level was 16 nmol/L (interquartile range [IQR], 8.7–19). Preoperative medical treatment was administered in 8 patients, and bulbar symptoms were present in 5 patients.

Surgical approaches included multiport RATS in 5 patients, uniportal RATS in 1 patient, and uniportal VATS in 4 patients. The median operative time was 126 minutes (IQR, 105–250). Combined resection of adjacent organs was required in 2 patients. One patient developed postoperative phrenic nerve paralysis and subsequently underwent diaphragmatic plication.

The median duration of chest tube placement was 0 days, and the median postoperative hospital stay was 4 days. No postoperative myasthenic crisis occurred. Among the 6 patients who were followed postoperatively while receiving prednisolone, 5 achieved Minimal Manifestations (MM) with a reduced prednisolone dose of  $\leq 5$  mg/day.

### Conclusions

The subxiphoid approach for extended thymectomy in patients with MG was safe and yielded favorable postoperative outcomes without myasthenic crisis. Owing to its excellent visualization of both phrenic nerves and the thymic upper poles, this approach represents a useful and effective technique for extended thymectomy.

### Keyword(s)

Uniportal VATS, Subxiphoid Approach, Myasthenia Gravis, Extended Thymectomy, Uniportal RATS

## Comparison of Median Sternotomy and Subxiphoid VATS in Extended Thymectomy

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*<sup>1</sup>Thoracic Surgery, Kansai Medical University Medical Center, Osaka, Japan*

### Objective

Extended thymectomy is the standard surgical treatment for myasthenia gravis. We have transitioned from median sternotomy to biportal and uniportal video-assisted thoracoscopic surgery (VATS), and then to uniportal robotic-assisted thoracoscopic surgery (RATS). This study compared the short-term outcomes and efficacy of treating myasthenia gravis between cases treated with the previous median sternotomy approach and those treated after introducing the subxiphoid VATS approach.

### Methods

A comparative study was conducted between patients who underwent extended thymectomy with a median sternotomy (OPEN group) and those with uniportal or biportal VATS or RATS (collectively termed VATS group) in patients who underwent extended thymectomy between 2016 and 2025. The efficacy of treating myasthenia gravis was evaluated in cases with a postoperative follow-up period of at least two years.

### Results

The analysis of short-term outcomes included six cases in the OPEN group and eleven cases in the VATS group. Thymoma was present in five cases in the OPEN group and two in the VATS group. The postoperative hospital stay was significantly shorter in the VATS group (9.6 days in the OPEN group, 5.7 days in the VATS group,  $p = 0.015$ ). No significant difference was observed in operative time (196.0 minutes vs. 170.9 minutes,  $p = 0.33$ ). Intraoperative blood loss was significantly lower in the VATS group (302.5 ml vs. 6.7 ml,  $p < 0.0001$ ). The analysis of surgical efficacy included five patients in the OPEN group and eight in the VATS group. Symptom improvement was observed in four patients in the OPEN group and seven in the VATS group. Reduction in medication dosage occurred in four patients in the OPEN group and three in the VATS group. A reduction of 50% or more in anti-AchR antibodies was seen in two patients in the OPEN group and three in the VATS group. No significant differences were observed in any of these outcomes.

### Conclusions

The minimally invasive nature of the subxiphoid approach thoracoscopic surgery is evidently less invasive than the median sternotomy. Although the number of cases in this study was small, the results showed no significant difference in outcomes between open thoracotomy and thoracoscopic surgery.

### Keyword(s)

Extended Thymectomy, Myasthenia Gravis, VATS, RATS, Subxiphoid Approach

## **Building a Multi-Institutional Database for Thymoma and Thymic Carcinoma in Taiwan: A Collaborative Study from Nine Medical Centers**

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### **Objective**

Thymoma and thymic carcinoma are uncommon tumors arising from the anterior mediastinum, and their rarity has long made it difficult to accumulate sufficient cases for meaningful analysis at any single institution. To overcome this limitation, we initiated a collaborative effort among thoracic surgery departments across Taiwan to build a shared clinical database for systematic research.

### **Methods**

We retrospectively reviewed patients with pathologically confirmed thymoma or thymic carcinoma treated at nine medical centers in Taiwan, with data collected from 1989 through 2025. Variables recorded included patient demographics, presenting symptoms, preoperative CT findings, operative details, pathological diagnosis, WHO histological classification, Masaoka-Koga and AJCC TNM 8th-edition staging, neoadjuvant and adjuvant treatment, recurrence, and survival. A standardized coding system was adopted across all participating centers to ensure consistency.

### **Results**

Over 1,600 patients were included, representing the full spectrum of WHO subtypes from Type A thymoma to thymic carcinoma across all disease stages. The database is currently being expanded to incorporate additional institutional data. Planned analyses include comparison of the TNM and Masaoka-Koga staging systems, the prognostic role of tumor size, surgical approach outcomes, recurrence patterns, and the effect of adjuvant therapy in early-stage disease.

### **Conclusions**

This multi-institutional database represents the largest systematically collected cohort of thymoma and thymic carcinoma in Taiwan to date. With 1,675 patients from nine medical centers, it provides a robust foundation for addressing unresolved clinical questions and generating high-level evidence to guide future guidelines.

### **Keyword(s)**

Thymic Neoplasm, Taiwan Local Data, Multi-Institutional Database, Thymoma, Thymic Carcinoma

## **Efficacy of Tracheobronchial Stenting for Central Airway Stenosis during Rigid Bronchoscopy with Extracorporeal Membrane Oxygenation Support**

**Tzu-Wei Kuo<sup>\*1</sup>; Tzu-Yi Yang<sup>1</sup>; Yun-Hen Liu<sup>1</sup>; Chien-Hung Chiu<sup>1</sup>**

<sup>1</sup>*Division of Thoracic Surgery, Chang Gung Memorial Hospital, Linkou, Taipei, Taiwan*

### **Objective**

Rigid bronchoscopy has been an invaluable tool to diagnose and manage central airway obstruction. However, the risks of inadequate ventilation and tumor bleeding still play an occult killer during the procedure. Recently, extracorporeal membrane oxygenation (ECMO) has been not only used to support patients with cardiac or respiratory failure, it has also been reported to manage difficult airway. This study reviewed the peri-operative outcomes of patients who received rigid bronchoscopy with stent insertion under ECMO support.

### **Methods**

This is a retrospective, single center study. During 2020 to 2023, there were 12 patients receiving rigid bronchoscopy with stent insertion under ECMO support. Peri-operative outcomes and short-term survival were included.

### **Results**

In total 12 patients, there were 11 patients under veno-venous ECMO support and one patient under veno-arterial ECMO support. All of them received dumon stent insertion successfully. The mean blood loss during surgery were 148.3ml. Although all of patients weaning from ECMO successfully after surgery, there were only half of them extubated after surgery and the in-hospital mortality were 58.3%. The main reason causing the mortality was the condition of patients with terminal cancer stage.

### **Conclusions**

Rigid bronchoscopy with stent insertion under ECMO support seemed to be a feasible and safe procedure for surgeons to manage central airway obstruction. Further study might need to confirm the findings.

## **The Pulsating Handle: Surgical Management of a Penetrating Chest Injury with Cardiac-Synchronous Movements and Minimal Pneumothorax**

**Chia Liu<sup>\*1</sup>; Po-Kuei Hsu<sup>1</sup>**

*<sup>1</sup>Department of surgery, division of thoracic surgery, Taipei Veterans General Hospital, Taipei, Taiwan*

### **Objective**

To describe the surgical management and multidisciplinary outcomes of a self-inflicted penetrating chest injury with a retained weapon. This report highlights the importance of controlled operative extraction when cardiac proximity is suspected, pulmonary parenchymal repair, and the necessity of integrated psychiatric-surgical postoperative care.

### **Results**

A 28-year-old male with a history of alcohol use disorder and sedative-hypnotic misuse presented with an impaled knife in the left precordium. Clinical examination revealed cardiac-synchronous pulsations of the knife handle, raising immediate concern for pericardial or myocardial involvement. Computed tomography (CT) demonstrated a metallic foreign body traversing the left lung, accompanied by only minimal pneumothorax and localized subcutaneous emphysema. The blade trajectory was in close proximity to the cardiac silhouette; however, no definitive hemopericardium was identified (Injury Severity Score: 9).

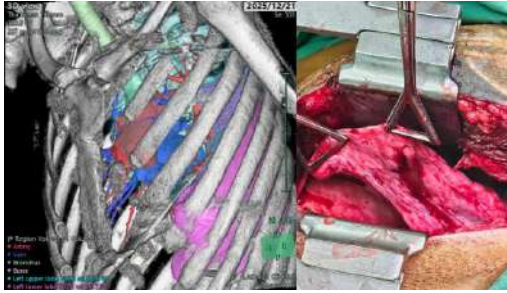
Given the high risk of catastrophic hemorrhage upon removal, the patient underwent emergent left thoracotomy. The incision was performed along the trajectory of the weapon to facilitate extraction under direct visualization. Intraoperative findings revealed a penetrating wound to the lingular segment of the left upper lobe. A wedge resection of the affected segment was performed to achieve definitive hemostasis and air-leak control. Following the stabilization of the primary injury, VATS was utilized to perform a systematic and exhaustive exploration of the entire thoracic cavity and pulmonary parenchyma, confirming no occult diaphragmatic or mediastinal injuries. The pericardium and myocardium were inspected and found to be intact.

The postoperative course was stable, although a transient episode of sinus tachycardia and premature ventricular contractions (PVCs) necessitated cardiology evaluation and management with propranolol. Concurrently, an integrated psychiatric consultation optimized the pharmacological treatment for his major depressive disorder. With sustained family support, the patient remained clinically stable without further self-harm and was discharged with a coordinated outpatient follow-up plan.

### **Conclusions**

Retained-knife penetrating chest trauma can be managed safely with operating-room, direct-vision extraction and lung resection/repair when indicated, particularly when clinical or imaging features suggest proximity to the heart. Serial postoperative imaging and integrated psychiatric care, including family support, are key elements of short-term recovery after self-harm-related trauma.





## Chronic Traumatic Diaphragmatic Hernia Masked for 8 Years: A Case Report of Complex Thoraco-abdominal Adhesion and Mesh Repair

**Ying-Che Ting<sup>\*1</sup>; Po-Kuei Hsu<sup>1</sup>**

<sup>1</sup>*Surgery, Taipei Veterans General Hospital, Taipei, Taiwan*

### Objective

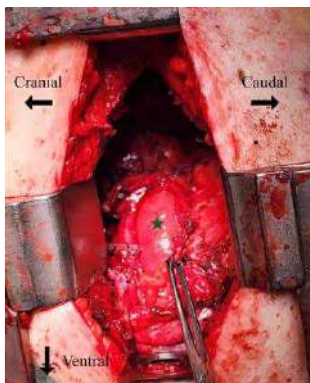
Traumatic diaphragmatic injury (TDI) is frequently missed during initial trauma evaluations, leading to delayed traumatic diaphragmatic hernia (DTDH) with a latent period that can span decades. Diagnostic delays are common due to non-specific symptoms or misdiagnosis in elderly populations.

### Results

We report a case of a 79-year-old male presenting with persistent coffee-ground vomitus and gastric outlet obstruction. His history was notable for blunt left chest trauma eight years prior. Computed tomography (CT) revealed a large diaphragmatic defect with gastric herniation into the left hemithorax. Due to failed conservative management, the patient underwent left-sided transthoracic exploration. Intraoperatively, the stomach and omentum were found herniated into the thoracic cavity with dense, chronic adhesions to the pulmonary lingula. After meticulous adhesiolysis and visceral reduction, intraoperative endoscopy confirmed gastric mucosal integrity and anatomical orientation. The defect was repaired with primary closure and reinforced with a lightweight Optilene mesh. The postoperative course was uneventful, and the patient was discharged on postoperative day 9.

### Conclusions

DTDH should be a key differential diagnosis in geriatric patients with remote trauma history presenting with gastrointestinal symptoms. A transthoracic approach combined with mesh reinforcement is an effective strategy for managing chronic cases with complex pleuropulmonary adhesions.



## **Postoperative ICU Nursing Management Following Video-Assisted Thoracoscopic Decortication for Empyema**

**Yi Peng Chen<sup>\*1</sup>**

<sup>1</sup>*CVCCU, Far Eastern Memorial Hospital, New Taipei City, Taiwan*

### **Objective**

To summarize key intensive care strategies for patients undergoing video-assisted thoracoscopic (VATS) decortication for empyema, emphasizing postoperative respiratory stabilization, hemodynamic optimization, chest tube management, pain control, comorbidity regulation, and complication prevention to improve surgical outcomes.

### **Results**

Immediately after surgery, the patient was admitted to the ICU for advanced hemodynamic and respiratory monitoring, including invasive arterial pressure, continuous ECG, oxygen saturation, arterial blood gases (ABG), and hourly chest tube drainage assessment. Due to pleural inflammation, lung restriction, and risk of residual atelectasis, the patient was predisposed to hypoxemia and ventilation-perfusion mismatch. Intensive respiratory care included early oxygen therapy, incentive spirometry, deep-breathing exercises, assisted coughing, chest physiotherapy, and optimal positioning to enhance lung expansion. Serial ABG monitoring demonstrated progressive improvement in oxygenation parameters, with maintained oxygen saturation above 95%.

Strict fluid management and input-output balance were implemented to prevent pulmonary edema and maintain hemodynamic stability. Electrolyte levels were closely monitored to avoid arrhythmia and metabolic imbalance. Early mobilization was initiated within 24–48 hours once stable, reducing the risk of ICU-acquired weakness and pulmonary complications.

Structured chest tube management focused on monitoring drainage volume, characteristics, negative pressure maintenance, and air leakage detection to ensure adequate lung re-expansion and prevent empyema recurrence or secondary infection. Pain scores initially ranged from 6–7 on the Numeric Rating Scale (NRS) and decreased to  $\leq 3$  following multimodal analgesia, facilitating effective pulmonary rehabilitation. Chronic comorbidities such as diabetes and hypertension were concurrently optimized to reduce perioperative instability. Anxiety was alleviated through therapeutic communication and perioperative education. No major complications, including respiratory failure, re-intubation, or re-intervention, occurred during ICU stay.

### **Conclusions**

Comprehensive ICU management following VATS decortication for empyema requires structured respiratory support, meticulous chest tube surveillance, optimized fluid and pain control, and multidisciplinary coordination. Early postoperative intervention enhances lung re-expansion, stabilizes hemodynamics, minimizes complications, and promotes functional recovery. This integrated ICU care model provides a reproducible and clinically effective framework for optimizing postoperative outcomes in thoracic surgical patients with empyema.

### **Keyword(s)**

ICU, Thoracoscopic, Empyema

## **Thoracic endometriosis syndrome with catamenial pneumothorax among patients who underwent surgery at the Lung Center of the Philippines**

**Richard Briones<sup>\*1</sup>; Edmund Villaroman<sup>1</sup>; Fernando Jr Melendres<sup>1</sup>; Jose Luis Danguilan<sup>1</sup>**

<sup>1</sup>*Thoracic Surgery and Anesthesia Department, Lung Center of the Philippines, Quezon City, Philippines*

### **Objective**

This study aims to characterize, manage, and evaluate the outcomes of TES-CP patients who underwent surgery at the Lung Center of the Philippines (LCP).

### **Methods**

*The researcher conducted a longitudinal study of all TES-CP patients who underwent surgery at LCP from January 2015 to June 2025. TES diagnosis was confirmed by histopathologic report. Data were collected via a retrospective review of medical charts.*

### **Results**

Among the 69 reproductive-aged female patients diagnosed with spontaneous pneumothorax, 26 (38%) had CP. Of these, 14 (54%) were reported as negative for endometriosis on the histopathology report, and four had unavailable biopsy results. Finally, 8 TES-CP patients were included in this study. The mean age of patients was 39 years (range: 25-46 years). Most were multigravid and multiparous, and all had normal BMI. Except for one, all had a history of pelvic endometriosis, while none were infertile. Seven cases had a history of previous pneumothorax episodes and prior surgeries (i.e., CTT and VATS). The interval from the first pneumothorax event to TES-CP diagnosis ranged from 3 days to 37 months. All presented dyspnea, while chest pain and shoulder pain are also common. Intraoperative findings revealed that only two patients had nodules, and the majority had pleural adhesions and diaphragmatic fenestrations. The mean time from admission to surgery was 3.5 days (range: 0-7 days). All underwent VATS, and the majority also underwent pleurodesis and diaphragmatic fenestration repair. All patients underwent pulmonary rehabilitation, while 75% patients received hormonal therapy. Recurrence was observed in two patients (25%). Among patients with recurrence, VATS alone was performed in the first patient, whereas the remaining patients underwent pleurodesis, diaphragmatic fenestration repair, and lung wedge resection. Pneumothorax recurred 18 days for the 1st patient and 75 days for the 2nd patient despite hormonal therapy. No prolonged air leak and mortalities were noted.

### **Conclusions**

A total of eight cases were reported in 11 years. Although CP was common in reproductive-aged women, most were negative for endometriosis on biopsy. Except for one case, all had a previous diagnosis of pneumothorax before the current admission, which did not resolve despite previous CTT or VATS. TES-CP should be considered in reproductive-aged women with recurrent pneumothorax. Accurate diagnosis, combined medical and surgical treatment, is important for minimizing recurrence. Studies with larger sample sizes examining predictors of recurrence in TES-CP are warranted.

## Intraoperative Lung Cancer Diagnosis Using Three Dimensional (3D) Optical Coherence Tomography (OCT) with Deep Learning

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### Objective

Cancer has been the leading cause of death in Taiwan for 43 consecutive years, with lung cancer ranking first in mortality for over two decades. Therefore, early, accurate, and rapid intraoperative diagnosis is crucial to guide surgical decision-making. However, conventional frozen section analysis is time-consuming and less accurate, particularly for small or early-stage lesions. This study investigates spectral-domain optical coherence tomography (SD-OCT) for real-time, high-resolution volumetric imaging of lung tissue during surgery, combined with deep learning for tumor classification and grading.

### Methods

Resected primary lung tumor specimens and adjacent normal tissues were collected intraoperatively. Tissue samples were scanned using our developed mobile cart SD-OCT system (840 nm, 20 kHz A-scan rate) to generate three-dimensional volumetric images. The reconstructed OCT data were analyzed using a trained three-dimensional convolutional neural network (3D CNN) for automated grading of normal tissue, minimally invasive adenocarcinoma (MIA), and invasive adenocarcinoma (IA).

### Results

The model achieved approximately 72% overall accuracy in three-class classification. Performance was stronger in classifying benign and normal tissues, whereas classification of invasive adenocarcinoma remained comparatively more challenging. These results suggest that volumetric 3D information improved tissue differentiation between normal and tumor grade levels.

### Conclusions

Our findings support the feasibility of OCT-based deep learning as an automated intraoperative tumor assessment tool.

### Keyword(s)

Automated Intraoperative Tumor Assessment, Deep Learning, Lung Cancer, Optical Coherence Tomography, Tumor Grading, 3D CNN

## **Development of a prediction model incorporating radiomic features from longitudinal lung CT images to distinguish invasiveness in early-stage lung adenocarcinomas: a retrospective study**

**Shan Jang Chen<sup>\*1</sup>; Jyh-Cheng Chen<sup>1</sup>; Hsuan-Hao Chang<sup>1</sup>; Po-Kuei Hsu<sup>2,3</sup>; Hung-Che Chien<sup>2</sup>; Chung-Yun Kuan<sup>2</sup>; Chih-Hao Yu<sup>2</sup>**

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### **Objective**

To develop and evaluate a radiomic model based on longitudinal follow-up CT images for predicting invasiveness in stage 0–1 lung adenocarcinoma.

### **Methods**

We retrospectively enrolled patients with pathologically confirmed stage 0–1 lung adenocarcinoma. All CT images were acquired with a 1-mm slice thickness. Adenocarcinoma in situ (AIS) was defined as pre-invasive disease, whereas minimally invasive adenocarcinoma (MIA) and invasive adenocarcinoma (IAC) were categorized as invasive lesions. For each lesion, two preoperative CT scans were analyzed: T1 (the last CT before surgery) and T2 (the CT preceding T1). Radiomic features were extracted from three-dimensional volumes of interest on both T1 and T2 images. Delta-radiomic features (D1) were calculated as the differences between T1 and T2 features and normalized to a 180-day interval to account for variable follow-up durations. After feature selection using t-tests, Spearman correlation analysis, and ANOVA, linear support vector machine (SVM) models with 5-fold cross-validation were constructed based on T1, T2, and D1 features separately, as well as in combination. Model performance was evaluated using the area under the receiver operating characteristic curve (AUC).

### **Results**

A total of 179 patients with pathologically confirmed stage 0–1 lung adenocarcinoma, comprising 199 lesions, were included between January 2020 and December 2025. In the initial cohort of 58 lesions, the T1-based model achieved an AUC of 0.917, the T2-based model achieved an AUC of 0.891, and the delta-radiomic (D1) model achieved an AUC of 0.924. The integrated model combining D1 and T1 features demonstrated the best performance, with an AUC of 0.932.

### **Conclusions**

Delta radiomics derived from longitudinal follow-up CT images improves discrimination of invasiveness in early-stage lung adenocarcinoma. Integration of delta features with conventional radiomic features from the last preoperative CT further enhances predictive performance compared with single time-point models. External validation using independent cohorts is warranted.

### **Keyword(s)**

Radiomics, CT Image, Lung Adenocarcinoma, Delta Radiomics

## CT-based Deep Learning for Prediction of Visceral Pleural Invasion in Lung Adenocarcinoma

**Hsueh-Ching Lin<sup>\*1</sup>; Li-Wei Chen<sup>2</sup>; Shun-Mao Yang<sup>3</sup>; Min-Shu Hsieh<sup>4</sup>; Yeun-Chung Chang<sup>5</sup>; Chung-Ming Chen<sup>2</sup>; Jin-Shing Chen<sup>6</sup>; Mong-Wei Lin<sup>6</sup>**

<sup>1</sup>Education, National Taiwan University Hospital, Taipei, Taiwan <sup>2</sup>Biomedical Engineering, College of Medicine and College of Engineering, National Taiwan University, Taipei, Taiwan <sup>3</sup>Surgery, National Taiwan University Hospital Biomedical Park Hospital, Hsinchu County, Taiwan <sup>4</sup>Pathology, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan <sup>5</sup>Radiology, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan <sup>6</sup>Surgery, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan

### Objective

Accurate preoperative prediction of visceral pleural invasion (VPI) in lung adenocarcinoma is crucial for surgical planning. Current models typically prioritize sensitivity at the expense of specificity; this may potentially lead to overtreatment. This study proposed chest wall information exclusion, aiming to develop a computed tomography-based deep learning model (DL) that enhances the specificity.

### Methods

We retrospectively recruited 835 cases with pathologically confirmed lung adenocarcinoma who underwent completed resection at two medical centers. A VPI-DL model was developed using a four-layer convolutional neural network was trained on a novel chest wall-masked CT images mechanism. The model was trained in 692 patients and validated in a cohort of 143 patients. Diagnostic performance was compared with the consolidation-to-tumor ratio (CTR), a published DL model, and thoracic surgeons' assessments. Performance was evaluated by area under the receiver operating characteristic curve (AUC), sensitivity, specificity, and accuracy at a predefined high-sensitivity operating threshold.

### Results

In validation cohort, the model held an AUC of 0.91, sensitivity of 91%, specificity of 82%, and accuracy of 83%, surpassing the CTR (specificity 63%), the published model (specificity 54%), and thoracic surgeons (specificity 57%) at pre-specified sensitivity threshold. The novel chest-wall-masked CT inputs training architecture effectively reduced spurious correlations and improved model interpretability.

### Conclusions

The proposed VPI-DL model holds promising results of VPI prediction. Achieved by intentionally waiving chest wall information, the specificity is improved while preserving high sensitivity. The model now offers physicians a robust and interpretable tool to aid preoperative planning and decide the proper treatment in early-stage lung adenocarcinoma.



**Keyword(s)**

Deep Learning, Lung Adenocarcinoma, Visceral Pleural Invasion

## Original Article Survival Outcomes of Patients with Esophageal Cancer and Post-chemoradiotherapy Surgical T4b Disease: Is Palliative Resection Justified?

**Tzu Yi Yang<sup>\*1</sup>; Yin Kai Chao<sup>2</sup>; Chien Hung Chiu<sup>2</sup>; Chi Ju Yeh<sup>2</sup>**

<sup>1</sup>thoracic department, Chang Gung Memorial Hospital, Taichung, Taiwan <sup>2</sup>thoracic department, Chang Gung Memorial Hospital, Taoyuan, Taiwan

### Objective

In patients with locally advanced esophageal cancer who had undergone chemoradiotherapy (CRT), the limitations of radiological evaluation may necessitate surgical exploration to ascertain disease resectability. Upon intraoperative confirmation of T4b disease (sT4b), the optimal management strategy remains unclear. While some surgeons may opt against resection, others advocate for palliative esophagectomy (PE). Regrettably, the current literature does not provide a consensus on the most effective approach for managing these intricate cases.

### Methods

The study cohort consisted of 68 patients with ESCC who presented with sT4b disease following CRT. The perioperative outcomes and overall survival (OS) were compared between patients who underwent PE (n = 56) and those who received an open-close (OC) procedure (n = 12).

### Results

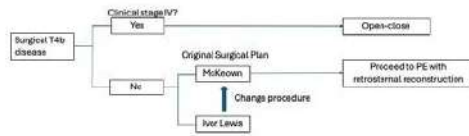
Patients who underwent an OC procedure experienced a shorter hospital stay (16.5 *versus* 28.8 days,  $p = 0.052$ ) and showed a non-significant reduction in the rate of major complications (33.9% *versus* 25%,  $p = 0.549$ ) and in-hospital mortality (0% *versus* 5.4%,  $p = 0.412$ ) than those who received PE. However, PE was associated with a superior 2-year OS rate than OC (9.6% *versus* 0%, respectively;  $p = 0.009$ ). In multivariable analysis, a pretreatment clinical stage of II/III (hazard ratio [HR] = 0.51, 95% confidence interval [CI] = 0.31–0.87,  $p = 0.013$ ) and PE with retrosternal reconstruction (HR = 0.38, 95% CI = 0.15–0.49,  $p = 0.010$ ) were independently associated with a more favorable OS.

### Conclusions

PE with retrosternal reconstruction may be a feasible approach for patients with ESCC exhibiting sT4b disease after CRT.

### Keyword(s)

Palliative Esophagectomy, Surgical T4b, Retrosternal Reconstruction



## Prognostic Value of Tumor Length in Clinical T1–2N0M0 Esophageal Squamous Cell Carcinoma

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### Objective

The TNM staging system for esophageal cancer defines the T stage by depth of invasion rather than tumor size. However, prognosis may vary within the same T stage. This study aimed to evaluate the prognostic value of tumor length in clinical T1–2N0M0 esophageal squamous cell carcinoma (ESCC).

### Methods

This retrospective single-center study included 923 patients who underwent upfront surgery for cT1–2N0M0 ESCC between 2006 and 2023. The prognostic impact of tumor length was analyzed using Kaplan–Meier curves, log-rank tests, and Cox regression models. Since current guidelines define  $\geq 30$  mm as a high-risk threshold, survival outcomes were compared using both the 30 mm cutoff and a cohort-derived cutoff identified by a maximally selected log-rank test.

### Results

The maximally selected log-rank test identified 40 mm as the optimal cutoff for tumor length. Kaplan–Meier analysis demonstrated a clear separation of curves: patients with tumor length  $\geq 40$  mm had significantly worse survival (5-year RFS 62% vs. 78%; 5-year OS 68% vs. 84%). Univariable Cox regression demonstrated that tumor length  $\geq 40$  mm was significantly associated with worse recurrence-free survival (HR 1.49,  $p=0.001$ ) and overall survival (HR 1.57,  $p<0.001$ ). However, in multivariable Cox regression, the prognostic effect of tumor length did not remain significant ( $p=0.076$ ), being largely explained by pT and pN stage. Independent predictors included age, pT, and pN stage.

### Conclusions

Tumor length  $\geq 40$  mm is associated with adverse survival in univariable analysis but does not act as an independent prognostic factor after adjustment for stage. Tumor length reflects tumor burden and should be considered a supportive marker rather than a standalone risk factor in early-stage ESCC.

### Keyword(s)

Esophageal Cancer, Esophageal Cancer Staging, Tumor Length

## **Delayed gastric conduit emptying after esophagectomy: Effects of Botox injection over pylorus**

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<sup>1</sup>*Thoracic Surgery, LK CGMH, Taoyuan, Taiwan*

### **Objective**

The efficacy of pyloric botulinum toxin (Botox) injection in preventing delayed gastric conduit emptying (DGCE) following esophagectomy remains controversial. This retrospective study aimed to evaluate the clinical benefit of this intervention based on institutional experience.

### **Methods**

A single-center retrospective analysis was conducted including 114 patients who underwent esophagectomy between January 2023 and December 2024. Patients were stratified by receipt of intraoperative pyloric Botox injection. Early DGCE was defined according to Konradsson's international consensus criteria published in 2020. The primary endpoint was the incidence of early DGCE (within postoperative day 14), analyzed using Fisher's exact test.

### **Results**

Among 114 patients, 84 received pyloric Botox injection while 30 did not. The incidence of early DGCE was 4.8% (4/84) in the Botox group versus 13.3% (4/30) in the control group. Fisher's exact test analysis yielded an odds ratio of 0.33 ( $p = 0.20$ ), indicating a potential protective effect that did not achieve statistical significance at the conventional  $\alpha = 0.05$  level.

### **Conclusions**

Pyloric Botox injection demonstrated a trend toward reduced early DGCE incidence following esophagectomy; however, this benefit did not reach statistical significance. These findings suggest the intervention may be less clinically effective than previously anticipated. Future investigations requiring larger patient cohorts and extended postoperative follow-up periods are warranted to comprehensively evaluate long-term quality of life outcomes and definitively establish the therapeutic value of this intervention.

## **Title: Two Cases of Intraoperative ICG Fluorescence Imaging for Thoracic Duct Visualization for Postoperative Chyle Leak After Esophagectomy**

**Himeko Mori<sup>\*1</sup>; Yusuke Saeki<sup>2</sup>; Yasuharu Sekine<sup>2</sup>; Naohiro Kobayashi<sup>2</sup>; Hideo Ichimura<sup>2</sup>; Yukio Sato<sup>2</sup>**

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### **Objective**

To report two cases in which intraoperative indocyanine green (ICG) fluorescence imaging facilitated visualization of the thoracic duct during thoracic duct ligation for postoperative chyle leak after esophagectomy. Methods: At anesthesia induction in the operating room, ICG (2.5 mg/mL) was injected under ultrasound guidance into bilateral inguinal lymph nodes (5 mg [2 mL] per side). During surgery, the course of the thoracic duct was assessed in real time using near-infrared thoracoscopy (VISERA ELITE III, Olympus, Tokyo, Japan).

### **Results**

**Case 1:** A 78-year-old man underwent esophagectomy with retrosternal gastric conduit reconstruction for esophageal cancer. On postoperative day 4, chylous drainage from the cervical drain and cervical swelling were noted. Conservative management with fasting and octreotide was initiated; however, the chyle leak persisted. Thoracic duct ligation was performed on postoperative day 10. Because the leakage site could not be identified through the cervical wound, a thoracic approach was adopted. When the anterior surface of the vertebral body was observed under near-infrared imaging, the thoracic duct could be clearly identified as an ICG-fluorescent structure. While confirming secure visualization of the thoracic duct under near-infrared imaging, the thoracic duct and surrounding connective tissue were clipped, thereby completing thoracic duct ligation. Following clipping, re-evaluation through the cervical wound confirmed complete cessation of the chyle leak.

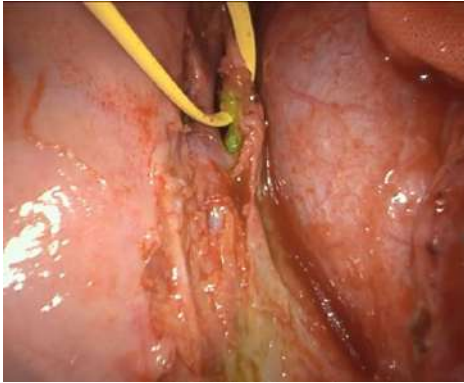
**Case 2:** A 67-year-old man had undergone esophagectomy with retrosternal gastric conduit reconstruction for esophageal cancer two months earlier. He noted mild postoperative cervical swelling that subsequently worsened. With a diagnosis of chyle leak, fasting and octreotide were administered; however, cervical swelling did not improve, and thoracic duct ligation was performed. Although the thoracic duct showed marked tortuosity from the ventral aspect of the vertebral body toward the dorsal side, it was clipped on the cranial side to complete thoracic duct ligation. Postoperatively, cervical swelling improved markedly.

### **Conclusions**

Intraoperative ICG fluorescence imaging with ultrasound-guided inguinal lymph node injection is a useful technique for identifying the thoracic duct and may facilitate safe and effective thoracic duct ligation for chyle leak after esophagectomy.

### **Keyword(s)**

Postoperative Chyle Leak, ICG Fluorescence Imaging, Thoracic Duct Ligation



## **Synchronous Esophageal SCC and Lung Adenocarcinoma with Post-Esophagectomy Gastric Tube Adenocarcinoma: A Case Report**

**Chieh-Ju Liao<sup>1,4</sup> Hsuan-Yu Chen<sup>2</sup> Kuang-Tai Kuo<sup>3,4</sup>**

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### **Introduction**

Synchronous esophageal squamous cell carcinoma and lung adenocarcinoma are rare and present challenges in planning the sequence of multimodal therapy. We report a case treated with curative intent, complicated by postoperative spinal dural arteriovenous fistula and later gastric tube adenocarcinoma.

### **Case**

A 73-year-old man presented with dysphagia and chest pain. Panendoscopy revealed lower-third esophageal squamous cell carcinoma, and chest computed tomography showed a 4.8 cm tumor with nodal disease and a 6 × 2.5 cm lesion in the left upper lobe. Biopsy confirmed papillary adenocarcinoma. He underwent video-assisted thoracoscopic wedge resection and port-a-cath implantation, followed by concurrent chemoradiotherapy with docetaxel, cisplatin, and fluorouracil, and radiotherapy delivering 50 Gy in 25 fractions. Three months later, thoracoscopic esophagectomy with laparoscopic gastric tube reconstruction was performed, and pathological examination confirmed a complete response.

One week postoperatively, bilateral leg weakness developed. Magnetic resonance imaging and angiography revealed multiple dural arteriovenous fistulas, which were treated with laminectomy and ligation, leading to complete neurological recovery.

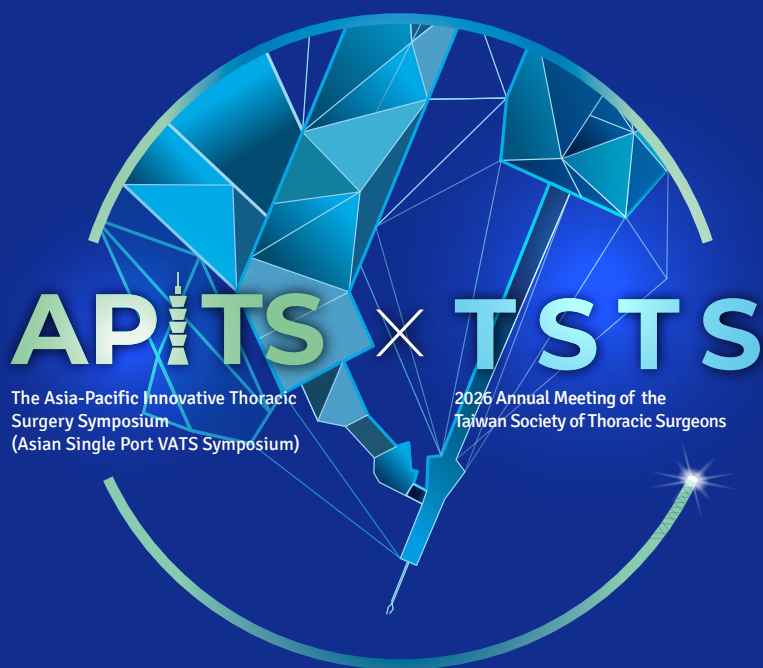
At 6 months, elevated carcinoembryonic antigen prompted endoscopy, which revealed an early gastric tube adenocarcinoma measuring less than 2 cm with signet-ring histology. Endoscopic submucosal dissection achieved margin-negative resection. One year later, recurrent lung adenocarcinoma required completion lobectomy. In 2024, positron emission tomography revealed pleural seeding and metastases, and systemic therapy with pembrolizumab in combination with pemetrexed and carboplatin was initiated.

### **Conclusion**

This case highlights the complexity of managing synchronous esophageal squamous cell carcinoma and lung adenocarcinoma requiring multimodal therapy. Gastric tube cancer develops in approximately 2.4% of patients within 5 years after esophagectomy and is often asymptomatic, underscoring the need for lifelong endoscopic surveillance. Multidisciplinary coordination is



essential to optimize treatment sequencing and to manage rare postoperative complications throughout the disease course.



MINIMALLY INVASIVE  
**MAX**IMALLY EFFECTIVE