Biomolecules and Biomedicine
ISSN: 2831-0896 (Print) | ISSN: 2831-090X (Online)
Journal Impact Factor® (2024): 2.2
CiteScore® (2024): 5.2
www.biomolbiomed.com | blog.bjbms.org

REVIEW

Zhang et al: Tubeless uniportal VATS outcomes

Tubeless uniportal VATS in thoracic surgery – Indications, ERAS pathways, and outcomes: A review

Bo Zhang[1*], Xian-hua Ye[2], De-shuang Xiao[3]

[1]Department of Thoracic surgery, The First People's Hospital of Wenling, Taizhou University Affiliated Wenling Hospital, School of Medicine, Taizhou University, Wenling, Zhejiang, China;

[2]Department of Anesthesiology, The First People's Hospital of Wenling, Taizhou University Affiliated Wenling Hospital, School of Medicine, Taizhou University, Wenling, Zhejiang, China;

[3]Department of General Surgery, The First People's Hospital of Wenling, Taizhou University Affiliated Wenling Hospital, School of Medicine, Taizhou University, Wenling, Zhejiang, China.

*Correspondence to Bo Zhang: 15356360702@163.com

DOI: https://doi.org/10.17305/bb.2026.13644

ABSTRACT

Tubeless uniportal video-assisted thoracoscopic surgery (VATS) is an innovative approach characterized by the use of non-intubated (spontaneous-breathing) anesthesia, the omission of routine postoperative chest drainage, and single-port access. This technique has gained traction in recent years for a variety of thoracic procedures. While practices reported in the literature may differ, this review primarily examines the combined non-intubated and drainless approach. This narrative review provides a comprehensive overview and critical analysis of its current clinical applications, including sympathectomy, pulmonary wedge resection, spontaneous pneumothorax, thymectomy, and early-stage lung cancer. It also addresses essential aspects of perioperative management and procedural indications within enhanced recovery-oriented pathways. A systematic literature search of PubMed, Embase, and Web of Science was conducted to identify pertinent studies published between January 2010 and April 2025. Current clinical reports indicate potential benefits such as reduced postoperative pain, shorter hospital stays, and accelerated recovery. However, the existing evidence largely stems from small, observational studies with varied methodologies, necessitating cautious interpretation. The broader implementation of this technique in more complex procedures depends on the establishment of standardized clinical pathways, the refinement of multidisciplinary perioperative strategies, and validation through multicenter prospective studies. Tubeless uniportal VATS shows promise as a significant advancement in function-preserving and recovery-oriented thoracic surgery.

Keywords: Tubeless thoracic surgery, uniportal video-assisted thoracoscopic surgery, minimally invasive thoracic surgery, non-intubated anesthesia, chest drain-free surgery, enhanced recovery after surgery, ERAS.

INTRODUCTION

As a surgical specialty closely linked to respiratory and circulatory physiology, thoracic surgery has consistently pursued the dual goals of trauma minimization and function preservation[1]. From traditional thoracotomy to multi-port thoracoscopy, and now to the increasingly adopted uniportal VATS, minimally invasive techniques have become the mainstream direction in thoracic surgical practice [2]. In parallel, the ongoing evolution of enhanced recovery after surgery (ERAS) has further propelled efforts toward minimizing surgical trauma and expediting postoperative rehabilitation. This has led to a growing interest in techniques that not only reduce intraoperative injury but also optimize physiological preservation and functional outcomes [3].

Against this backdrop, tubeless thoracoscopic surgery has emerged as a novel approach aimed at further minimizing perioperative invasiveness. In its most widely accepted form, tubeless uniportal VATS is characterized by the combination of non-intubated (spontaneous-breathing) anesthesia and omission of routine postoperative chest drainage, performed through a single-port approach [4]. In the literature, related practices may vary and include non-intubated or drainless variants; in this review, the term "tubeless uniportal VATS" primarily refers to the combined non-intubated and drainless approach, while related variants are discussed where relevant. Adjunctive measures, such as opioid-sparing analgesia and avoidance of postoperative analgesic pumps, are commonly incorporated as part of enhanced recovery pathways but are not considered mandatory definitional components. Built upon the foundation of uniportal VATS, this technique represents a further refinement in minimally invasive thoracic surgery[5]. Initial applications have demonstrated favorable outcomes in relatively low-risk procedures, such as thoracic sympathectomy, spontaneous pneumothorax, and pulmonary wedge resection. More recently, exploratory use in more complex interventions—such as thymectomy and early-stage lung cancer resection—has also been reported [6, 7].

Nevertheless, despite its potential, current research on tubeless techniques predominantly consists of single-procedure reports or small-scale case studies. There

is a lack of comprehensive narrative syntheses encompassing its broader application, including key factors such as procedural indications, patient selection criteria, intraoperative risk management, and long-term outcomes. This limited evidence base hinders its widespread implementation, especially in oncologic or technically demanding surgeries.

Therefore, this narrative review aims to comprehensively summarize and critically discuss the clinical application of tubeless uniportal thoracoscopic surgery across a spectrum of thoracic procedures—from benign to malignant conditions. Particular emphasis is placed on its clinical feasibility, advantages, limitations, and future prospects. We also propose a framework for its structured adoption, aligned with minimally invasive and ERAS principles, to inform both clinical practice and future research.

LITERATURE SEARCH STRATEGY

To inform this narrative review, a literature search was performed using PubMed, Embase, and Web of Science databases to identify relevant studies on tubeless uniportal VATS published between January 2010 and April 2025. The search strategy included combinations of keywords such as “tubeless VATS,” “non-intubated thoracic surgery,” “uniportal thoracoscopy,” and “enhanced recovery after surgery.” The search focused on English-language articles reporting clinical applications, perioperative techniques, or outcomes. Relevant publications were reviewed at the title/abstract and full-text levels to identify studies pertinent to the scope of this review. Case reports with fewer than three patients, animal studies, and conference abstracts without full articles were not considered.

For the purpose of this review, studies were considered eligible if they involved uniportal VATS and reported the use of non-intubated (spontaneous-breathing) anesthesia and/or omission of routine postoperative chest drainage. Procedures fulfilling both non-intubated and drainless criteria were classified as “completely tubeless,” which constituted the primary focus of this review. Studies adopting only

one of these elements were categorized as related variants and were discussed where relevant. Adjunctive perioperative measures, including analgesic strategies, were not used as eligibility criteria.

BASIC CONCEPTS AND DEVELOPMENT HISTORY OF TUBELESS UNIPORTAL THORACOSCOPIC TECHNOLOGY

Definition and core concept of tubeless technology

Tubeless thoracoscopic surgery refers to a novel approach in thoracic surgery that aims to achieve a high level of minimal invasiveness by significantly reducing perioperative intervention [8]. In the context of this review, tubeless uniportal VATS is operationally defined by two mandatory core components: non-intubated (spontaneous-breathing) anesthesia and omission of routine postoperative chest drainage, performed through a uniportal approach [9, 10]. These two elements constitute the defining features used to classify and interpret the literature discussed in this review. Additional perioperative measures, such as opioid-sparing analgesia, avoidance of postoperative analgesic pumps, or other enhanced recovery–oriented strategies, are frequently adopted in clinical practice and are closely aligned with ERAS principles. However, these measures are not considered mandatory definitional components of tubeless uniportal VATS and were not used as inclusion criteria when summarizing published studies. An overview distinguishing core definitional components from adjunctive ERAS-related measures is illustrated in **Figure 1**. Beyond technical modifications, the tubeless concept reflects a broader shift in surgical philosophy toward functional preservation and enhanced recovery [11, 12]. Its conceptual foundation is closely linked to ERAS, which emphasizes minimizing surgical stress and preserving physiological function to facilitate early postoperative rehabilitation [13, 14].

The tubeless approach advocates for more than just smaller incisions—it promotes reduced physiological disruption and preservation of patient autonomy [15]. Compared with traditional intubation anesthesia, tubeless techniques preserve

spontaneous respiration, decrease the risk of complications such as pharyngeal discomfort and bronchospasm, and potentially reduce alveolar damage and immune suppression associated with mechanical ventilation [16, 17]. Moreover, eliminating chest drainage tubes, together with ERAS-aligned analgesic strategies, may reduce postoperative pain, anxiety, and immobilization time, thereby contributing to a smoother and faster recovery process [18, 19]. In this context, tubeless surgery represents not only a technical innovation, but also a patient-centered approach aimed at functional preservation and rapid rehabilitation.

Evolution from traditional VATS to tubeless-uniportal approach

The development of tubeless technology is closely linked to the continuous evolution of thoracoscopic surgical techniques [20]. Initially, multiportal VATS utilized several incisions for instrument access, which marked progress in reducing surgical trauma but was still associated with considerable postoperative pain and risk of intercostal nerve injury [21, 22]. The subsequent advancement of uniportal VATS allowed all procedures to be performed through a single intercostal incision, enhancing visualization and instrument coordination, while also demonstrating clear benefits in terms of pain reduction, fewer complications, and improved patient satisfaction [23].

However, even in uniportal VATS, endotracheal intubation anesthesia and routine postoperative chest drainage remain standard practice, thereby limiting the extent of physiological preservation[24]. The tubeless uniportal approach was therefore introduced to further minimize perioperative invasiveness by combining non-intubated anesthesia and spontaneous ventilation with selective omission of postoperative chest drainage. By extending the minimally invasive advantages of uniportal VATS, this approach has shown particular promise in low-complexity procedures such as pulmonary wedge resection and thoracic sympathectomy, where feasibility and safety have already been demonstrated in early clinical experiences [25].

Key enablers: progress in perioperative management

Successful implementation of tubeless uniportal thoracoscopic surgery depends

on a well-integrated perioperative management strategy, encompassing anesthesia techniques, respiratory support, pain control, and postoperative care [7]. Non-intubated anesthesia is central to the tubeless concept. In most cases, total intravenous anesthesia (TIVA) combined with regional nerve blocks—such as thoracic paravertebral block (TPVB), intercostal nerve block (INB), or erector spinae plane block (ESPB)—is employed to achieve adequate anesthesia and analgesia without endotracheal intubation [26, 27]. Patients maintain spontaneous ventilation via high-flow nasal cannula (HFNC) or laryngeal mask airway, which ensures oxygenation while avoiding the complications associated with positive pressure ventilation.

Effective perioperative analgesia is essential to support spontaneous breathing and early mobilization. In addition to regional nerve blocks, intraoperative infiltration with long-acting local anesthetics such as ropivacaine is commonly used to reduce postoperative analgesic requirements [28]. Furthermore, selective omission of chest drainage requires meticulous intraoperative hemostasis and careful assessment of air leakage. Surgeons must confirm complete lung re-expansion and hemostatic stability before concluding the procedure [6]. Collectively, these strategies aim to maintain physiological stability and facilitate early recovery, thereby supporting the safe implementation of the "no intubation, no drain" paradigm within minimally invasive thoracic surgery.

CURRENT STATUS OF APPLICATION OF TUBELESS UNIPORTAL THORACOSCOPIC SURGERY IN DIFFERENT THORACIC PROCEDURES

With the refinement of non-intubated anesthesia and perioperative management protocols, tubeless uniportal thoracoscopic surgery has gained increasing attention across various thoracic procedures. Its clinical application has gradually expanded from low-complexity surgeries such as thoracic sympathectomy to more technically demanding interventions, including pulmonary wedge resection, mediastinal tumor excision, and early-stage lung cancer [29, 30]. This section provides a categorized overview of its current clinical applications across different surgical scenarios.

Applications of tubeless technology in different surgical procedures are illustrated in **Figure 2**.

Primary palmar hyperhidrosis (thoracic sympathectomy)

Thoracic sympathectomy is one of the earliest and most established applications of tubeless uniportal VATS[31]. It is commonly performed in younger patients with severe palmar sweating, which negatively affects their quality of life and social function [32]. Given its superficial anatomy, limited dissection, and minimal bleeding risk, sympathectomy offers favorable conditions for applying tubeless principles, characterized by non-intubated anesthesia with preserved spontaneous breathing and drainage-free surgery [33]. From an anesthetic and perioperative management perspective, non-intubated total intravenous anesthesia (TIVA) combined with regional techniques such as thoracic paravertebral block (TPVB) or erector spinae plane block (ESPB) is commonly employed. Oxygenation is typically maintained using a laryngeal mask airway or high-flow nasal cannula, which helps minimize airway trauma while ensuring adequate ventilation and surgical exposure [34]. Additional intercostal nerve blocks or local infiltration with long-acting anesthetics may be applied to further optimize postoperative analgesia. Clinical evidence consistently supports the feasibility and safety of tubeless endoscopic thoracic sympathectomy. In a large clinical series, Shao et al.[31] reported 172 patients undergoing tubeless sympathectomy with no intraoperative conversion, minimal postoperative pain (median visual analog scale score of 2 on postoperative day 0), and a median length of hospital stay of 1 day. Beyond procedure-specific series, a recent meta-analysis comparing non-intubated and conventional intubated VATS demonstrated lower postoperative pain scores and improved early postoperative recovery in the non-intubated group [35]. Furthermore, Majeed et al. [36] reported sustained improvements in quality of life and high patient satisfaction during follow-up in a large cohort of patients undergoing single-port endoscopic thoracic sympathectomy.

Overall, thoracic sympathectomy constitutes a highly standardized and low-risk

setting for the application of tubeless uniportal VATS. The predictable anatomy, limited physiological disturbance, and favorable perioperative outcomes observed in this procedure make it an important reference model for the stepwise extension of tubeless techniques to more complex thoracic surgical interventions.

Pulmonary wedge resection / spontaneous pneumothorax surgery

Spontaneous pneumothorax and bullous lung disease are among the most frequent benign indications for thoracic surgery and represent a logical next step in the application of tubeless uniportal VATS [37]. These conditions typically involve peripheral lesions and limited resection margins, which provide favorable anatomical conditions for non-intubated and selectively drain-free thoracoscopic techniques [38]. Accordingly, tubeless pulmonary wedge resection is generally performed in young and otherwise healthy patients with preserved pulmonary function and without extensive pleural adhesions or emphysema.

From a technical standpoint, successful tubeless wedge resection relies on meticulous intraoperative hemostasis, effective prevention and management of air leaks, and confirmation of complete lung re-expansion without routine postoperative chest drainage[39]. Careful patient selection and intraoperative assessment are therefore critical to ensure procedural safety under spontaneous ventilation conditions. Clinical evidence supports the feasibility of this approach in selected patients. In a representative clinical series, Li et al.[38] reported that tubeless uniportal thoracoscopic surgery for pneumothorax and pulmonary bullae was feasible and safe, with a mean postoperative hospital stay of approximately 3.5 days and no major perioperative complications. These findings suggest that tubeless wedge resection can be reliably performed when strict selection criteria and standardized operative principles are applied.

Beyond its immediate clinical role, pulmonary wedge resection occupies an important transitional position in the stepwise adoption of tubeless techniques. Its relatively standardized operative workflow, limited extent of resection, and manageable intraoperative variability make it a suitable platform for accumulating

experience in non-intubated anesthesia, air-leak control, and postoperative monitoring[40]. With continued refinement of perioperative management strategies, tubeless uniportal VATS in this setting may facilitate broader acceptance of tubeless concepts and support their extension to more complex thoracic procedures[17].

Thymoma resection/anterior mediastinal lesions

While tubeless uniportal VATS has been well established in selected benign thoracic procedures, its application in anterior mediastinal tumors such as thymoma remains limited and largely exploratory[41]. Owing to the anatomical proximity of the anterior mediastinum to vital structures, including the great vessels and pericardium, as well as the confined operative space, non-intubated uniportal thymectomy within a tubeless-oriented framework under spontaneous ventilation poses distinct technical challenges. As a result, reported clinical experience has largely been restricted to carefully selected patients with small, well-circumscribed early-stage thymomas (Masaoka stage I–II).

From a technical and anesthetic perspective, maintaining a stable surgical field during spontaneous breathing represents a major concern in non-intubated uniportal thymectomy within a tubeless-oriented framework. Diaphragmatic motion and mediastinal excursion may compromise visualization and increase the difficulty of precise dissection, particularly in close proximity to major vascular structures. To mitigate these challenges, specialized centers have adopted strategies such as optimized patient positioning, customized curved instruments, and refined endoscopic visualization techniques. Thorough preoperative imaging evaluation and detailed knowledge of thymic and perithymic vascular anatomy are therefore essential to minimize intraoperative risks[17].

Anesthetic management plays a central enabling role in the safe conduct of non-intubated uniportal thymectomy within a tubeless-oriented framework. Deep total intravenous anesthesia with propofol and remifentanil, combined with thoracic paravertebral or erector spinae plane block, is commonly employed [42]. Controlled respiratory suppression, including brief apnea or assisted ventilation at critical

procedural moments, is often applied to facilitate accurate dissection. Successful execution of these procedures requires close coordination between surgical and anesthesia teams to ensure airway security, hemodynamic stability, and optimal operative exposure[43].

Clinical evidence supporting tubeless or tubeless-related thymectomy remains limited but encouraging in carefully selected early-stage patient cohorts. In a representative case series, Liu et al.(44) reported ten patients with early-stage thymoma associated with myasthenia gravis who underwent non-intubated uniportal subxiphoid thoracoscopic extended thymectomy. All procedures were completed successfully without conversion to intubated anesthesia or thoracotomy, and no major perioperative complications were observed. Although postoperative chest drainage was still employed in this series, postoperative pain was generally mild, with reported visual analog scale (VAS) scores ranging from 1 to 3, supporting the technical feasibility of non-intubated uniportal thymectomy in specialized settings.

Overall, although the current evidence base is limited, available reports suggest that non-intubated uniportal thymectomy within a tubeless-oriented framework is feasible and safe in carefully selected patients when performed in experienced centers. The technical complexity, restricted indications, and reliance on advanced anesthetic–surgical coordination underscore the need for cautious patient selection and further accumulation of clinical experience before broader adoption can be considered.

Radical resection of lung cancer (lobectomy, segmentectomy)

The widespread implementation of low-dose computed tomography screening has increased the detection of early-stage non-small cell lung cancer (NSCLC), prompting interest in extending tubeless uniportal VATS to anatomical lung resections[45]. At present, its application remains largely restricted to carefully selected patients with stage I disease, small peripheral tumors, and no radiological or intraoperative evidence of lymph node involvement, making patient selection a prerequisite for oncologic safety[46].

Compared with limited resections for benign disease or small pulmonary nodules, anatomical lung resection under tubeless conditions poses substantially greater technical and oncologic challenges. Although non-intubated and tubeless-oriented strategies have been increasingly explored in wedge resection and other sublobar procedures, dedicated clinical series focusing specifically on completely tubeless uniportal segmentectomy or lobectomy are still scarce, and most available evidence is derived from small, single-center experiences or mixed procedural cohorts.

From a technical standpoint, the prevention and management of intraoperative air leakage represents a critical challenge in tubeless anatomical lung resection. Strategies including meticulous water seal testing, selective use of biological sealants, and confirmation of postoperative lung re-expansion by bedside ultrasound or chest radiography have been adopted, and some centers employ short-term "tubeless observation protocols" for early detection of complications[47, 48]. In parallel, expert consensus statements and technical reviews emphasize patient selection, air-leak control, and readiness for prompt conversion when necessary[49, 50], while acknowledging that these sources provide conceptual guidance rather than primary patient-level outcome data.

From an oncologic standpoint, extending tubeless uniportal VATS to anatomical lung resection warrants cautious evaluation. Adequate lymph node dissection and sufficient resection margins are central to curative lung cancer surgery, yet both may be technically more demanding under spontaneous ventilation and limited operative exposure, particularly during complex hilar procedures or segmentectomy. In addition, the learning curve of tubeless uniportal anatomical resection should not be underestimated, as current experience is largely derived from high-volume centers and early adoption may be associated with higher conversion rates or prolonged operative times[51].

Overall, while preliminary experience suggests that tubeless-oriented uniportal approaches may be technically feasible in carefully selected cases of early-stage lung cancer, the current evidence base remains limited. Although a randomized clinical trial has evaluated minimally invasive lung surgery using completely or partially

tubeless protocols[14], robust large-scale multicenter randomized controlled trials specifically addressing completely tubeless uniportal anatomical resections—particularly lobectomy—are still lacking. Further well-designed prospective studies are therefore required to validate oncologic safety, reproducibility, and broader clinical applicability. The currently available primary clinical evidence supporting tubeless uniportal VATS, predominantly in sympathectomy and sublobar procedures, is summarized in **Table 1**.

ADVANTAGES AND CHALLENGES OF TUBELESS UNIPORTAL TECHNOLOGY

With the expanding clinical adoption of tubeless uniportal thoracoscopic surgery across multiple thoracic procedures, increasing attention has been directed toward its therapeutic value and translational potential. Drawing upon clinical experience in sympathectomy, pulmonary wedge resection, thymectomy, and early-stage lung cancer resection, this section summarizes the key benefits and implementation challenges associated with this technique.

Clinical advantages: promoting postoperative rehabilitation and optimizing patient experience

The primary clinical benefit of tubeless uniportal VATS is generally considered to lie in its ability to minimize perioperative invasiveness, thereby enhancing postoperative recovery and patient comfort(52). Non-intubated anesthesia avoids complications related to tracheal intubation—such as sore throat, bronchospasm, and atelectasis. Eliminating the use of chest drains significantly reduces pain associated with intercostal irritation and allows for earlier mobilization, which in turn facilitates the recovery of pulmonary function(53). In addition, ERAS-oriented, opioid-sparing analgesic strategies—often implemented alongside tubeless protocols—may help reduce opioid-related side effects and simplify nursing care.

These advantages are supported by several clinical studies. For example, Wang et al.[54] reported lower postoperative pain scores during the early postoperative period

and a tendency toward shorter hospital stays in patients undergoing non-intubated or tubeless-oriented segmentectomy within their cohort. Similarly, Pompeo et al.[17] observed early postoperative ambulation and reduced postoperative analgesic requirements following tubeless wedge resection. These observations are consistent with the principles of enhanced recovery after surgery (ERAS) and highlight the potential role of tubeless VATS in facilitating postoperative rehabilitation.

Practical limitations of technology and promotion

Despite its clinical promise, the broader implementation of tubeless uniportal VATS remains limited by several technical and systemic challenges. First, the technique itself is inherently complex. Non-intubated anesthesia requires the maintenance of stable spontaneous ventilation, while thoracoscopic manipulation may be affected by diaphragmatic movement and fluctuating visual fields. Such dynamics increase the demand for precise surgical coordination, particularly during procedures involving hilar dissection or bronchial division(5).

Second, successful execution is highly dependent on the experience and coordination of both the surgical and anesthesia teams. Maintaining adequate analgesia, oxygenation, and field exposure under spontaneous breathing conditions necessitates a high level of intraoperative collaboration. Moreover, a lack of standardized clinical pathways—including protocols for patient selection, air leak management, and postoperative drainage strategies—continues to impede widespread adoption. The current evidence base is also limited. Most published studies are retrospective, single-center analyses with small sample sizes. The absence of multicenter prospective RCTs has constrained the development of consensus guidelines and evidence-based recommendations. To facilitate broader adoption, future efforts should focus on the establishment of unified technical standards, multidisciplinary training programs, and high-quality clinical trials. A comparison of tubeless and conventional VATS techniques is presented in **Table 2**, highlighting their respective clinical features and limitations.

It should be noted that the current evidence supporting tubeless uniportal VATS

is heterogeneous in study design and clinical context. Most available studies are retrospective or observational series with small sample sizes, and only a limited number of randomized or comparative trials have been reported. Moreover, favorable outcomes are predominantly derived from high-volume centers with substantial expertise in non-intubated thoracic anesthesia and advanced uniportal techniques, introducing potential selection and center-experience bias. Accordingly, existing data should be interpreted with appropriate caution when extrapolating to broader clinical settings.

Beyond evidence-related limitations, tubeless uniportal VATS is associated with specific intraoperative risks and failure-to-proceed scenarios. Hypoxemia related to hypoventilation or prolonged lung collapse, inadequate suppression of the cough reflex, hemodynamic instability, and unexpected bleeding may necessitate conversion[55]. Both anesthesiologic and surgical learning curves play a critical role in mitigating these risks, as early adoption is often associated with higher conversion rates and longer operative times. These considerations underscore the importance of structured training, stepwise implementation, and clearly defined conversion criteria.

Patient selection: inclusion criteria and contraindications

Given the central role of patient selection in the safety and feasibility of tubeless uniportal VATS, commonly reported inclusion criteria and contraindications warrant summary. Suitable candidates typically have adequate cardiopulmonary reserve, stable respiratory function, and a low risk of airway compromise, and undergo anatomically straightforward procedures with limited bleeding risk under spontaneous ventilation. Relative contraindications include obesity, moderate chronic obstructive pulmonary disease, anticipated difficult airway, extensive pleural adhesions, or complex hilar dissection[56]. Absolute contraindications commonly cited are severe hypoxemia, unstable cardiopulmonary disease, high aspiration risk, anticipated massive bleeding, or inability to ensure timely conversion to intubated anesthesia. These considerations emphasize the importance of careful patient selection and appropriate institutional experience[57].

In clinical practice, clear conversion criteria are essential to ensure patient safety during tubeless uniportal VATS. Commonly reported triggers for conversion to endotracheal intubation include persistent hypoxemia despite optimization of spontaneous ventilation, uncontrolled hypercapnia, excessive patient movement or cough compromising surgical safety, hemodynamic instability, and unexpected major bleeding[58]. Inability to maintain a stable operative field under spontaneous breathing is also frequently cited. Indications for chest drain placement during or after tubeless procedures commonly include significant or persistent air leakage, incomplete lung re-expansion, or intraoperative bleeding requiring postoperative monitoring. Importantly, timely conversion or drain placement should be regarded as a safety measure rather than a procedural failure, and predefined conversion thresholds are widely emphasized in expert reports[55].

OUTLOOK AND FUTURE DEVELOPMENT DIRECTION

Tubeless uniportal thoracoscopic surgery represents a promising advancement in the field of minimally invasive thoracic procedures. It has demonstrated clinical feasibility and early success across multiple surgical indications. However, its transition from experimental application to widespread adoption requires further development across several dimensions, including technical standardization, intelligent assistance, evidence accumulation, and integration with perioperative care frameworks. This section outlines four key directions for future advancement.

Technical standardization and clinical guideline construction

Currently, no unified protocols exist for patient selection, anesthesia strategies, intraoperative management, or postoperative care in tubeless uniportal VATS. Variation across centers in drainage management, as well as in ERAS-oriented pain control methods, and contingency plans significantly affects reproducibility and generalizability. Establishing standardized procedural pathways—stratified by surgical complexity—would support broader implementation. It is recommended that academic organizations collaborate to publish consensus-based clinical guidelines to

define procedural classifications, intraoperative milestones, and conversion thresholds, accompanied by training platforms and simulation-based education(10).

Integration of artificial intelligence and surgical navigation

Intraoperative control remains one of the most technically demanding aspects of tubeless thoracic surgery, especially under spontaneous ventilation. Emerging technologies such as artificial intelligence (AI), augmented reality (AR), and intraoperative imaging offer potential solutions. For example, three-dimensional segmentation algorithms and vascular mapping from preoperative CT imaging can assist in surgical planning. AI-guided risk prediction models may eventually support real-time decision-making based on intraoperative respiratory fluctuations or bleeding risk(59, 60). These tools are still in development, and future studies are required to validate their utility in tubeless contexts.

The need for multicenter prospective studies and randomized controlled trials

Most existing data on tubeless VATS are derived from single-center, retrospective case series with limited sample sizes. Although randomized evidence has begun to emerge for minimally invasive lung surgery using tubeless protocols, robust multicenter RCTs specifically focused on completely tubeless uniportal procedures remain limited, which restricts the generalizability of current findings. To strengthen the evidence base, prospective multicenter RCTs should systematically assess efficacy, safety, and long-term outcomes across specific procedures, including segmentectomy, thymectomy, and lobectomy. Relevant endpoints should include postoperative complication rates, pulmonary function recovery, immune modulation, and quality-of-life measures. In addition, registry-based real-world studies may complement RCT data by providing insights into economic outcomes and scalability in routine clinical practice.

Integration with ERAS concept: creating a complete minimally invasive chain from preoperative to intraoperative to postoperative

The essential goals of tubeless technology are highly consistent with the ERAS

concept. In the future, tubeless uniportal VATS may be incorporated within ERAS-aligned thoracic surgical pathways as a key intraoperative strategy, rather than as a standalone perioperative framework. From a broader perspective, ERAS-oriented care spans preoperative optimization (e.g., nutrition, psychological preparation, pulmonary training), intraoperative management (e.g., non-intubated anesthesia, spontaneous breathing, selective omission of drainage), and postoperative rehabilitation (e.g., analgesia optimization, early mobilization, individualized discharge criteria). By integrating tubeless principles into ERAS-based pathways, it may be possible to further shorten hospital stay, reduce perioperative risks, and improve patient-centered outcomes.

In summary, the continued evolution of tubeless uniportal thoracoscopic surgery will depend on interdisciplinary collaboration, technological innovation, and robust clinical validation. These efforts will be essential to transition the technique from a niche approach to a standardized component of modern thoracic surgery.

Stepwise implementation and training pathway

Given the strong dependence of tubeless uniportal VATS on multidisciplinary experience, a stepwise implementation strategy is advisable. Initial adoption is generally recommended in low-risk, standardized procedures such as thoracic sympathectomy, allowing teams to become familiar with non-intubated anesthesia, spontaneous ventilation, and conversion protocols. With increasing experience, progression to pulmonary wedge resection or spontaneous pneumothorax surgery may be considered, introducing air-leak management and lung re-expansion assessment while maintaining limited procedural complexity. Mediastinal procedures, such as thymectomy, require further refinement of anesthetic–surgical coordination to ensure field stability under spontaneous breathing. Anatomical lung resections, including segmentectomy and selected lobectomy, should be reserved for centers with substantial expertise, where strict patient selection, predefined conversion criteria, and close intraoperative collaboration are in place. Such a staged pathway may facilitate safe adoption and gradual expansion of tubeless uniportal VATS.

Limitations

Several limitations of this review should be acknowledged. As a narrative review, the literature synthesis was qualitative rather than systematic, and no formal study-level quality appraisal or quantitative comparison was performed. The review was restricted to English-language publications, which may have led to the omission of relevant studies. In addition, substantial heterogeneity exists in procedural definitions, patient selection criteria, and interpretations of "tubeless" protocols across studies, limiting direct comparability. Finally, the available evidence is largely derived from small, single-center observational studies, and potential publication bias toward favorable outcomes cannot be excluded. These limitations should be considered when interpreting the findings and highlight the need for more standardized reporting and higher-quality prospective studies.

CONCLUSION

Tubeless uniportal thoracoscopic surgery has shown favorable feasibility, safety, and early recovery benefits in selected thoracic procedures, particularly sympathectomy, wedge resection, and early-stage lung cancer. As an advanced minimally invasive technique, it offers a patient-centered option that reduces perioperative trauma. Broader adoption will require standardized clinical pathways, intelligent assistance, and multicenter validation to ensure safe and evidence-based application in more complex operations.

Conflicts of interest: Authors declare no conflicts of interest.

Funding: Authors received no specific funding for this work.

Submitted: December 1, 2025

Accepted: January 6, 2026

Published online: January 20, 2026

REFERENCES

1. Geldenhuys A. Thoracic damage control surgery. Current Trauma Reports. 2018;4:177–82. https://doi.org/10.1007/s40719-018-0137-z
2. Yan Y, Huang Q, Han H, Zhang Y, Chen H. Uniportal versus multiportal video-assisted thoracoscopic anatomical resection for NSCLC: a meta-analysis. J Cardiothorac Surg. 2020;15(1):238. https://doi.org/10.1186/s13019-020-01280-2
3. Shen C, Che G. No drains in thoracic surgery with ERAS program. J Cardiothorac Surg. 2020;15(1):112. https://doi.org/10.1186/s13019-020-01164-5
4. Liu CY, Hsu PK, Chien HC, Hsieh CC, Ting CK, Tsou MY. Tubeless single-port thoracoscopic sublobar resection: indication and safety. J Thorac Dis. 2018;10(6):3729–37. https://doi.org/10.21037/jtd.2018.05.119
5. Koh LY, Hwang NC. Anesthesia for nonintubated video-assisted thoracoscopic surgery. J Cardiothorac Vasc Anesth. 2023;37(7):1275–83. https://doi.org/10.1053/j.jvca.2023.02.048
6. Liu J, Liang H, Cui F, Liu H, Zhu C, Liang W, et al. Spontaneous versus mechanical ventilation during video-assisted thoracoscopic surgery for spontaneous pneumothorax: a randomized trial. J Thorac Cardiovasc Surg. 2022;163(5):1702–14.e7.
7. Huang K, Zhang Z, Hu T, Qiao L. Advances in the use of non-intubated spontaneous-ventilation video-assisted thoracoscopic surgery. Front Surg. 2025;12:1584017. https://doi.org/10.3389/fsurg.2025.1584017
8. Hung MH, Hsu HH, Cheng YJ, Chen JS. Nonintubated thoracoscopic surgery: state of the art and future directions. J Thorac Dis. 2014;6(1):2–9.

9. Cui F, Liu J, Li S, Yin W, Xin X, Shao W, et al. Tubeless video-assisted thoracoscopic surgery (VATS) under non-intubated, intravenous anesthesia with spontaneous ventilation and no placement of chest tube postoperatively. J Thorac Dis. 2016;8(8):2226–32. https://doi.org/10.21037/jtd.2016.08.02
10. He J, Liu J, Zhu C, Dai T, Cai K, Zhang Z, et al. Expert consensus on tubeless video-assisted thoracoscopic surgery (Guangzhou). J Thorac Dis. 2019;11(10):4101–8. https://doi.org/10.21037/jtd.2019.10.04
11. Janik M, Juhos P, Lucenic M, Tarabova K. Non-intubated thoracoscopic surgery – pros and cons. Front Surg. 2021;8:801718. https://doi.org/10.3389/fsurg.2021.801718
12. Umari M, Falini S, Segat M, Zuliani M, Crisman M, Comuzzi L, et al. Anesthesia and fast-track in video-assisted thoracic surgery (VATS): from evidence to practice. J Thorac Dis. 2018;10(Suppl 4):S542–S54. https://doi.org/10.21037/jtd.2017.12.83
13. Khoury AL, Kolarczyk LM, Strassle PD, Feltner C, Hance LM, Teeter EG, et al. Thoracic enhanced recovery after surgery: single academic center observations after implementation. Ann Thorac Surg. 2021;111(3):1036–43. https://doi.org/10.1016/j.athoracsur.2020.06.021
14. Zhao Y, Shan L, Zhang W, Li P, Li N, Zhang H, et al. Minimally invasive lung surgery with an intraoperative completely or partially tubeless protocol: randomized clinical trial. BJS Open. 2024;9(1):zrae132. https://doi.org/10.1093/bjsopen/zrae132
15. Huang Y, Bo Y, Li Y, Zhao Y, Li X, Chen D, et al. The impact of tubeless anesthesia versus intubated anesthesia on cerebral oxygen saturation and postoperative cognitive function in patients undergoing video-assisted thoracoscopic surgery: a randomized trial. J Thorac Dis. 2022;14(10):4012–30. https://doi.org/10.21037/jtd-22-1165

16. Szabo Z, Fabo C, Oszlanyi A, Hawchar F, Geczi T, Lantos J, et al. Anesthetic (r)evolution from the conventional concept to the minimally invasive techniques in thoracic surgery: narrative review. J Thorac Dis. 2022;14(8):3045–60. https://doi.org/10.21037/jtd-22-80
17. Pompeo E. From awake to minimalist spontaneous ventilation thoracoscopic lung surgery: an ongoing journey. J Clin Med. 2025;14(7):2475. https://doi.org/10.3390/jcm14072475
18. Batchelor TJP. Enhanced recovery after surgery and chest tube management. J Thorac Dis. 2023;15(2):901–8. https://doi.org/10.21037/jtd-22-1373
19. Tsai CS, Tung HH, Fang CJ, Chen CT. Effectiveness of non-pharmacological interventions for pain reduction following chest tube removal: a systematic review and network meta-analysis. Intensive Crit Care Nurs. 2025;87:103909. https://doi.org/10.1016/j.iccn.2024.103909
20. Hung WT, Cheng YJ, Chen JS. Video-assisted thoracoscopic surgery lobectomy for lung cancer in nonintubated anesthesia. Thorac Surg Clin. 2020;30(1):73–82. https://doi.org/10.1016/j.thorsurg.2019.09.002
21. Fu Z, Wang L, Hu W, Zhou Y, Zhou Q. Comparison of the efficacy of subxiphoid and intercostal uniportal video-assisted thoracoscopic surgery in patients with early-stage non-small cell lung cancer. Pak J Med Sci. 2025;41(2):359–65. https://doi.org/10.12669/pjms.41.2.11096
22. Alanwar M, Elsharawy M, Brik A, Ahmady I, Shemais DS. Safety and perioperative outcomes of uniportal versus multiportal video-assisted thoracoscopic surgery. J Minim Access Surg. 2024;20(3):294–300. https://doi.org/10.4103/jmas.jmas_84_23
23. Elsayed HH, Moharram AA. Tailored anaesthesia for thoracoscopic surgery promoting enhanced recovery: the state of the art. Anaesth Crit Care Pain Med. 2021;40(2):100846. https://doi.org/10.1016/j.accpm.2021.100846

24. Wang LF, Qi F, Feng HX, Shi YH, Li Y, Zheng MT, et al. Risk and benefit analysis of single-shot nerve block for postoperative analgesia for uniportal video-assisted thoracic surgery (uVATS): a randomized controlled trial. BMC Anesthesiol. 2025;25(1):68. https://doi.org/10.1186/s12871-025-02955-w
25. Galvez C, Bolufer S, Galvez E, Navarro-Martinez J, Galiana-Ivars M, Sesma J, et al. Anatomic segmentectomy in nonintubated video-assisted thoracoscopic surgery. Thorac Surg Clin. 2020;30(1):61–72. https://doi.org/10.1016/j.thorsurg.2019.09.003
26. Tacconi F, Pompeo E. Non-intubated video-assisted thoracic surgery: where does evidence stand? J Thorac Dis. 2016;8(Suppl 4):S364–75. https://doi.org/10.21037/jtd.2016.04.39
27. Jo Y, Park S, Oh C, Pak Y, Jeong K, Yun S, et al. Regional analgesia techniques for video-assisted thoracic surgery: a frequentist network meta-analysis. Korean J Anesthesiol. 2022;75(3):231–44. https://doi.org/10.4097/kja.21330
28. Fabo C, Oszlanyi A, Lantos J, Rarosi F, Horvath T, Barta Z, et al. Non-intubated thoracoscopic surgery – tips and tricks from anesthesiological aspects: a mini review. Front Surg. 2021;8:818456. https://doi.org/10.3389/fsurg.2021.818456
29. Chen KC, Cheng YJ, Hung MH, Tseng YD, Chen JS. Nonintubated thoracoscopic lung resection: a 3-year experience with 285 cases in a single institution. J Thorac Dis. 2012;4(4):347–51.
30. Gonzalez-Rivas D, Bonome C, Fieira E, Aymerich H, Fernandez R, Delgado M, et al. Non-intubated video-assisted thoracoscopic lung resections: the future of thoracic surgery? Eur J Cardiothorac Surg. 2016;49(3):721–31. https://doi.org/10.1093/ejcts/ezv136
31. Shao GQ, Pang DZ, Zhang JT, Wang HX, Liuru TY, Liu ZH, et al. Spontaneous ventilation anesthesia combined with uniportal and tubeless thoracoscopic sympathectomy in selected patients with primary palmar hyperhidrosis. J

Cardiothorac Surg. 2022;17(1):177. https://doi.org/10.1186/s13019-022-01917-4

32. Sang HW, Li GL, Xiong P, Zhu MC, Zhu M. Optimal targeting of sympathetic chain levels for treatment of palmar hyperhidrosis: an updated systematic review. Surg Endosc. 2017;31(11):4357–69. https://doi.org/10.1007/s00464-017-5508-y
33. Chen JF, Lin JB, Tu YR, Lin M, Li X, Lai FC, et al. Nonintubated transareolar single-port thoracic sympathicotomy with a needle scope in a series of 85 male patients. Surg Endosc. 2016;30(8):3447–53. https://doi.org/10.1007/s00464-015-4628-5
34. Cao J, Gao X, Zhang X, Li J, Zhang J. Feasibility of laryngeal mask anesthesia combined with nerve block in adult patients undergoing internal fixation of rib fractures: a prospective observational study. BMC Anesthesiol. 2020;20(1):170. https://doi.org/10.1186/s12871-020-01082-y
35. Magouliotis DE, Karamolegkou AP, Zotos PA, Minervini F, Cioffi U, Scarci M. Is less more? A meta-analysis of non-intubated versus intubated VATS for anatomic resections in non-small cell lung cancer. J Clin Med. 2025;14(19):6731. https://doi.org/10.3390/jcm14196731
36. Majeed ZS, Baram A, Izac AY. Quality of life and patient satisfaction after single-port endoscopic thoracic sympathectomy for primary focal hyperhidrosis: a follow-up of 250 patients. International Journal of Surgery Open. 2024;62(4):373–8. https://doi.org/10.1097/IO9.0000000000000097
37. Igai H, Matsuura N, Numajiri K, Ohsawa F, Kamiyoshihara M. Feasibility of tubeless thoracoscopic bullectomy in primary spontaneous pneumothorax patients. Gen Thorac Cardiovasc Surg. 2023;71(2):138–44. https://doi.org/10.1007/s11748-022-01869-5
38. Li X, Wang X, Zhang H, Cheng H, Cao Q. Unilateral single-port thoracoscopic surgery for bilateral pneumothorax or pulmonary bullae. J Cardiothorac Surg.

2019;14(1):71.
https://doi.org/10.1186/s13019-019-0894-y

39. Chen PH, Hung WT, Chen JS. Nonintubated video-assisted thoracic surgery for the management of primary and secondary spontaneous pneumothorax. Thorac Surg Clin. 2020;30(1):15–24.
https://doi.org/10.1016/j.thorsurg.2019.08.001
40. Mineo TC, Ambrogi V, Sellitri F. Non-intubated video-assisted thoracic surgery from multi to uniport approaches: single-centre experience. Eur Med J Respir. 2016;4:104–12.
https://doi.org/10.33590/emjrespir/10312090
41. Cui W, Huang D, Liang H, Peng G, Liu M, Li R, et al. Tubeless video-assisted thoracoscopic surgery in mediastinal tumor resection. Gland Surg. 2021;10(4):1387–96.
https://doi.org/10.21037/gs-20-682
42. Németh T. Pathophysiological background and perioperative outcome of thymus removal with spontaneous ventilation by intubation. Moving Forward With Minimal Invasiveness. Szeged University (Hungary); 2023.
43. Rosboch GL, Lyberis P, Ceraolo E, Balzani E, Cedrone M, Piccioni F, et al. The anesthesiologist's perspective regarding non-intubated thoracic surgery: a scoping review. Front Surg. 2022;9:868287.
https://doi.org/10.3389/fsurg.2022.868287
44. Liu Z, Zhang L, Tang W, Yang R. Non-intubated uniportal subxiphoid thoracoscopic extended thymectomy for thymoma associated with myasthenia gravis. World J Surg Oncol. 2021;19(1):342.
https://doi.org/10.1186/s12957-021-02430-z
45. Moon MH. Beyond the limits: journey to feasible and safe uniportal VATS surgery for lung cancer. J Thorac Dis. 2023;15(2):246–9.
https://doi.org/10.21037/jtd-22-1877

46. Yang SM, Hsu HH, Chen JS. Recent advances in surgical management of early lung cancer. J Formos Med Assoc. 2017;116(12):917–23. https://doi.org/10.1016/j.jfma.2017.07.009
47. Kreso A, Mathisen DJ. Management of air leaks and residual spaces following lung resection. Thorac Surg Clin. 2021;31(3):265–71. https://doi.org/10.1016/j.thorsurg.2021.04.005
48. Messina G, Natale G, Bove M, Opromolla G, Di Filippo V, Martone M, et al. Intraoperative ventilatory leak: real-time guidance for management of air leak in lung cancer patients undergoing VATS lobectomy. Thorac Cancer. 2023;14(18):1782–8. https://doi.org/10.1111/1759-7714.14925
49. He J, Liang H, Wang W, Akopov A, Aiolfi A, Ang KL, et al. Tubeless video-assisted thoracic surgery for pulmonary ground-glass nodules: expert consensus and protocol (Guangzhou). Transl Lung Cancer Res. 2021;10(8):3503–19. https://doi.org/10.21037/tlcr-21-663
50. Scarci M, Gkikas A, Patrini D, Minervini F, Cerfolio RJ. Editorial: early chest drain removal following lung resection. Front Surg. 2023;10:1185334. https://doi.org/10.3389/fsurg.2023.1185334
51. Yu J, Tantraworasin A, Laohathai S. Non-intubated versus intubated video-assisted thoracoscopic lobectomy for lung cancer patients. Asian J Surg. 2024;47(1):402–6. https://doi.org/10.1016/j.asjsur.2023.09.038
52. Watanabe T, Tanahashi M, Chiba M, Hashimoto K, Sakakura N, Okazaki M, et al. Postoperative pain reduction and clinical value of uniportal video-assisted thoracic surgery: a secondary analysis of the J-RATSIG 01 study. Clin Lung Cancer. 2025. https://doi.org/10.5090/jcs.2025S1.25S-0007
53. Holbek BL, Hansen HJ, Kehlet H, Petersen RH. Thoracoscopic pulmonary wedge resection without post-operative chest drain: an observational study. Gen Thorac

Cardiovasc Surg. 2016;64(10):612–7.
https://doi.org/10.1007/s11748-016-0692-6

54. Wang R, Wang Q, Jiang S, Chen C, Zheng J, Liu H, et al. Spontaneous ventilation video-assisted thoracoscopic surgery for non-small-cell lung cancer patients with poor lung function: short- and long-term outcomes. Front Surg. 2022;9:800082.
https://doi.org/10.3389/fsurg.2022.800082
55. Anile M, Vannucci J, Ferrante F, Bruno K, De Paolo D, Bassi M, et al. Non-intubated thoracic surgery: standpoints and perspectives. Front Surg. 2022;9:937633.
https://doi.org/10.3389/fsurg.2022.937633
56. Cherchi R, Ferrari PA, Guerrera F, Grimaldi G, Pinna-Susnik M, Murenu A, et al. Lung biopsy with a non-intubated VATS approach in an obese population: indications and results. Front Surg. 2022;9:829976.
https://doi.org/10.3389/fsurg.2022.829976
57. Grott M, Eichhorn M, Eichhorn F, Schmidt W, Kreuter M, Winter H. Thoracic surgery in the non-intubated spontaneously breathing patient. Respir Res. 2022;23(1):379.
https://doi.org/10.1186/s12931-022-02250-z
58. Furak J, Szabo Z, Tanczos T, Paszt A, Rieth A, Nemeth T, et al. Conversion method to manage surgical difficulties in non-intubated uniportal video-assisted thoracic surgery for major lung resection: simple thoracotomy without intubation. J Thorac Dis. 2020;12(5):2061–9.
https://doi.org/10.21037/jtd-19-3830
59. Abbaker N, Minervini F, Guttadauro A, Solli P, Cioffi U, Scarci M. The future of artificial intelligence in thoracic surgery for non-small cell lung cancer treatment: a narrative review. Front Oncol. 2024;14:1347464.
https://doi.org/10.3389/fonc.2024.1347464

60. Poullis M. The transformation of risk modelling in cardiac and thoracic surgery through artificial intelligence. Eur J Cardiothorac Surg. 2024;65(1):ezae013. https://doi.org/10.1093/ejcts/ezae013
61. Li S, Jiang L, Ang KL, Chen H, Dong Q, Yang H, et al. New tubeless video-assisted thoracoscopic surgery for small pulmonary nodules. Eur J Cardiothorac Surg. 2017;51(4):689–93. https://doi.org/10.1093/ejcts/ezw364
62. Yang SM, Wang ML, Hung MH, Hsu HH, Cheng YJ, Chen JS. Tubeless uniportal thoracoscopic wedge resection for peripheral lung nodules. Ann Thorac Surg. 2017;103(2):462–8. https://doi.org/10.1016/j.athoracsur.2016.09.006

TABLES AND FIGURES WITH LEGENDS

Table 1. Summary of representative clinical case series on tubeless uniportal VATS

Procedure	Author (year)	Study design	Sample size	Anesthesia	Chest drain	Key outcomes
ETS	Shao et al. (2022)(31)	Case series	172	SVA / non-intubated anesthesia	No	POD0 VAS (median) 2; LOS (median) 1 day; no conversion to intubated anesthesia
PSP / Wedge Resection	Li et al. (2019)(38)	Case series	18	Spontaneous breathing	No	Feasible and safe; mean LOS 3.5 days; no major complications
Thymoma	Liu et al. (2021)(44)	Case series	10	TIVA + LMA	Yes (bilateral small-bore catheter drainage, 3–5 days)	Feasible in selected patients; no conversion; low postoperative pain (VAS 1–3)
SPN / Wedge resection	Li et al. (2017)(61)	Case series	34	Spontaneous ventilation (non-intubated)	No	No conversion; VAS 2 ± 1; LOS 1 ± 1 day
Peripheral	Yang et	Case	30	Non-intubat	No	No conversion;

lung nodules / Wedge resection	al. (2017)(62)	series		ed spontaneous ventilation		POD1 VAS 1.0 ± 0.8; LOS 3.1 ± 0.7 days

Note: "Tubeless" refers to the intentional exclusion of routine postoperative chest drainage; selective drainage, when clinically warranted, is reported accordingly. Abbreviations: SVA: Spontaneous ventilation anesthesia; TIVA: Total intravenous anesthesia; LMA: Laryngeal mask airway; ETS: Endoscopic thoracic sympathectomy; PSP: Primary spontaneous pneumothorax; SPN: Solitary pulmonary nodule; VATS: Video-assisted thoracoscopic surgery.

Table 2. Comparative analysis of tubeless uniportal VATS versus conventional VATS

Parameter	Tubeless uniportal VATS	Conventional VATS
Anesthesia	Non-intubated, spontaneous breathing	Intubated general anesthesia
Chest drain	Often omitted (reported in selected series)	Routinely placed
Postoperative pain	Generally lower postoperative pain reported (reported in selected series/centers)	Generally higher postoperative pain reported
Recovery time	Shorter hospital stay; early ambulation (in carefully selected patients)	Longer hospitalization
Patient selection	Strict; low-risk cases	Broader inclusion criteria
Technical complexity	High; requires experienced team	Moderate; more standardized
Evidence level	Mainly derived from case series and limited randomized evidence	Supported by multiple randomized trials and meta-analyses

Abbreviation: VATS: Video-assisted thoracoscopic surgery.

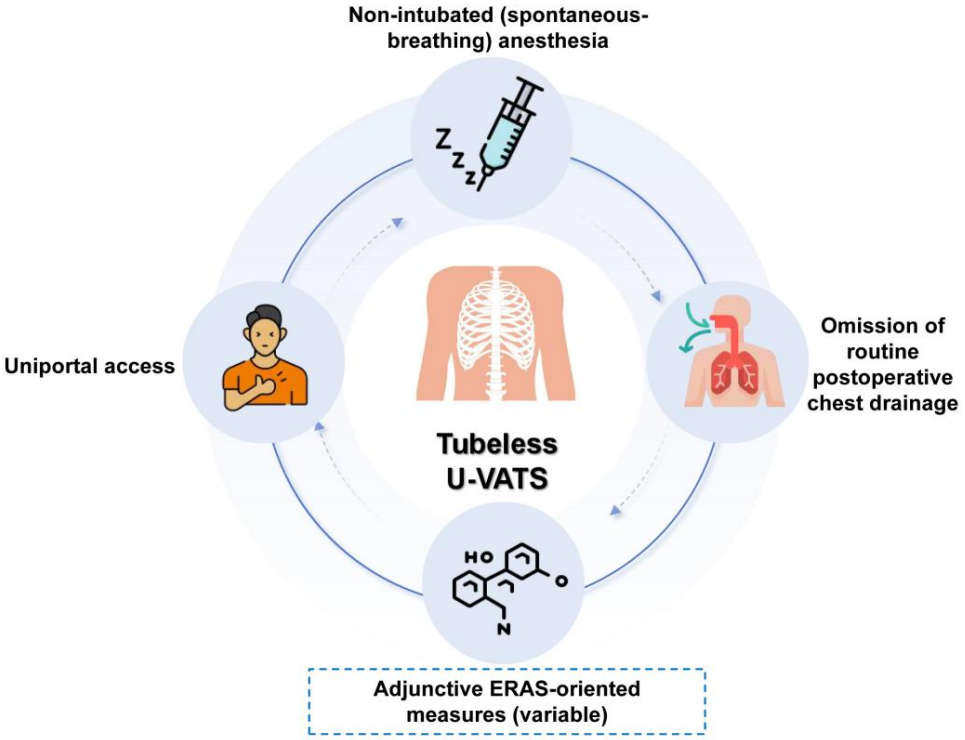

Figure 1. Schematic overview of tubeless uniportal video-assisted thoracoscopic surgery (U-VATS) and adjunctive ERAS-oriented measures. The tubeless U-VATS concept integrates uniportal access, non-intubated (spontaneous-breathing) anesthesia, and omission of routine postoperative chest drainage (core components). Adjunctive ERAS-oriented measures (variable; e.g., opioid-sparing analgesia and avoidance of postoperative analgesic pumps) may be added according to institutional protocols but are not mandatory definitional elements. Abbreviations: VATS: Video-assisted thoracoscopic surgery; U-VATS: Uniportal VATS; ERAS: Enhanced recovery after surgery.

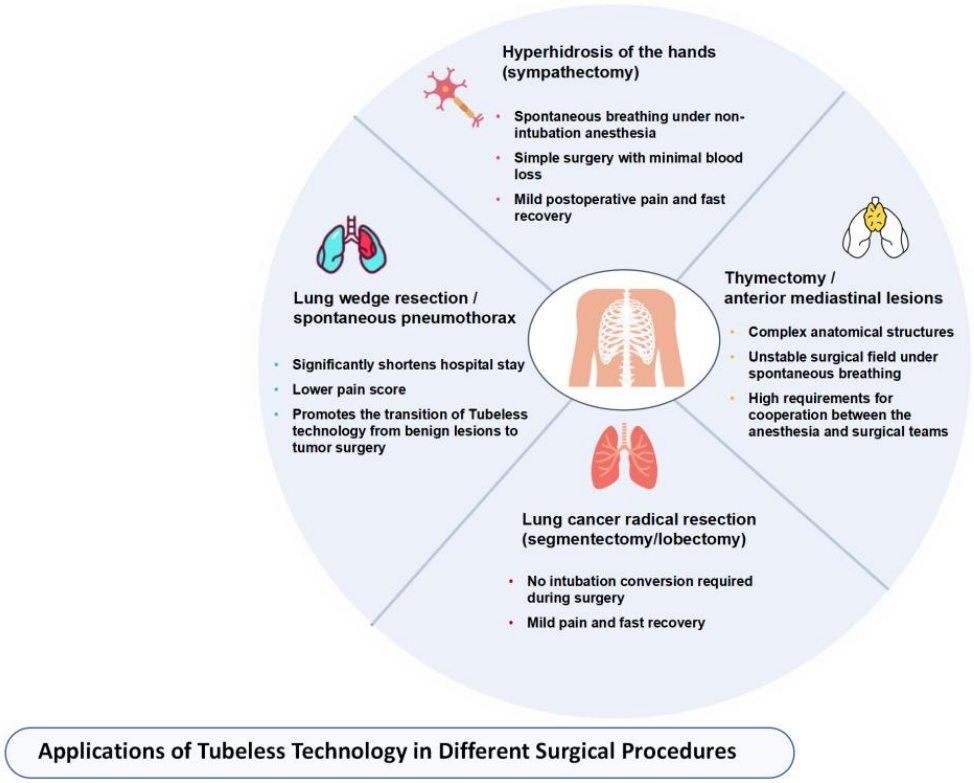

Figure 2. Applications of tubeless uniportal VATS across thoracic procedures.

The diagram categorizes current clinical use into four representative settings—endoscopic thoracic sympathectomy for palmar hyperhidrosis, lung wedge resection for spontaneous pneumothorax, thymectomy/anterior mediastinal lesion resection, and anatomical lung cancer resection (segmentectomy/lobectomy)—reflecting the stepwise extension of tubeless practice from lower- to higher-complexity operations as perioperative protocols have matured. Abbreviation: VATS: Video-assisted thoracoscopic surgery.