Review Article



# Video-assisted thoracoscopic surgery (VATS) in trauma: a narrative review

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**Background and Objective:** Video-assisted thoracoscopic surgery (VATS) techniques have expanded rapidly in elective thoracic surgery over the past several decades. During the same time, the role of minimally invasive therapies in trauma surgery, such as laparoscopy and endovascular interventions, have also expanded tremendously. VATS is being increasingly utilized in the care of trauma patients, however the role of VATS in the management of an acute injured patient or in the management of the sequalae of traumatic injury is not well defined in guidelines. The purpose of this narrative review is to provide the reader with the most up-to-date evidence regarding the utility of VATS in trauma surgery.

**Methods:** We performed a literature review of studies describing the use of thoracoscopy in trauma patients in PubMed. There were no date restrictions. The review was limited to studies written in English. Studies were included for evaluation based on the title and abstract, and subsequently reviewed in detail by the authors. Additional studies regarding injury patterns and management techniques were queried and reviewed as necessary.

**Key Content and Findings:** The most common indication for VATS in trauma, and intervention that is best supported by data, is evacuation of retained hemothorax. The use of VATS is also well supported and commonly utilized in acute hemothorax in a hemodynamically stable patient, persistent pneumothorax or prolonged air leak, diagnosis and treatment of hemopericardium in select patients, and diagnosis and treatment of diaphragm injuries. Minimally invasive approaches to surgical stabilization of rib fractures are under development, but the precise role of surgical management of rib fractures and flail chest is not well established.

**Conclusions:** A growing body of evidence supports the use of VATS in the management of acutely injured patients with thoracic injuries as well as traumatically injured patients with sub-acute or chronic sequelae of their injures.

**Keywords:** Video-assisted thoracoscopic surgery (VATS); trauma; hemothorax; pneumothorax; hemopericardium

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## Introduction

Trauma is the fourth leading cause of death in the United States, accounting for over 210,000 deaths in 2021, which was significantly increased since 2020 (1). Thoracic injuries are estimated to be the primary cause of 25% of trauma deaths and significantly contribute to another 25–50% of deaths in trauma patients (2,3). Most thoracic injuries requiring surgery are managed with either tube thoracostomy or thoracotomy, however video-assisted thoracoscopic surgery (VATS) has a long history in the diagnosis and management of thoracic injuries. VATS, like other minimally invasive modalities such as laparoscopy and endovascular interventions, is associated with lower rates of morbidity and rapid recovery in comparison to open techniques and has therefore been increasingly utilized in the care of the trauma patient (4-7).

The purpose of this article is to provide a narrative review of the most up to date guidelines and published evidence regarding the utility of VATS in trauma with a focus on hemothorax, retained hemothorax, pneumothorax and persistent air leak, diaphragm injuries, hemopericardium, rib fractures, and flail chest. We also provide a brief history of thoracoscopy in the care of the trauma patient. We present this article in accordance with the Narrative Review reporting checklist (available at https://vats.amegroups.com/article/view/10.21037/vats-23-61/rc).

## Methods

We performed a review of studies in PubMed investigating thoracoscopic surgery in the management of several common thoracic injuries. The review was limited to studies in English. Studies were initially evaluated based on title and abstract. Meta-analyses, randomized controlled trials, prospective observation studies, and retrospective cohort studies were included. There were no publication date restrictions. *Table 1* provides details of the literature search strategy. The authors performed a detailed review of each manuscript to determine inclusion; qualitative and quantitative analysis was not performed. Thirty-seven studies were included. Additional studies regarding general background information or specific injury patterns were queried, reviewed, and included as necessary—seven additional studies were included for these purposes.

## Brief history of VATS in trauma

There is controversy regarding the origins of thoracoscopy. However, credit is generally given to H.C. Jacobaeus, an internist from Stockholm who published reports of using a modified cystoscope to inspect the pleural cavity and perform lysis of adhesions for patients with tuberculosis in 1910. This procedure was performed commonly for many years until the introduction of intrapleural streptokinase in 1945 (8,9). In 1946, Dr. Branco from Rio de Janeiro provided the first widely published case series of thoracoscopy in trauma. He reported five cases of penetrating chest trauma, stab wounds and gunshot wounds managed acutely with thoracoscopy, evacuation of blood, and irrigation of the pleural cavity. Branco wrote: "*I feel certain that thoracoscopy will be very useful for the diagnosis of all varieties of such wounds*." (10).

In 1981, Dr. J.W. Jones and colleagues from Tulane University in New Orleans published their case series of 36 patients taken to the operating room urgently for thoracoscopy after penetrating thoracic trauma. After chest tube placement and appropriate resuscitation in the trauma bay, hemodynamically stable patients were taken to the operating room where the chest tube was removed and a thoracoscope was placed under local anesthesia. The chest was explored, hemothorax evacuated, all injuries identified, and, in some cases, active bleeding stopped with electrocautery. Interestingly, eight of these patients had initial chest tube output of greater than 1,500 mL of blood and an additional seven patients had greater than 200 mL of blood per hour for two or more consecutive hours; these patients were spared thoracotomy after inspection of the chest with the thoracoscope demonstrated no ongoing bleeding. The authors concluded that thoracoscopy is a useful tool for early management of hemothorax, however this practice pattern was not adopted (11).

VATS continued to be used in the care of trauma patients through the 1990's and early 2000's, correlating with the expansion of VATS for elective thoracic surgery including lobectomy, with small studies noting efficacy and safety in diagnosis and management of diaphragm injury, retained hemothorax, empyema, and on-going chest tube bleeding (12). More recently, stronger evidence has emerged for these and several other indications for VATS in the traumatically injured patient, as will be described in the subsequent sections of this review.

## Hemothorax & retained hemothorax

There are approximately 300,000 cases of hemothorax in the US each year, making it a common sequela of

**Table 1** Literature search strategy summary

| Items | Specification |
|---|---|
| Date of search | August 2023 |
| Database | PubMed |
| Search terms used | - VATS |
| | - Video-assisted thoracoscopic surgery |
| | - Hemothorax |
| | - Retained hemothorax |
| | - Persistent air leak |
| | - Pneumothorax |
| | - Hemopericardium |
| | - Cardiac tamponade |
| | - Diaphragm injury |
| | - Trauma diaphragm hernia |
| | - Rib fractures |
| | - Rib plating |
| | - Surgical stabilization of rib fractures |
| Timeframe | Up until date of search |
| Inclusion criteria | English language only |
| Selection process | Studies selected by authors without qualitative or quantitative review based on relevance and currency |

VATS, video-assisted thoracoscopic surgery.

blunt and penetrating thoracic trauma. Approximately one third of blunt thoracic trauma patients present with hemothorax (13). Traditional management includes immediate tube thoracostomy with progression to thoracotomy for hemodynamically unstable patients or for patients with high chest tube output (4). The role of VATS in the acute management of hemothorax in hemodynamically stable patients is not well defined. There are published case series describing VATS for hemodynamically normal patients with high chest tube output, often with discovery of a lung laceration or chest wall vessel injury as the culprit, allowing for hemorrhage control in a minimally invasive manner and avoiding thoracotomy. A VATS approach to acute hemothorax may not be feasible in the setting of heavy bleeding that obscures visualization or inability to maintain lung isolation. Advocates for VATS in acute hemothorax call attention to the additional utility of diagnosing esophageal or diaphragm injuries via direct inspection with a thoracoscope, which may be difficult to diagnose with imaging alone (14). There are currently no consensus guidelines regarding the utility of VATS for the management of acute hemothorax. Described techniques for obtaining hemostasis in the chest during VATS exploration include packing, application of clips and electrocautery to chest wall vessel injuries, and wedge resection of pulmonary parenchyma injuries (15).

VATS has a much more defined role in the management of retained hemothorax, which is commonly defined as either 300 or 500 mL of undrained blood after tube thoracostomy. No consensus exists on precise volumes of small, moderate, or large retained hemothorax, however a multicenter prospective trial found that estimated retained hemothorax volume less than 300 mL was the single strongest independent predictor of successful observation (16).

About 3% of patients with hemothorax will develop retained hemothorax, many of whom will go on to develop empyema (26.8%) or pneumonia (19.5%) (13,16). Retained hemothorax is the most common indication for VATS in trauma patients (17). National guidelines presently recommend evacuation of retained hemothorax via VATS over treatment with intrapleural lytic therapy, though this is a weak recommendation based on low levels of evidence. Studies have shown intra-pleural thrombolytics are associated with higher rates of empyema and need for additional procedures in comparison to initial management with VATS evacuation of retained hematoma, however, the diagnosis definitions, treatment algorithms, and outcomes reporting in these studies are not consistent (4,18).

The optimal timing of evacuation of retained hemothorax has been the topic of much study. Prior to the use of VATS for evacuation of retained hemothorax, Mattox published a case series demonstrating zero mortalities and 10-day mean hospital length of stay (LOS) in patients undergoing thoracotomy within 5 days of injury, in comparison to 2.4% mortality and 25-day hospital LOS for evacuation after 5 days (13). Smith *et al.* showed that when using a VATS approach, early surgery (less than 5 days) was associated with lower conversion to open thoracotomy (8% *vs.* 29.4%, $P<0.05$) and shorter hospital LOS (11±6 *vs.* 16±8 days, $P<0.05$). Additionally, zero patients who underwent early VATS for retained hemothorax went on to develop empyema and were therefore spared additional interventions such as percutaneous drainage, tube thoracostomy, or additional operative interventions (17). The Eastern Association for the Surgery of Trauma defines "early" evacuation of retained hemothorax as 4 or

fewer days after injury, with "late" defined as 5 or greater days, and recommends early VATS evacuation of retained hemothorax (4). However, this recommendation is based on low quality evidence and has not been validated in a randomized controlled trial.

## Pneumothorax & persistent air leak

Pneumothorax continues to be common in trauma patients, perhaps increasingly so as chest computed tomography is more liberally used in the trauma bay and more occult pneumothoraces are discovered. Management of traumatic pneumothorax has evolved over the past 10–15 years, with more data emerging to support observation of small, asymptomatic or minimally symptomatic pneumothoraxes rather than routine use of chest tubes (19). For those pneumothoraxes that require tube thoracostomy, development of a persistent air leak may be an indication for operative intervention. Presently there is no standard definition for "persistent" air leak. The Society of Thoracic Surgeons (STS) database tracks air leaks greater than 5 days as a performance measure after lobectomy, so this is a generally agreed upon definition. Various authors and investigators have used between 3–5 days as a cut-off within a given institution or case series. Also lacking is a widely agreed upon system for measuring or assessing severity of an air leak.

Based on several small case series, VATS may have a role in the management of persistent air leaks after traumatic pneumothorax. In one small series specifically studying persistent posttraumatic air leak greater than 3 days, VATS was superior to nonoperative management in terms of chest tube days (8.1 *vs.* 11.8 days) and hospital LOS (9.7 *vs.* 16.5 days). These authors offered VATS if the patient was otherwise ready to discharge home. The operation consisted of leak-testing the lung using a combination of VATS and bronchoscopy, resecting any parenchymal injury, performing mechanical pleurodesis, and placing a chest tube (20). Because of the lack of robust data on management of persistent air leak in traumatic pneumothorax, it is reasonable to use other management strategies similar to persistent air leak after lung resection such as expectant management, blood patch, bronchoscopy and endobronchial valve, or chemical pleurodesis.

## Diaphragm injury

The use of thoracoscopy for the identification of traumatic diaphragm injuries was first described in 1993 (21). Despite tremendous improvements in cross sectional imaging technology and widespread use of routine CT scans for trauma patients, diagnosis of traumatic diaphragm injury continues to rely upon direct visualization of the diaphragm. Most traumatic diaphragm injuries are identified and repaired via laparotomy performed to address associated intraperitoneal injuries (22). But in stable patients who otherwise do not have an indication for laparotomy or thoracotomy, national trauma guidelines currently recommend laparoscopy or thoracoscopy for left sided penetrating thoracoabdominal trauma to diagnose acute traumatic diaphragm injury.

There are currently no studies directly comparing laparoscopy and thoracoscopy for the diagnosis and management of traumatic diaphragm injuries. The decision whether to perform laparoscopy or VATS to will depend on each individual case and on the surgeon's experience and comfort-level with both techniques. Laparoscopy has been shown to be useful in diagnosing diaphragm injuries, with many authors recommending laparoscopy in all hemodynamically stable patients with penetrating trauma to the left thoracoabdominal region given the high incidence of associated diaphragm injuries (23). Additionally, laparoscopy allows for the identification and management of concomitant intra-abdominal injuries which more frequently require surgical intervention, as opposed to concomitant intra-thoracic injuries identified with VATS which can often be managed with tube thoracostomy alone (24).

VATS has shown to be an accurate method of identifying diaphragmatic injuries with an accuracy rate of 98–100%. Unlike laparoscopy, there is no risk of capnothorax from abdominal insufflation in the setting of a diaphragmatic injury. However, a VATS approach may be more technically challenging, and unlike laparoscopy VATS requires the placement of a thoracostomy tube (25).

Due to difficulties identifying diaphragm injuries on imaging, many are missed upon initial evaluation after trauma leading to delayed presentation with visceral herniation. The natural history of chronic traumatic diaphragm hernia is not well known. The physiologic pressure gradient between the pleural and peritoneal cavities would suggest that these hernias will enlarge over time and gradually displace more abdominal viscera into the chest, potentially leading to obstruction or strangulation of the GI tract or respiratory compromise. Most authors therefore recommend repair of chronic traumatic diaphragm hernias when they are discovered (26). There are a variety of approaches to repair these chronic defects—open versus

**Table 2** Comparison of advantages and disadvantage of abdominal versus thoracic approach to traumatic diaphragm injury

| Laparoscopy | VATS |
|---|---|
| Allows for identification of intra-abdominal injuries which often require intervention | Allows for identification of intra-thoracic injuries |
| Tension pneumothorax can occur with insufflation in the setting of TDI | No risk of tension pneumothorax from insufflation |
| Proven effective in the diagnosis of TDIs | Highly accurate for diagnosis of TDIs |
| No thoracostomy tube required | Requires thoracostomy tube placement even if negative |
| Repair can be performed more easily | Performing TDI repair can be difficult and requires an experienced surgeon |

VATS, video-assisted thoracoscopic surgery; TDI, traumatic diaphragm injury.

minimally invasive, thoracic versus abdominal, primary repair versus reinforcement with mesh—with little data to guide clinical decision-making regarding optimal technique. Early reports comparing laparotomy to thoracotomy noted similar outcomes between the two approaches, with the exception of higher rates of pneumonia amongst thoracotomy patients (27).

Some contemporary authors advocate for a minimally invasive approach, often with a combination of laparoscopy and thoracoscopy, while others report routine use of thoracotomy (28,29). VATS has been reported as a useful adjunct in laparoscopic repair of chronic diaphragm injuries, particularly for right sided defects, posterior defects, and obese patients (28). Comparative studies are lacking, and the surgical approach to these repairs should be individualized based on the surgeon's skill and experience as well as specific characteristics of the patient and the defect. Advantages and disadvantages of VATS and laparoscopy in the diagnosis and management of traumatic diaphragm hernia are detailed in *Table 2*.

## Hemopericardium

The presence of pericardial fluid on ultrasound after penetrating thoracic trauma is a concerning finding and is traditionally managed by subxiphoid pericardial window and progression to sternotomy or anterolateral thoracotomy for repair of the underlying cardiac injury (30). Due to the inherent potential instability of cardiac injuries which can rapidly deteriorate due to hemorrhage or tamponade, these patients tend to be managed emergently with little role for novel or minimally invasive techniques. Despite this, there are several case series regarding the use of VATS in hemopericardium.

In one of the earliest and largest case series, Morales *et al.* reported 108 patients with suspected cardiac injuries due to anatomic proximity (i.e., penetrating injuries to the "cardiac box") who underwent thoracoscopy and pericardiotomy. These patients were hemodynamically normal with no obvious signs of cardiac injury. To perform the pericardiotomy, the authors made a 2-cm incision in the 5$^{th}$ intercostal space at the mid-clavicular line, through which the camera was placed, and a 3-cm incision over the cardiac silhouette through which the pericardiotomy was made using Allis clamps and Metzenbaum scissors. They reported excellent sensitivity, specificity, and accuracy for diagnosing hemopericardium in comparison to subxiphoid window, with minimal perioperative complications, and with the added benefit of inspection of the entire chest for other injuries (31). However, this technique was not widely adopted. In a subsequent case series from a different institution, investigators reported inability to perform VATS pericardial window in two patients due to excessive pericardial fat in one patient and extensive adhesions in a second patient. These authors saw no benefit and abandoned the approach in favor of subxiphoid window (32). In modern practice, VATS pericardial window may be the preferred approach for pericardial drainage in the setting of penetrating thoracic trauma, a hemodynamically stable patient, equivocal pericardial ultrasound findings, and an associated hemothorax, though underlying cardiac injuries are generally not amenable to minimally invasive repair (33).

## Rib fractures & flail chest

Rib fractures are common in blunt thoracic trauma and can be associated with significant morbidity and mortality, especially for elderly or frail patients and those with underlying chronic lung disease (34). Interest in the surgical management of rib fractures has dramatically

increased over the past decade with the creation of an entire professional society in 2016, the Chest Wall Injury Society, dedicated to the operative and nonoperative management of chest wall injuries (35). The role of VATS in the management of chest wall injury, particularly in the setting of rib fractures and flail chest, is an area of active investigation and innovation.

The indications and outcomes of surgical stabilization of rib fractures (SSRF) are evolving as innovations in technology, equipment, and techniques are being developed and published. Presently, SSRF is conditionally recommended by multiple national societies in the setting of flail chest causing respiratory derangements and inability to wean from mechanical ventilation (34,36). Multiple small randomized controlled trials have shown shorter duration of mechanical ventilation and shorter intensive care unit LOS after SSRF in comparison to nonoperative management in select patients. Other benefits have included lower incidence of pneumonia, lower incidence of tracheostomy, improved pain, faster return to employment, and improved pulmonary function tests months after injury (37-39).

The most commonly employed technique for SSRF involves incision on the chest wall directly over the fractures to allow for reduction of the fracture and surgical fixation of the rib with plates and screws. There are small case series of a completely VATS approach demonstrating feasibility with conventional external plates adjusted for internal use, as well as new plating systems and instrumentation intended for intrapleural placement (40,41). Surgeons performing a totally VATS approach to SSRF have suggested that this technique may be less invasive, replacing large external incisions with three or four small VATS incisions, and may allow better access to posterior rib fractures adjacent to the spine or under the scapula. There are reports of performing SSRF in patients with three or more displaced ribs when VATS is otherwise indicated for retained hemothorax, including one small single-institution observational study demonstrating lower opiate use and shorter LOS in the group that underwent VATS SSRF in addition to evacuation of retained hemothorax (42). VATS has also been suggested as a mean of assessing rib fractures at the time of surgical stabilization, possibly allowing the surgeon to achieve optimal chest wall stability without stabilizing all fractured ribs (43). One additional innovation in the field of VATS and SSRF is an "extra-thoracic" approach in which the space between the external aspect of the chest wall and the overlying musculature is expanded using a dissecting balloon insufflated with carbon dioxide, allowing for the repair in a minimally invasive manner (44).

The innovation of these investigators is noteworthy, however, quality data supporting SSRF is limited to several small RCTs showing benefit in a narrow patient population. VATS SSRF may be technically feasible, but the benefits are unclear when compared to open fixation or nonoperative management, and the technical reproducibility and cost effectiveness have not been sufficiently addressed. This is an area that will certainly continue to see innovation in the years to come and may eventually see widespread use with more investigation and supporting evidence.

## Strengths and limitations

This review has several notable strengths and limitations. The review is based upon an extensive review of existing literature and presents best available evidence, however, many of these topics have not been extensively investigated and the quality of evidence is therefore low. We did not quantitively assess quality of evidence or risk of bias in reviewed articles. Also our references are representative of the current state of evidence but not comprehensive.

## Conclusions

VATS plays a critical role in the management of trauma patients. Evacuation of retained hemothorax is the most common VATS intervention for retained hemothorax and is very well supported by data and national guidelines as first line therapy. VATS for management of acute hemothorax, persistent air leak after traumatic pneumothorax, and the diagnosis and management of traumatic diaphragm injury are also common interventions described in the literature with varying levels of data to support their use. Thoracoscopic repair of diaphragmatic hernias after traumatic diaphragm injuries and VATS pericardial window for hemopericardium have been reported, but have not been broadly adopted due to lack of supporting evidence or limitations in techniques. Lastly, emerging techniques and innovative technologies in management of chest wall injury, including rib fractures and flail chest, have shown great promise and may lead to increased use of VATS in this patient population in the future.

With the notable exception of retained hemothorax, the evidence supporting the use of VATS in trauma is low quality and scarce, and there are ample opportunities for future studies to help guide thoracic and trauma surgeons in the role and VATS in the care of the trauma patient.

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## Footnote

*Reporting Checklist:* The authors have completed the Narrative Review reporting checklist. Available at https://vats.amegroups.com/article/view/10.21037/vats-23-61/rc

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