Heart Surgery Forum 2025; 28(8): E635–E643
doi: 10.59958/hsf.8577

Review

Implementation of Uniportal Video-Assisted Thoracoscopic Surgery to Treat Pericardial Effusion: A Review

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Submitted: 12 March 2025 Revised: 2 June 2025 Accepted: 18 June 2025 Published: 26 August 2025

Abstract

Pericardial effusion is the pathological accumulation of fluid in the pericardial cavity and can lead to life-threatening complications such as cardiac tamponade. While pericardiocentesis and surgical pericardial window creation remain the mainstay of treatment, uniportal video-assisted thoracoscopic surgery (UVATS) has emerged as a minimally invasive alternative with potential advantages over conventional approaches. This study comprehensively reviewed the existing literature to evaluate the safety, efficacy, and clinical outcomes of UVATS in managing pericardial effusion. A comprehensive search across the PubMed, Cochrane, and Google Scholar databases identified studies published from 2000 onward, focusing on the application of UVATS in thoracic surgery. The findings indicate that UVATS is associated with shorter hospital stays, reduced postoperative pain, and lower recurrence rates compared to multiportal VATS and the subxiphoid approach. Additionally, since UVATS is a single-incision technique, this method minimizes intercostal trauma, instead enhancing postoperative recovery. However, challenges remain, including a steep learning curve, technical limitations, and the requirement for specialized instrumentation. Despite these concerns, UVATS continues to evolve with advancements in instrumentation, imaging, and robotic assistance, further improving its feasibility and outcomes. As the adoption of UVATS grows, future research should focus on long-term efficacy, standardization of techniques, and expanded indications to optimize its role in thoracic surgery.

Keywords

uniportal VATS; pericardial effusion; minimally invasive surgery; thoracic surgery; pericardial window

Introduction

Over the past two decades, video-assisted thoracoscopic surgery (VATS) has achieved substantial advancements and success in the detection and management of a multitude of pulmonary and cardiac conditions [1,2]. With developments in technology, VATS has consistently become a safer treatment option, particularly for older and critically ill patients [3]. Meanwhile, numerous technical and procedural advancements have made it possible for surgeons to undertake increasingly sophisticated thoracic procedures with a single, double, or multiple microscopic incisions, thereby eliminating the intrinsic morbidity associated with the usual open thoracotomy.

Among its notable developments is uniportal VATS (UVATS), which enables complex thoracic procedures through a single small incision, reducing surgical trauma and postoperative morbidity. The concept was established in 1998 to perform lung decortication, mediastinum, lung, and pleura biopsies, partial pleurectomy and talc pleurodesis for pneumothorax, clotted hemothorax, active bleeding, sympathectomies, and debridement for loculated pleural effusion, as well as the removal of station 4R, 5, 8, or 9 lymph nodes for staging [4–6]. This technique involved using two or three instruments (VATS or instruments for open surgery) that were separated from the rigid optic through a single port [7].

Currently, UVATS is widely utilized for both simple thoracic procedures and lung resections, as well as more sophisticated thoracic procedures that typically require open techniques, such as pneumonectomy, bronchoplastic surgery, and pulmonary artery sleeve and chest wall resections. The increasing global adoption of UVATS, along with the growing body of scientific literature, highlights its significance in contemporary thoracic surgery. Designed to improve postoperative pain and quality of life, UVATS was intended to perform procedures more easily than traditional multiport VATS or thoracotomy, while still achieving the same or better clinical outcomes in a less traumatic manner. Initially, at the time of its pioneering, the surgeon (MM) envisioned overcoming some constraints by reducing the size of the devices. Although it is undoubtedly not a method for everyone, UVATS must be used cautiously and respectfully to develop the capacity to operate independently, safely, and efficiently.

Pericardial effusion (PE) is defined as the pathological accumulation of fluid between the heart and the pericardium, mainly resulting from an imbalance between pericardial fluid production and absorption [8]. To date, several techniques have been described for the diagnosis and treatment of PE, including pericardiocentesis, balloon pericardiotomy, pericardioperitoneal shunt, subxiphoid pericardial fenestration, anterior thoracotomy, percutaneous and subxiphoid catheter drainage, and thoracoscopy to create a pericardial window [9,10]. Meanwhile, UVATS has proven to be a highly effective and minimally invasive technique for pericardial drainage, biopsy, and window creation. Moreover, in addition to the diagnostic capabilities of UVATS, this technique also facilitates the simultaneous treatment of pulmonary and pleural illnesses [11].

This review examines the advancements, procedural techniques, and challenges of UVATS in managing pericardial effusion, while discussing its role in post-operative care and future innovations.

Methodology

A comprehensive literature search was conducted using the PubMed/MEDLINE, Cochrane, and Google Scholar databases. Articles were initially screened based on their abstracts, using the following inclusion criteria: (1) relevance to topics including uniportal VATS in thoracic surgery, pericardial window creation, comparisons between uniportal and multiportal VATS, and surgical techniques for pericardial effusion; (2) publication in English in a peer-reviewed journal.

Full-text manuscripts were then independently reviewed by three authors (MUA, BSA, and ROC) for final inclusion. No restrictions were placed on the year of publication. Although the inclusion criteria prioritized clinical trials and meta-analyses published from 2000 onward, observational studies, case series, and other study designs were also considered, given the limited volume of literature available on the topic. Additionally, reference lists of selected articles were screened to identify further relevant studies.

Given the heterogeneity and limited number of studies specifically addressing UVATS for pericardial effusion, a formal quality assessment using tools such as Grading of Recommendations Assessment, Development and Evaluation (GRADE) or Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was not deemed applicable. Nonetheless, all included studies were published in peer-reviewed journals and were critically evaluated for relevance and scientific merit.

Clinical Pathophysiology and Conventional Management of Pericardial Effusion

The clinical pathophysiology of pericardial effusion involves the abnormal accumulation of fluid within the pericardial cavity [12]. Under normal physiological conditions, the pericardial space contains 10–50 mL of serous fluid, which acts as a lubricant to minimize friction during the movement of the cardiac chambers [13]. Pericardial effusion presents with a wide range of clinical manifestations, such as exertional dyspnea, which may progress to orthopnea, along with chest pain or a sensation of fullness. Occasionally, symptoms caused by localized compression can occur, such as nausea (resulting from diaphragm involvement), dysphagia (due to esophageal compression), hoarseness (from involvement of the recurrent laryngeal nerve), and hiccups (related to phrenic nerve irritation) [14].

The condition arises from various causes, broadly classified into inflammatory and non-inflammatory categories. These include idiopathic pericarditis, infections, trauma, radiation therapy, tumors, autoimmune disorders, cardiac injuries, and exposure to toxic substances [15–17]. Several diagnostic techniques are employed to assess PE, including chest X-ray, electrocardiogram, transthoracic echocardiography, CT scan (Fig. 1), cardiac MRI, and pericardiocentesis.

The selection of a particular procedure largely depends on the etiology of the pericardial effusion. Pericardial effusion is treated using a combination of invasive and non-invasive approaches. When fluid accumulates in the pericardial sac, this fluid can restrict the ability of the chamber within the heart to pump sufficient blood, potentially resulting in tamponade, a critical cardiac emergency. To address this, pericardiocentesis is often performed, involving the insertion of a needle and catheter to drain the excess fluid. The choice of intervention depends on factors such as the underlying cause and the size of the effusion (Fig. 2) [14,18–20].

Uniportal VATS: Technical Insights

UVATS has been widely described in the literature as a minimally invasive approach offering both diagnostic and therapeutic benefits. UVATS allows for the execution of nearly all procedures typically performed via thoracotomy through a single incision. Using a minimal (3 cm) incision, the camera and surgical instruments enter through the same port, providing a thoracotomy-equivalent surgical view. The surgical advantage of UVATS enables the appli-

Fig. 1. A computed tomography image of a 21-year-old male with pyopericardium.

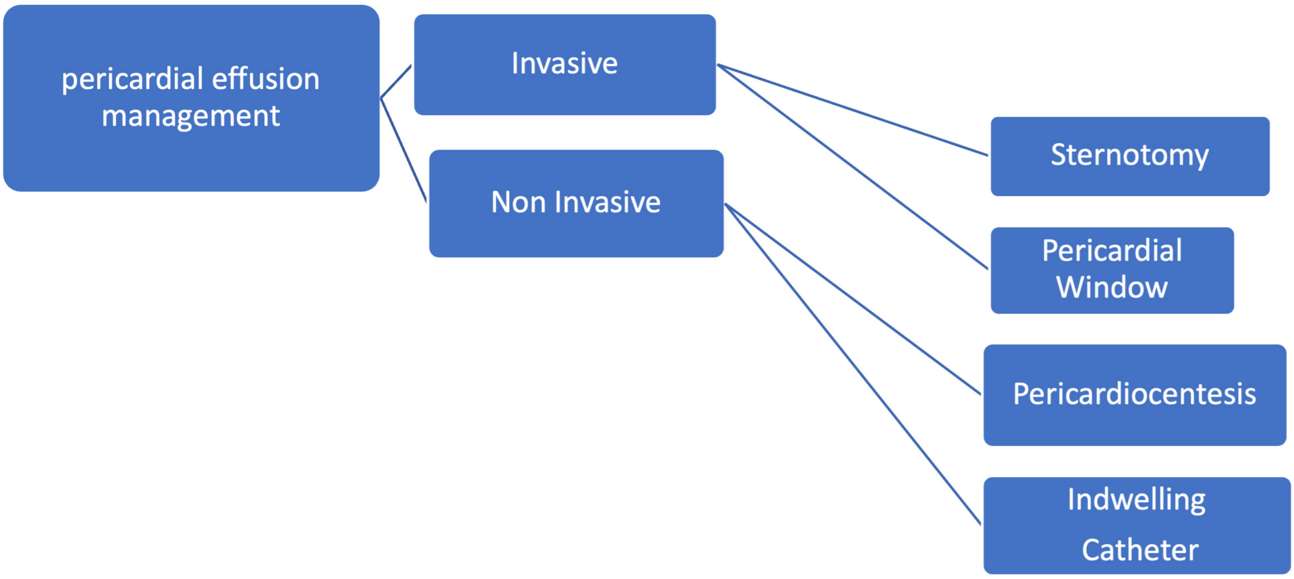

Fig. 2. Classification of pericardial effusion management strategies, divided into invasive and non-invasive approaches.

cation of this technique across various patient populations [8]. This method offers an alternative to traditional multi-port VATS, as it requires only a single, small incision and does not necessitate the use of retractors or further intercostal space dissection. Key technical considerations for UVATS are summarized below in Table 1.

Historical Context and Evolution

The evolution of UVATS represents a pivotal advancement in minimally invasive thoracic surgery, driven by both technological progress and innovative surgical techniques. The origins of thoracoscopy can be traced back to Hans Christian Jacobaeus in 1910, who pioneered the use of a ureteroscope to visualize the pleural cavity, laying the foundation for what would eventually become VATS [21,22]. However, the modern era of single-port thoracic surgery began in the late 20th century, with early studies exploring the feasibility of single-trocar VATS for both diagnostic and therapeutic procedures [6].

During 1998–2000, Migliore and colleagues demonstrated that various thoracic procedures, including pleural and lung biopsies, mediastinal node biopsies, hemothorax, and sympathectomies, could be performed through a single incision using modified flexible ports, enhancing visualiza-

Table 1. Key technical aspects of Uniportal VATS, including incision, approach, optics, instruments, and anesthesia.

Parameter	Details
Incision length	A single incision ≤2.5 cm is standard. Minor procedures (e.g., undetermined pleural effusions, sympathectomies) can be performed with 1 cm incisions. Larger resections may require incisions of 3–5 cm, primarily for specimen retrieval.
Incision location and approach	Initially, incision placement should be adaptable to optimize lesion access. With experience, UVATS can be used for various thoracic lesions via the fourth to sixth intercostal spaces (midaxillary line). Alternative approaches include subxiphoid, trans-subcostal, transaxillary, transsternal, transdiaphragmatic, and transcervical routes.
Optical systems	Multiple options include rigid, flexible, coaxial cable, chip-on-tip, and needle-scopic optics.
Instrumentation	Instruments may be straight, curved, articulating, flexible, or pre-bent, allowing for procedural adaptability.
Anesthetic considerations	General anesthesia is the standard approach, although some centers have successfully performed UVATS on awake or sedated patients.

UVATS, uniportal video-assisted thoracoscopic surgery.

Table 2. Summary of UVATS procedures for pericardial effusion reported in the reviewed literature.

No.	Study	Number of UVATS cases	Patient context
1	Georghiou *et al.* [26]	18 patients	Chest tube was maintained for a mean of 2.3 days; 1 case of arrhythmia; 0% 30-day mortality rate
2	Çardak and Külahçıoğlu [27]	35 patients	Malignant pleuropericardial effusions; 4 deaths (11.4%) not related to procedure
3	O'Brien *et al.* [28]	15 VATS vs. 56 subxiphoid patients	Compared VATS vs. subxiphoid (7 deaths in the subxiphoid group)
4	Geissbühler *et al.* [29]	24 patients	3 complications, 0 treatment-related mortality
5	Geissbühler *et al.* [29]	12 (subset)	1 recurrence at 3 months, 1 at 33-month follow-up
6	Çardak and Külahçıoğlu [27] and Özyurtkan *et al.* [30]	36 patients	No recurrence reported
7	Çardak *et al.* [31]	20 patients	Awake UVATS case for pericardial effusion

VATS, video-assisted thoracoscopic surgery.

tion, maneuverability, and bleeding control. The technique was formally introduced on the international stage during the 2000 Naples International Symposium, marking a significant milestone in the historical development of UVATS [5]. Nonetheless, despite the early promise of UVATS, the widespread adoption of this technique was initially limited, and the significance of these early contributions has often been underrecognized in subsequent literature.

Interest in minimally invasive thoracic surgery was reignited in the early 2000s, fueled by advancements in VAT, which provided panoramic views of the hemithorax, and the introduction of linear mechanical staplers for lung resections [23]. These innovations set the stage for the further evolution of UVATS. Subsequently, Gonzalez and colleagues [24] introduced the first single-incision thoracoscopic lobectomy in 2011, marking a turning point in the global adoption of the technique and sparking a surge in published studies exploring its applications for both minor and major thoracic procedures [7,23].

While the contributions of Gonzalez accelerated the dissemination of UVATS, the early work by Migliore laid the groundwork for the feasibility and safety of this technique [6]. The consensus report from the Uniportal VATS Interest Group (UVIG) of the European Society of Thoracic Surgeons has recognized the advancements and benefits of UVATS, highlighting its improved visualization, reduced invasiveness, and positive patient outcomes. In addition to being inaccurate about the original pioneers of the technique, the consensus report is also exclusive, as it ignores the opinions of other seasoned surgeons [25]. The evolution of UVATS reflects the broader trajectory of minimally invasive surgery, driven by continuous innovation, technological advancements, and a growing body of evidence highlighting the advantages of this technique in reducing surgical trauma while maintaining oncological outcomes.

Despite ongoing challenges such as instrument crowding and a steeper learning curve, UVATS has become an integral part of modern thoracic surgery, with applications extending beyond lung resections to include sympathectomy, thymectomy, and esophageal surgery [23]. Thus, as the technique continues to evolve, further refinement and global collaboration will shape its future role in thoracic surgical practice. A summary of UVATS procedures for pericardial effusion reported in the literature is presented in Table 2 (Ref. [26–31]).

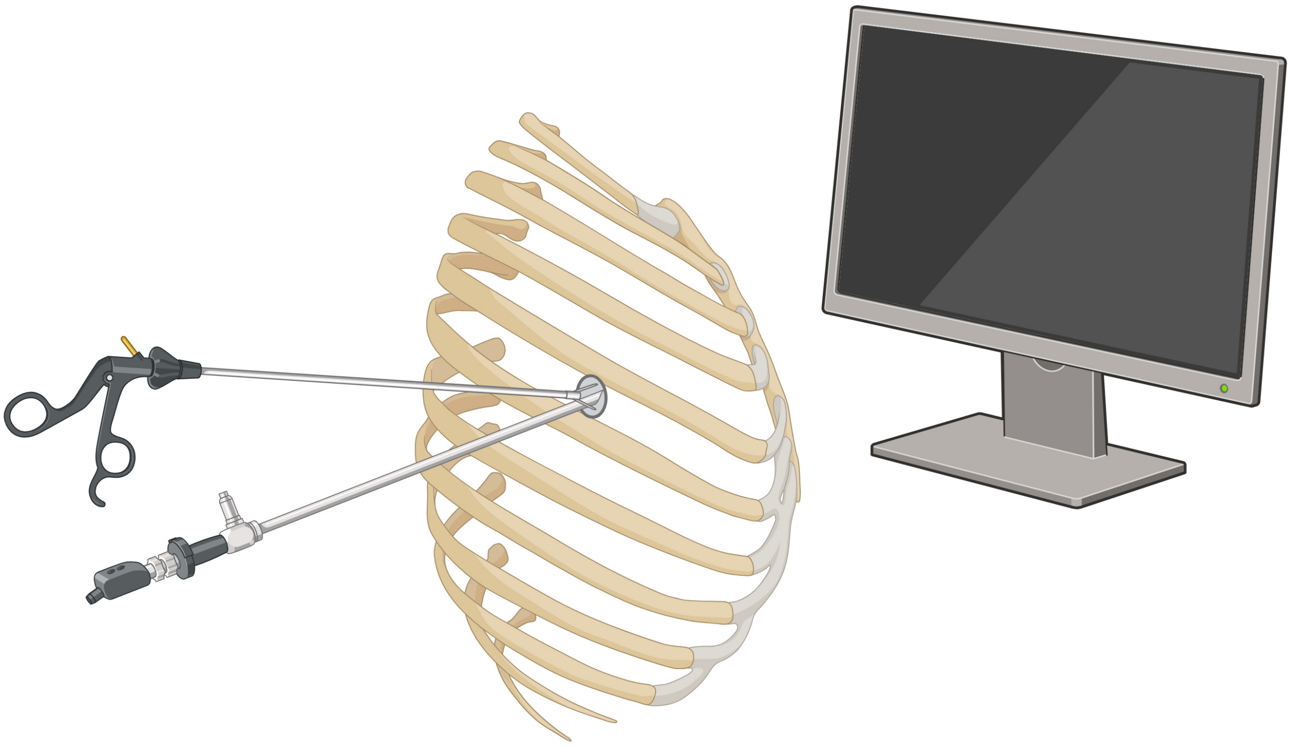

Fig. 3. Schematic representation of UVATS pericardial window, showing the position of the thoracoscope and instruments through the single incision, with the port placed in the fifth intercostal space. Fig. 3 was created using BioRender.com.

Procedural Technique for Pericardial Effusion and Advancements in the Field

The preoperative process for UVATS is similar to other thoracic procedures, typically involving general anesthesia and single-lung ventilation, although UVATS can be performed in some circumstances without intubation [32]. We prefer to position the patient supine or with the chosen hemithorax elevated at a 45° angle. A 2–3 cm incision is made in the fifth intercostal space along the axillary line. A 5 mm thoracoscope is introduced, and the pleural cavity is examined [26]. After the phrenic nerve is identified, the target zone is chosen. Pericardiotomy is performed on the surface of the pericardium with scissors or cautery, and fluid is drained. Samples are taken for cytologic and microbiological examination. The pericardium is then grasped, and the pericardiotomy is widened by opening a window of about 4–5 cm (Fig. 3). A chest tube is placed through the same incision and left in place at the end of the procedure.

Postoperative Management

Postoperative management following thoracoscopic pericardial window procedures primarily involves careful drain management and systematic follow-up to prevent recurrence. In our experience, we aim to remove the drain as soon as possible. A chest X-ray is performed after the operation and the day after. In the reviewed cases, chest tube drainage was maintained for a mean duration of 2.3 days (range, 1–5 days), ensuring adequate evacuation of pericardial fluid. Routine monitoring was essential to assess drain functionality and detect any potential complications, such as displacement or obstruction. Postoperative complications were minimal, with no intraoperative adverse events reported. A single patient (5%) experienced supraventricular arrhythmia secondary to chest tube migration into the pericardium, which resolved spontaneously following drain removal. This highlights the importance of vigilant postoperative monitoring to identify and manage potential complications promptly. The 30-day mortality rate was 0%, with one patient (5%) succumbing to malignancy progression rather than a treatment-related cause. Importantly, all surviving patients reported symptomatic relief at the three-month follow-up, further supporting the effectiveness of the procedure in managing pericardial effusions [26].

Surgical technique: An appropriate site on the pericardium is selected following identification of the phrenic nerve. Pericardiotomy is initiated with scissors or cautery to incise the pericardial surface, allowing for the pericardial fluid to be drained. Specimens are collected for cytological and microbiological analyses. The pericardium is then gently grasped, and the incision is extended to create a window measuring approximately 4–5 cm in diameter, as shown in Fig. 4.

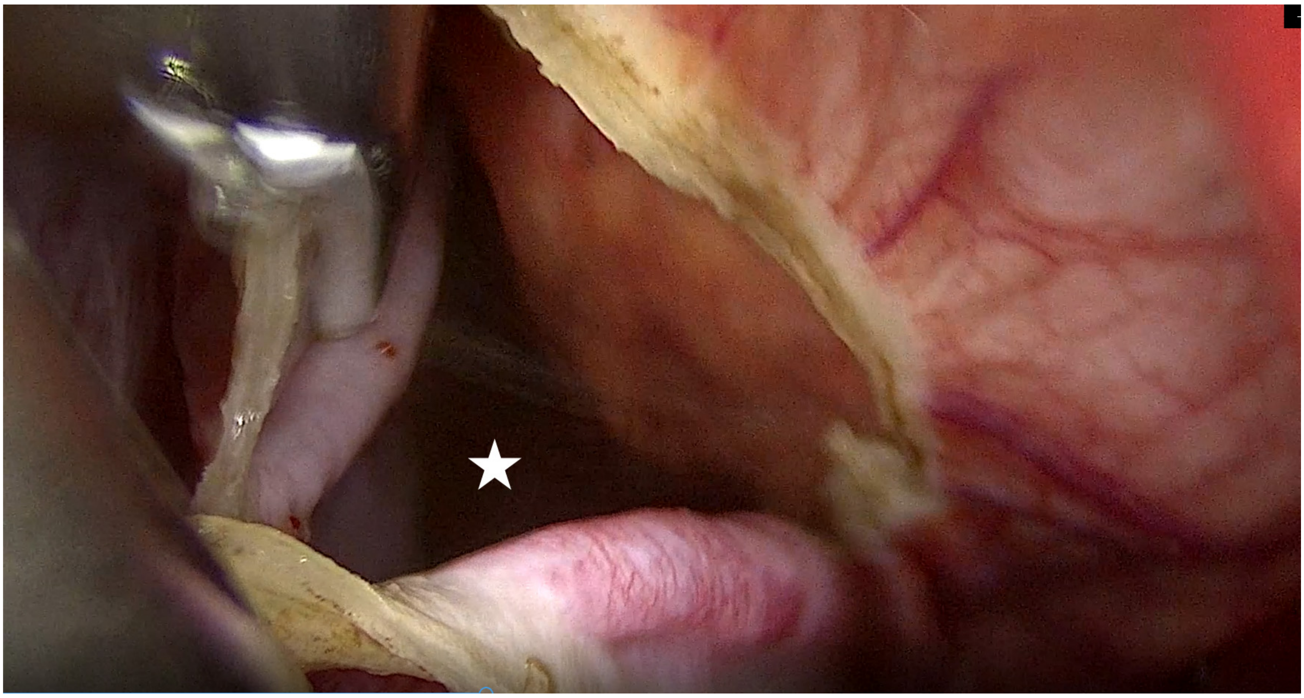

Fig. 4. Intraoperative view during creation of a right pericardial window, with the right atrium located behind the pericardium. A star indicates the pericardial fluid visible within the pericardial space.

Clinical Outcomes and Challenges

Multiple studies on the use of UVATS in thoracic surgery have demonstrated that this technique yields excellent postoperative outcomes, with mortality rates reported as inferior to those with thoracoscopy compared to the subxiphoidal approach [33]. Similarly, in a paper discussing the effectiveness of UVATS for creating a pericardial window, in patients with malignant pleuropericardial effusions, the study reported a 30-day mortality rate of 11.4% (4 out of 35 patients), those mortalities were not attributed to the pericardial procedure but were associated with the aggressiveness of the underlying malignancy [27]. To rectify its superiority, an adjacent study comparing VATS pericardial window with its counterpart, the subxiphoid procedure, found that mortality was greater after the subxiphoid procedure, with none of the cases related to the intervention (7 (13%) vs. 0 (0%)) [28]. However, it is important to note that the median survival time of patients with cytology-positive pericardial fluid was longer than that of patients with a negative cytology [34]. In a prospective study by Geissbühler *et al.* [29] evaluating video-assisted pericardial fenestration, 3 out of 24 patients (12%) who underwent VAT pericardial fenestration experienced postoperative complications, including peripheral pulmonary embolism and supraventricular arrhythmia, highlighting its limitations; however, there was no treatment-related 30-day mortality. Nevertheless, the chief benefits of UVATS include reduced pain and paresthesia, fewer overall complications, shorter hospital stays, and significantly lower postoperative morbidity and mortality, demonstrating its potential in improving patient outcomes and greatly outweighing the risks [35,36].

Comparing recurrence rates between patients undergoing thoracoscopy and those treated via the subxiphoid approach, reported recurrence occurred in 8% and 10% of cases, respectively, with no statistically significant difference; however, the Kaplan–Meier analysis indicated a trend toward longer recurrence-free intervals following thoracoscopy (mean time, 36.1 months vs. 11.4 months; p = 0.16) [28]. Importantly, a multivariate analysis revealed that patients undergoing the thoracoscopic surgical approach are 59% (relative risk (RR) of 0.41) less likely to experience disease recurrence (p = 0.014). These findings suggest that although recurrence rates may appear comparable, the thoracoscopic technique could offer a meaningful advantage in prolonging recurrence-free survival, emphasizing its potential utility in select patient populations. The prospective study by Geissbühler *et al.* [29] recorded only one patient (4%) who experienced recurrence within 3 months postoperatively, and an additional recurrence was identified during the 33-month follow-up among 12 patients with non-malignant pericardial effusion. Conversely, a different study analyzing the safety and efficacy of UVATS for pericardial window, involving 36 patients, reported no recurrences [27,30].

Potential contraindications were found for the VATS approach in patients with concomitant pleural pathologies and compromised cardiorespiratory status [29,37]. For the sake of comparison, it was noted that the subxiphoidal approach, despite being the gold standard technique, was found to have a few disadvantages, namely, the inability of this method to achieve a true pericardial window as it does not allow the transition from the pericardial space to the pleural space, in addition to not allowing direct exploration of the pericardial space [27]. Although rates of pneumothorax and prolonged air leaks were more prominent with VATS pericardiectomy, there was better long-term control of the effusion compared to the subxiphoid procedure [34]. Naturally, since UVATS utilizes specialized reticulating disposable instruments, concerns arise regarding potential increased surgical costs and decreased maneuverability due to the use of rigid trocars, as opposed to flexible trocars that might collapse the intercostal space [38]. Another comorbidity was noted in a previously compensated patient with pericardial effusion, whereby the induction of general anesthesia for surgical drainage of the fluid may lead to abrupt hemodynamic deterioration and decompensation [31,39]. Furthermore, Çardak *et al*. [31] also highlighted that the use of single-lung ventilation was strongly associated with intubation-related complications and postoperative outcomes such as acute lung injury and adult respiratory distress syndrome.

Innovations, Future Directions, Ethical Considerations, and Accessibility

Recent innovations, such as the development of ergonomic surgical instruments, high-definition cameras, and robotic-assisted UVATS, have addressed some of the technical challenges associated with the single-port approach [40]. As previously established, the performance of UVATS, while the patient is awake, avoids the need for general anesthesia and is a promising technique for improving patient outcomes and reducing recovery times [32]. These innovations emphasize the potential for the field to expand the indications for UVATS to more complicated procedures, such as vascular reconstructions and extended resections. Despite these advancements, the future of UVATS will rely heavily on addressing key research gaps, particularly regarding the long-term outcomes, which are linked to unclear ethical considerations, quality of life, and survival rates. Long-term studies are needed to evaluate the oncological safety of this technique compared to multiportal VATS and pericardial fenestration.

The swift adoption raises numerous ethical considerations, including its costs, implementation challenges, steep learning curves, and limited availability. Initially, surgeons may face higher complication rates and technical difficulties, which could compromise patient safety. To mitigate these risks, we could implement simulation-based training programs and proctors during the initial phases of implementing this procedure, and adhere to theoretical knowledge and technical competence [41]. Moreover, the higher costs of specialized equipment needed may be challenging for equitable access, leaving those in low-income or resource-constrained settings in a blind spot.

To properly implement UVATS in surgical training, we need to bridge the gap between current routine practice and innovation. There is a need to standardize the surgical approach, which could be facilitated by case observation, didactic coursework, discussions, and the highest level of training, as well as the wet-laboratory experience [32,42]. Furthermore, a crucial aspect of clinical integration is the assimilation of newer technological advancements to facilitate their seamless execution in a clinical setting, such as the use of endostaplers, advancements in three-dimensional (3D) and 4K (Ultra High Definition, 3840 $\times$ 2160 pixels) display resolution visualization; and the development of narrower thoracoscopes with increased flexibility [30]. These advancements would address concerns, such as reducing the learning curve, simplifying the surgical workflow, enhancing patient safety, and expanding indications. Furthermore, we must address logistical challenges, cost-effectiveness, and resource allocation, since the success of UVATS ultimately relies on ensuring that the procedure and its advancements are accessible and adaptable in diverse healthcare settings.

Study Limitations

This narrative review provides an integrative overview of the current literature on UVATS for the management of pericardial effusion. However, several limitations should be acknowledged. First, the majority of studies included in this review are retrospective and often involve small sample sizes, which may limit the generalizability and robustness of their findings. Second, due to the heterogeneity and limited volume of available literature, a formal grading of evidence levels or risk of bias assessment was not conducted. Finally, the absence of standardized outcome measures across studies poses challenges in drawing direct comparisons or performing pooled analyses. Despite these limitations, this review aimed to highlight current trends, procedural insights, and areas for future investigation to support the evolving role of UVATS in thoracic surgery.

Conclusion

UVATS has emerged as a highly effective and minimally invasive approach for managing pericardial effusion. Compared to traditional multiportal VATS and the subxiphoid approach, UVATS offers several advantages, including reduced postoperative pain, shorter hospital stays, and lower recurrence rates. The evolution of UVATS, driven by advancements in optics, instrumentation, and surgical techniques, has expanded the applications of this technique in thoracic surgery. Despite its benefits, challenges such as a steep learning curve, the need for specialized equipment, and potential cost implications must be addressed to ensure broader adoption.

Future research should focus on long-term clinical outcomes, standardization of procedural techniques, and the integration of emerging technologies such as robotic-assisted UVATS and enhanced imaging modalities. Additionally, efforts to improve accessibility, surgeon training, and cost-effectiveness are essential in optimizing the role of UVATS in clinical practice. As evidence supporting its safety and efficacy continues to grow, UVATS is poised to become a standard technique in the surgical management of pericardial effusion, providing improved outcomes for patients worldwide.

Author Contributions

Conceptualization: MM and MUA; Methodology: MUA; Validation: MM and MUA; Formal Analysis: MM; Investigation: MUA, BSA and ROC; Resources: MUA, BSA and ROC; Data Curation: MUA, BSA, MN and ROC; Writing—Original Draft Preparation: MUA, BSA, ROC, MN and MM; Writing—Review and Editing: MUA, BSA, ROC, MN and MM; Visualization: BSA, ROC, MN and MUA; Supervision: MM; Project Administration: MM. All authors have read and agreed to the published version of the manuscript. All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

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