Review Article

Open thoracic surgery: video-assisted thoracoscopic surgery (VATS) conversion to thoracotomy

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Abstract: Video-assisted thoracoscopic surgery (VATS) approaches are becoming a mainstream technique within the discipline of thoracic surgery. Just as valuable however is to consider when VATS should not be considered, and even more important, when a case that began as VATS should be converted to thoracotomy, and if so, then how. Today the only documented absolute contraindication to VATS is the inability to achieve adequate visualization of the hemithorax. Patients who cannot tolerate single lung ventilation and situations in which lung isolation is not possible typically are not amenable to thoracoscopic approaches. Relative contraindications to VATS include: bronchoplastic procedures, chest wall deformities limiting visualization, large lesions that limit visibility and would ultimately require a large incision and rib spreading for extraction, central/hilar lesions requiring proximal and/or intrapericardial dissection, dense adhesions requiring decortication, calcified hilar adenopathy, neoadjuvant chemotherapy or radiation with challenging dissection, or extensive chest wall involvement. Given the amply available technology, surgeons may often choose to perform an intra-operative VATS exploration prior to thoracotomy. In such a setting, this should not be considered a conversion. Instead we offer the term "adjunctive VATS" to clarify the distinction. Surgeons often begin with a thoracoscopic port placed in the anterior axillary line anywhere in the 8th–9th intercostal space and ultimately utilize that incision as the site for chest tube insertion at the end of the procedure. This is distinctively different from aborting a planned VATS procedure and performing a thoracotomy. Published rates of conversion from VATS to thoracotomy vary. Reasons for conversion can be classified as: intraoperative complications, technical challenges, anatomic problems and oncologic conditions. As important as the technique of conversion, is the ability to make a timely and systematic decision to abort a VATS procedure. Surgeons must be aware that a conversion from VATS to thoracotomy does not represent surgical failure. There are essentially two types of conversions: planned and emergent. Based on the type of conversion, the approach to thoracotomy can differ. Once the decision to convert to VATS is made important principles and technical consideration need to be followed. The core tenant of these is the completion of a safe and oncologically sound operation.

Keywords: Video-assisted thoracoscopic surgery (VATS); thoracotomy; conversion; complication; completion

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Introduction

With the advent of minimally invasive surgery, video-assisted thoracoscopic surgery (VATS) has developed substantial traction since its introduction in the early 1990s (1-4). Despite some initial trepidation regarding comparative safety profile and oncologic equivalence to thoracotomy, VATS approaches are becoming a mainstream technique within the discipline of thoracic surgery (5-7). This minimally invasive approach is currently employed for diagnostic and therapeutic lung surgery, as well as other procedures involving the mediastinum, chest wall, pericardium, esophagus and diaphragm. Emerging data continues to support the safety of VATS with associated decreases in postoperative morbidity, pain scores and hospital length of stay (8-10). In addition, various reports have demonstrated equivalence with regards to oncologic and long-term survival outcomes (11,12). Recent efforts have focused on expanding the application of VATS to high-risk patients with poor preoperative performance status as well as the elderly (13,14).

This increased prevalence of VATS has led to a large paradigm shift in training, where trainees and surgeons alike continue to expand on and adjust their "open" surgery skills to minimally invasive approaches. While some technical concepts are transferrable, the transition has led to increased complexity and a steep learning curve. The latter remains the largest obstacle to widespread application of VATS. As new trained thoracic surgeons continue to expound their minimally invasive armamentarium, the technical considerations distinguishing minimally invasive approaches [including VATS and robotic-assisted thoracic surgery (RATS)] continue to be defined. Most VATS training principles focus on correctly choosing the appropriate VATS candidate and outlining unique technical approaches to thoracoscopic surgery. Just as valuable however is to consider when VATS should not be considered, and even more important, when a case that began as VATS should be converted to thoracotomy, and if so, then how. This chapter outlines some of the technical differences in choosing the different surgical approaches, and outlines contraindications to VATS, and the various considerations when converting from thoracoscopic surgery to open thoracotomy.

Contraindications to VATS

The scope of thoracoscopic approaches continues to evolve and expand. Surgeons (as one would expect) are steadily and safely pushing the envelope of VATS, and there are now few complete limitations of VATS. Minimally invasive thoracic surgeons are eager to demonstrate the limitless scope of VATS and in so doing have demonstrated remarkable proficiency and outcomes. Nonetheless, a selection bias exits and VATS technical aptitude continues to demonstrate large variance (15).

Over the last 3 decades, the contraindications of VATS have continued to decrease. Surgeons have been able to extend indications and overcome previous challenges. Historically, contraindications to VATS included: prior chest surgery, neoadjuvant chemotherapy or radiation, central or endobronchial lesions, chest wall involvement and vessel involvement (16). Today the only documented absolute contraindication to VATS is the inability to achieve adequate visualization of the hemithorax. Patients who cannot tolerate single lung ventilation and situations in which lung isolation is not possible (previous pneumonectomy on the contralateral side, challenging airway anatomy, technical challenges with double-lumen endotracheal tube placement or bronchial blockers) typically are not amenable to thoracoscopic approaches. However, brief operations (bullectomy or pleural/lung biopsies) can be undertaken via VATS using intermittent apnea, without the need for thoracotomy. In addition, the use of VATS for spontaneously breathing patients continues to increase, with the assistance of regional anesthesia and conscience sedation. This technique has been safely employed for procedure involving the lung, pleura and mediastinum and has recently expanded to include complex airway surgery, bronchoplastic procedures and vascular resections/reconstruction (17-30).

Relative contraindications to VATS include: bronchoplastic procedures (sleeve resection), chest wall deformities limiting visualization, large lesions that limit visibility and would ultimately require a large incision and rib spreading for extraction (a threshold of 6 cm has been previously reported) (21), central/hilar lesions requiring proximal and/or intrapericardial dissection, dense adhesions (due to infectious etiology or previous surgery) requiring decortication, calcified hilar adenopathy, neoadjuvant chemotherapy or radiation with challenging dissection, or extensive chest wall involvement. The limitations of VATS in redo surgery have been challenged recently, particularly given the fact that thoracoscopic approaches facilitate adhesiolysis and visualization of the pleural space. The question of VATS as an oncologically sound technique in

the setting of non-small cell lung cancer (NSCLC) with N2 disease has been debated. Some argue that complete mediastinal lymphadenectomy is limited in VATS, however published retrospective series have repeatedly demonstrated comparable efficacy of nodal dissection between both VATS and thoracotomy (31-33).

It is important to note however, that these only stand as relative contraindications. Many surgeons are not limited by these factors and consider VATS as an advantage in these scenarios, particularly due to heightened visualization. Nonetheless, for less experience individuals, the above represent obstacles that tend to sway the surgical decision-making towards thoracotomy. Even when VATS techniques are chosen in such scenarios, there is often a low threshold for conversion intraoperatively.

VATS adjunctive to thoracotomy

An important distinction needs to be made between conversion to thoracotomy and the planned use of thoracoscopy as an adjunct to an already planned open resection via thoracotomy. Given the amply available technology, surgeons may often choose to perform an intra-operative VATS exploration prior to thoracotomy. In such a setting, this should not be considered a conversion. Instead we offer the term "adjunctive VATS" to clarify the distinction. Surgeons often begin with a thoracoscopic port placed in the anterior axillary line anywhere in the 8th–9th intercostal space and ultimately utilize that incision as the site for chest tube insertion at the end of the procedure. This is distinctively different from aborting a planned VATS procedure and performing a thoracotomy.

This technique is often utilized when undertaking a planned large resection. Even in the era where preoperative staging technology continues to improve and minimize false negatives. In the setting of extensive surgery, surgeons can utilize VATS as a prior assessment of the hemithorax and the pleural space prior to committing the patient to a thoracotomy. This can prove advantageous in evaluating for disseminated pleural carcinomatosis, examining pleural effusions prior to resection in order to rule out metastatic disease, and in performing biopsies in order to establish a definitive diagnosis. Moreover, intraoperative pleuroscopy can assist in planning a thoracotomy to locate the ideal location of the incision. This is particularly true in the setting of large tumour involving the chest wall or Pancoast tumors. Adjunctive VATS is not only limited to a single port, and often multiple other ports can be used to facilitate the insertion of minimally invasive VATS instruments in order to assist with the planned resection. At times, parts of the resection can be performed thoracoscopically (such as vessel division, fissure completion, nodal dissection) and thereafter, the remaining extended resection can follow via thoracotomy.

The use of VATS as an adjunct to an open resection is encouraged in the following scenarios: when undergoing a major resection to rule out metastases and confirm resectability, to outline anatomy that may be distorted by the underlying pathology, in the setting of diagnostic uncertainty, to establish a definitive tissue diagnosis when one could not be performed prior to surgery, to complete mediastinal/hilar lymph node biopsies for nodal stating, to perform adhesiolysis in the apex of the hemithorax or the diaphragmatic sulcus (where visualization during thoracotomy is relatively limited), or in the setting of chest wall involvement requiring concomitant chest wall resection.

Causes of conversion to thoracotomy

Published reports outlining the conversion rate from VATS procedures to thoracotomy vary, and differ based on surgeon experience, institutional practice patterns and type of resection. Published rates of conversion range from as low as 2% to as high as 23% (24-40). Early single-center cohort studies by Krasna *et al*. [1996] (41) and Yim *et al*. [1995] (42) reported conversion rates of 8% and 11% respectively, and nearly one-third of conversions were for non-oncologic reasons. Continued experience has led to a decrease in reported conversion rates. In a review of 1,093 VATS procedures by Imperatori *et al*. in 2008, the conversion rate was only 1.7% (43). Similarly, a 2013 single-institution cohort analysis at Duke University of 916 attempted VATS lobectomies reported a 4% conversion rate (44). The evolution of time and heightened experience has led to greater surgeon resolve in pursing VATS approaches for operations that would only be deemed feasible via thoracotomy. Moreover, continued technologic advances have also allowed for an expansion of technique. Better equipment that is easier to use allows for easier and safer conduct of operations. Accordingly, this has certainly contributed to the decrease in conversion rates of VATS operations.

In their review of VATS contraindications and complications, Hanna *et al*. identify four distinct categories for causes of conversion from VATS to thoracotomy (16).

Intraoperative complications

Intraoperative complications typically are the result of a surgical misadventure due to surgical error or a complicated procedure leading to an adverse outcome (either due to difficult dissection or poor technique). The most concerning complication leading to conversion is bleeding from the pulmonary artery or arterial branches. This can be a result of inadvertent injury during dissection or excessive tension during retraction leading to vascular rupture. Indeed, this can even be misconstrued as stapler malfunction, when in reality it represents an operative error. Injuries can also occur to the pulmonary vein leading to bleeding, esophagus, or bronchus.

Operative features concerning for bleeding include dense adhesions secondary to prior intervention, neoadjuvant chemotherapy/radiation or an infectious etiology. Moreover, large tumors or masses may often limit adequate visualization and require excessive force of retraction. Such a force can lead to vessel rupture and dangerous bleeding.

Despite a large variance in rates of conversion, the literature demonstrates that bleeding and vascular anatomical variations remain a major cause for conversion from VATS to a thoracotomy. This is a consistent finding irrespective of how often conversion occurs. In a retrospective review of 63 VATS lobectomies, Flores *et al*. converted 12 cases (1% conversion rate), with 7 conversions (58%) of bleeding or inadvertent stapling of the main pulmonary artery of the main pulmonary vein (45). Similarly, in a published abstract reviewing the results of 1,009 VATS lobectomies from Cornell, there were 66 (6.5%) conversions, and of those 21.2% were secondary to bleeding (46).

Technical challenges

In contrast to surgical error, technical challenges can also lead to conversion to thoracotomy, and are the result of equipment failure or limited visualization rendering the VATS approach either non-feasible or unsafe. Examples of technical causes of conversion include stapler malfunction, poor visualization or limited access to necessary minimally-invasive equipment. Although staple line malfunctions can be associated with bleeding (particularly when attempting to ligate pulmonary vessels), these challenges may not necessitate emergent conversion, and are often results of poor procedural progression. Of note, it is important to ensure proper utilization of equipment for optimal results. For example, the use of metal clips during hilar or parenchymal dissection can interfere with the appropriate stapler function and lead to significant bleeding.

Anatomical problems

Anatomical problems are typically patient-related factors that challenge the surgeon's ability to complete a VATS procedure. This type of limitation is more frequent when performing anatomic lung resections, esophagectomies or mediastinal VATS surgery. Expertise obviously serves as a key determinant in a surgeon's ability to navigate anatomical challenges and complex dissection. Examples of anatomic features complicating VATS procedures include: fused fissures, calcified lymph nodes in close proximity to pulmonary artery branches, dense pleural adhesions with limited working space or visualization, chest wall invasion necessitating a large incision, aberrant anatomy, morbid obesity or large tumour size with difficulty removing the specimen via a standard utility incision.

In order to anticipate and possibly prevent conversions due to anatomic abnormalities, it is imperative to carefully evaluate the patient's preoperative imaging prior to embarking on an unexpectedly challenging VATS procedure. CT scans of the chest with contrast are an integral and necessary part of the preoperative work-up for most patients, and provide fine detail outlining any aberrant anatomy (particularly abnormal vasculature or airway changes, as well as involvement of adjacent structures)

The presence of calcifications and dense hilar adhesions should always alert the surgeon as to the probability of a difficult dissection, and potentially a low threshold for conversion. Samson *et al*. and Park *et al*. identify hilar calcification and fibrosis as the inciting cause of conversion in 37% and 41% of lobectomy conversions from VATS to thoracotomy (47-49).

During VATS, non-anatomic or sublobar resection, it can sometimes be difficult to identify a specific lesion. This is more typical with central small lesions, partly solid or pure ground glass opacities. If the anatomic location of a nodule is not easily correlated between preoperative imaging and thoracoscopy, then careful palpation of the lung may need to be performed by thoracotomy—although a VATS utility incision may also prove valuable for this purpose.

Oncological conditions

Oncological conditions represent the most relative indication for conversion, and heavily rely on surgeon

experience and comfort. The presence of mediastinal nodal disease requiring mediastinal lymphadenectomy can serve as an indication for conversion to some surgeons in order to assure adequate removal of lymph nodes. Local invasion is also a common cause of conversion, however, with improved technology and precision of preoperative imaging, invasion has become much less of a surprise to surgeons than historically. Finally, inadequate oncologic surgery via VATS is a clear cause to perform a thoracotomy for adequate resection.

The decision to convert

As important as the technique of conversion, is the ability to make a timely and systematic decision to abort a VATS procedure. The choice to convert to a thoracotomy is not only made at times of emergencies or to deal with intra-operative catastrophes. Given the large difference in surgeon expertise and comfort the determinants of need for conversion will always vary. Nonetheless, surgeons should have a clear perception of their abilities and level of comfort and identify individualized criteria serving as markers of the need for conversions.

A balance needs to be struck between deterministic conversion, and a surgeon's ability to push the envelope, accept new challenges and enhance his or her skills. This is often a fine balance that evolves over time. However, it is important to note that anticipatory/planned conversion, prior to any major incident allows for the best outcomes and the safest completion of the procedure. One must anticipate the complexity of an operation and develop a sense of anticipation when continued VATS may prove excessively challenging. Preoperative imaging identifying features of pleural thickening and calcifications can assist in identifying VATS procedures at high risk of conversion (42).

Certain characteristics can allow surgeons to anticipate the need for conversion prior to any injury or forced thoracotomy. Failure to progress via thoracoscopy is always a sign of possible need for conversion. Of course, progress is a vaguely defined concept lacking specific qualifiers. Nonetheless, surgeons should have an internal assessment of their ability to progress through the various technical steps of an operation. Other identifiers of a low threshold for conversion include: calcified lymph nodes, extensive perivascular scarring, extensive pleural adhesions limiting visualization or the need for proximal vascular control.

Most importantly, surgeons must be aware that a conversion from VATS to thoracotomy does not represent surgical failure. The primary goal is the safe completion of a technically sound operation, following good surgical and/or oncologic principles. VATS and thoracotomy are means that are available to the surgeon for the completion of the task. A safe and planned conversion does not constitute technical incompetence. This is an important fallacy that should not guide surgical decision making when performing any VATS operation.

Conversion techniques

There are essentially two types of conversions: planned and emergent. Based on the type of conversion, the approach to thoracotomy can differ. Once the decision to convert to VATS is made, several important conversion principles need to be followed. These generally apply to the context of emergent and planned conversion.

Firstly, it is important to maintain visualization during the conversion. This can guide the incision, and also ensures safety. With the thoracoscope in place, it is easy for the surgeon to have the assistant hold the camera in place to maintain visualization of the hemithorax. The camera allows for choice of the correct interspace for entry into the chest and assists in surgical planning. In the setting of bleeding from a pulmonary arterial branch or the pulmonary vein, it is crucial to maintain visualization of the bleeding vessel. Usually, the bleeding is temporarily controlled with local compression and pressure. If during conversion, loss of control occurs, visualization can alert the surgeon for the need to re-establish control or expedite the conversion. The camera can also serve the added benefit of maintaining good communication within the operating room, and keeping team members aware as to the nature of the situation. For example, if the anesthesiologist can see that bleeding is controlled, then he or she can accordingly plan for resuscitation as necessary. Finally, if conversion is due to limited visualization due to dense adhesions requiring decortication, the camera is an important adjunct to assist in performing adhesiolysis even through the thoracotomy incision. This is particularly useful when mobilizing the lung in the apex of the lung or the diaphragmatic sulcus.

If bleeding is present, it is imperative to have thoracoscopic control of bleeding while performing the thoracotomy. When bleeding is present, the focus should first be on achieving control without worsening the situation—not on the performance of the thoracotomy. Several steps are important when substantial bleeding is encountered. Keeping visualization is the first key step.

The assistant holding the camera should retract the camera far enough to prevent soiling the lens with blood, and yet maintain an accurate view of the site of bleeding. Adequate suctions must be available, and should be used by the assistant and surgeon to maintain a clear field. When substantial bleeding exists, two suctions should be available.

Certain maneuvers can also be used to temporarily control bleeding while conversion occurs. The most conservative approach is to tamponade the bleeding with gentle pressure using a pledgetted thoracoscopic instrument. The pulmonary vasculature represents a low-pressure system, and accordingly, local pressure can often sufficiently control bleeding. It is crucial to resist the tendency to apply excessive pressure over a bleeding area, even if only partial control is obtained. Most disastrous outcomes are a result of a series of actions leading to a larger, uncontrollable tear, usually secondary to excessive force over delicate vascular structures. As such, if the primary surgeon is to perform the thoracotomy, he/she should give clear and deliberate instructions to the assistant providing local pressure, while instructing the rest of the team and opening the chest. Other control measures include the use of topical hemostatic agents, thoracoscopic clipping of bleeding vessels or intracorporeal suturing. If an initially controlled situation begins to bleed again while converting, focus should be placed on re-establishing control if possible prior to expediting conversion. Occasionally, retracting and pushing the lung on top of a bleeding vessel might help with partial control, until safe open access is achieved.

The choice of incision needs to be guided based on the operation being performed and the location of bleeding (if that is the reason for conversion). In a controlled situation, the use of muscle sparing thoracotomies can serve as a middle-ground between a large posterolateral thoracotomy and minimally invasive techniques. Preserving the latissimus dorsi and serratus anterior muscles potentially minimizes post-operative pain, and does not require extensive operating time. Based on the extent of thoracoscopic dissection already performed, the thoracotomy incision may be tailored for the completion of the procedure. If several steps of the operation had already been completed, smaller incisions may be feasible for the completion of the procedure. Of course, in the context of an emergent conversion for bleeding, one must not compromise adequate exposure for fear of post-operative pain.

Planning the thoracotomy incision can often be challenged by the presence of the VATS incisions/ports in place. In an emergent situation, a standard posterolateral thoracotomy should be performed irrespective of the incisions already present. VATS incisions, which are typically small and not associated with any rib spreading will add minimal morbidity to the thoracotomy being performed and should be disregarded when the need for quick conversion exists. In the setting of a planned conversion, the surgeon may choose to tailor their incision in order to incorporate one or more of the VATS incisions in place. For example, a more anterior thoracotomy can be performed in the 4th or 5th intercostal space in order to incorporate the most anterior access/utility incision (which is often the largest in the setting of VATS). In fact, some surgeons plan their thoracoscopic incisions along the line of a thoracotomy incision should one be required. Finally, the camera port can continue to be used for visualization, and at the end of the procedure can serve as the chest tube insertion site.

Most importantly, effective and clear communication is vita during the process of conversion. In addition to the technical aspects/considerations, the surgeon should demonstrate strong leadership skills—notifying the operative and anesthesia teams of the situation at hand, providing status updates, and clarifying concrete steps of action. With the entire team focused and aware, a series of clear instructions and demands should be given outlining the need for equipment, additional intravenous access, blood products and personnel. At such a critical juncture, communication is as important as the technical maneuvers to be performed. The surgeon should maintain constant dialogue with the anesthesiologist and together, both should outline a resuscitative and operative plan.

Outcomes following conversion

The core tenant of performing minimally invasive surgery is to ensure safety and not to comprise surgical outcomes for the sake of a smaller incision. Evidence demonstrates that complication rates are greater following VATS conversions as compared to procedures entirely performed thoracoscopically. Retrospective cohort studies have shown that as compared to completed VATS operations, VATS conversions were associated with increased risk of postoperative atrial fibrillation, increased length of stay, increased duration of chest tube drainage, as well as longer operating time and greater estimated blood loss (47,50). Interestingly, these findings are not echoed when comparing converted VATS operations to planned resections via thoracotomy. In such a context, VATS conversion has only

been independently associated with longer operating time, but no difference in immediate and long-term postoperative outcomes (16,51). These findings are to be expected, given that cases requiring conversion likely represent a subset of attempted VATS procedures with increased complexity and accordingly, greater likelihood of postoperative complications.

A large-scale collaborative effort by the European Society of Thoracic Surgeons (ESTS), combining the results of six European centres evaluated the associated complication of VATS lung resection in 3,076 patients (52). The reported conversion rate was 5.5% (21.8% for oncologic reasons, 29.4% for technical reasons, and 48.8% for operative complications). The data demonstrated that while infrequent, VATS intraoperative complications were not always necessarily related to surgeon experience, highlighting the importance of planning and preparation. Importantly, patients who had intraoperative complications also had associated post-operative complications with worsened immediate outcomes. Accordingly, in their publication, the ESTS outlines recommendations and preventive measures resulting from panel discussion reflective of the complications presented in the report. These are valuable, and should be seriously evaluated and considered by surgeons performing VATS surgery (52).

Future considerations

Much of the literature evaluating VATS conversions is based on retrospective single-institution reviews and is inherently subject to selection and recall bias. More importantly, the majority of publications on the topic of conversion to thoracotomy are in patients undergoing lobectomies. While conversions during sub-lobar resections are less likely, they do constitute a small subset of converted procedures—typically in the setting of an unidentifiable nodule not amenable to resection. Moreover, the indications for VATS continue to expand, with a large array of operations being performed thoracoscopically, including mediastinal and foregut surgery. With a growing procedure base, the causes for conversion will continue to change based on the associated technical challenges of difference procedures. For example, minimally invasive esophagectomies with a thoracoscopic component are less likely to require conversion due to pulmonary arterial bleeding. However, a conversion to thoracotomy may be the result of inadvertent airway injury, inadequate resection margins or inability to perform a proper anastomosis. As the prevalence of VATS operations and indications continue to grow, the incidence of conversions will naturally continue to decrease given the heightened experience and comfort. However, the implications surrounding conversions will continue to evolve, and will require careful analysis in order to improve patient outcomes and surgeon aptitude.

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