Video-assisted thoracic surgery utility in veterans: a narrative review

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Background and Objective: Over the last several decades, the use of minimally invasive techniques in thoracic surgery has rapidly expanded. This trend has also been observed at veterans affairs (VA) medical centers, though their uptake of video-assisted thoracic surgery (VATS) is thought to have lagged behind civilian hospitals. This review aims to outline the available evidence related to the use of these techniques within the VA system.

Methods: We performed a review of studies describing thoracoscopic surgery at the VA in PubMed. We identified studies that were published in the English language. There were no publication date restrictions. We excluded review articles or systematic reviews with no accompanying meta-analysis. Studies were evaluated for inclusion based on title and abstract. The authors then performed a more detailed review of the full manuscript for inclusion. A total of 10 studies met inclusion criteria and were included in our review.

Key Content and Findings: Most investigations on the implementation and efficacy of VATS within the VA healthcare system have focused on the treatment of early-stage lung cancers, which have demonstrated that VATS use decreases pulmonary complications in addition to minimizing direct tissue trauma and pain. Thus, VATS has become the predominant technique used in VA pulmonary resections over the last decade. VATS use at the VA has also increased for other procedures, including thymectomy and esophagectomy, with promising improvements in the rate of patient complications. As uniportal and robotic-assisted techniques have begun to gain traction nationally, VA centers have also begun to incorporate them into routine thoracic surgery practice. However, data comparing outcomes to VATS techniques in VA populations remains lacking.

Conclusions: Thoracoscopic procedures decrease perioperative pain and disability, improve patient outcomes, and are feasible to perform within the VA system. It is critically important that the VA continue to incorporate minimally invasive techniques in an effort to optimize care for the veteran population and its unique set of needs.

Keywords: Video-assisted thoracic surgery (VATS); veterans affairs (VA); veterans health administration

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Introduction

Since its development in the 1990s, the use of video-assisted thoracic surgery (VATS; also called “thoracoscopic” surgery) has grown from a highly specialized and infrequently used modality to a core pillar of modern thoracic surgery. In recent history, the techniques gained traction after safety and feasibility was robustly demonstrated in a prospective and multi-institutional study by the Cancer and Leukemia Group B (CALGB) (1). The group used a standardized definition for VATS lobectomy for the trial, marked by mandated avoidance of rib spreading and a specimen removal incision of maximum length of 8 cm, as well as dissection of the vein, arteries, and airway with standard node sampling.

VATS is currently the preferred approach for surgical resection of early-stage lung cancer (2,3), and is becoming commonplace in a variety of other intra-thoracic procedures, including fundoplication and thymectomy. However, VATS uptake in veterans affairs (VA) facilities is thought to be slow, though evidence documenting this phenomenon over time has been minimal (4,5).

It is established that the veteran population suffers from unique medical needs, some secondary to combat exposure (6), and some secondary to stress and trauma related disorders (7,8). Even in other areas, veterans continue to have overall poorer health status and more medical comorbidities than their peers in the civilian population (9). Given that there is evidence that VATS is better tolerated than open surgery in patients with poorer health (10-12), this would seem to provide a prime opportunity for the techniques to be used to their greatest advantage.

Despite the unique and sometimes increased medical needs of the US veteran population, surgical outcomes at VA medical centers are often equivalent to civilian centers. Specifically within the field of thoracic surgery, however, the evidence is mixed. Evidence has demonstrated both equivalent (13) and also worsened (14,15) perioperative outcomes for lung cancer patients at VA *vs.* non-VA centers. Lung cancer outcomes have historically been worse in the VA population (16), though there is evidence that this has been improving over time (17-19). Outcomes are generally improved at higher volume centers (20), though some studies have demonstrated no association between case volumes at VA centers and 30-day mortality rate (21). With evidence that continues to be mixed in nature, it remains important to investigate the mechanisms of these differences to identify systemic issues and target them to optimize care in our veteran population. Below, we review the available literature on the utilization of VATS in the VA system.

Understanding the patterns of utilization of minimally invasive technologies in the field of thoracic surgery is critical not only to the assessment of the usefulness of these techniques in improving VA patient outcomes, but also as a means of identifying potential obstacles in implementation, particularly since technology continues to advance at a rapid rate. The integration of new technologies into surgical care in an evidence-based manner is important to ensuring that the VA continues to deliver optimal care to its large population of our nation’s servicemembers. A body of evidence regarding these topics has accumulated since the development of VATS techniques, and the field of thoracic surgery has subsequently undergone a change towards minimally invasive approaches. This review aims to outline the available evidence related to the use of VATS techniques within the VA system. We present this article in accordance with the Narrative Review reporting checklist (available at https://vats.amegroups.org/article/view/10.21037/vats-22-51/rc).

Methods

We performed a review of studies that investigated thoracoscopic surgery at VA centers in PubMed (*Table 1*). We identified studies that were published in the English language. There were no publication date restrictions. Randomized controlled trials, prospective observational, and retrospective cohort studies were included, with the exclusion of review articles or systematic reviews with no accompanying meta-analysis. Studies were evaluated for inclusion based on title and abstract. The authors then performed a more detailed review of the full manuscript for inclusion. A total of 10 studies met inclusion criteria and were included in our review.

VATS as an alternative to open pulmonary resection

Most investigations on the implementation and efficacy of VATS within the VA healthcare system have focused on the treatment of early-stage lung cancers, comparing patient outcomes using VATS techniques *vs.* open resections. In one such study, Cajipe *et al.* analyzed the outcomes of patients undergoing lobectomy to treat stage 1 and 2 lung cancers at a single VA center (*Table 2*) (5). Perioperatively,

Table 1 Literature search strategy summary

Items	Specification
Date of search	9/06/2022
Databases and other sources searched	PubMed
Search terms used	VATS OR video assisted thoracic surgery AND Veterans OR robotics OR Veteran Health Administration
Timeframe	No date restriction
Inclusion and exclusion criteria	Excluded review articles and systematic review articles without meta-analysis, English language
Selection process	Literature selection by Drs. Halbert, Napolitano, Antevil, and Trachiotis

Table 2 Summary of studies reporting the use of VATS at the VA

Study	Year of publication	Design	N	Patient population
Cajipe *et al.*	2012	Single center, retrospective cohort	91	Patients undergoing lobectomy for primary stage I or stage II lung cancer
DeArmond *et al.*	2012	Retrospective cohort, single surgeon, three centers: VA, university-affiliated county hospital, private community hospital	50	Patients with early-stage lung cancer, adequate pulmonary reserve and comorbidities; VA patients with higher # of preoperative risk factors (P=0.006) and higher rate of smokers (P=0.02)
Maiga *et al.*	2019	Retrospective cohort study, national VA database	11,004	Patients undergoing resection for known or suspected lung cancer
Holleran *et al.*	2022	Retrospective cohort study, national VA database	4,216	Patients undergoing VATS lobectomy, divided into cohorts based on development of a pulmonary complication within 30 days (11.3%) and those who did not (88.7%) (excluding patients with preoperative pneumonia or ventilator dependence, or emergent cases
Holleran *et al.*	2021	Retrospective cohort study, national VA database	594	Patients undergoing thymectomy
Skancke *et al.*	2017	Retrospective cohort study, single center	27	Newly diagnosed esophageal cancer with resectable malignancy (before or after neoadjuvant treatment)
Dyas *et al.*	2022	Retrospective cohort, single center	108	Patients undergoing surgery for intention to treat lung masses; divided into pre- (n=63) and post-robotic (n=45) implementation at the center, with subgroups of VATS (19%), robotic (30%), and open (51%) sub-groups
Holleran *et al.*	2022	Retrospective cohort study, national VA database	8,212	Patients undergoing pulmonary resections via uniportal (n=176) or multiportal (n=8,036) VATS approaches
Napolitano *et al.*	2022	Retrospective cohort study, national VA database	16,895	Patients undergoing pulmonary resections (i.e., wedge, segmentectomy, lobectomy, sleeve lobectomy, and pneumonectomy): 5,748 VATS and 5,748 open after propensity matching
Cornwell *et al.*	2018	Single center, retrospective cohort	183	Patients undergoing VATS lobectomy (n=127) or stereotactic body radiotherapy (n=56) for clinical stage I NSCLC

VATS, video-assisted thoracic surgery; VA, veterans affairs; NSCLC, non-small cell lung cancer.

Table 3 Summary of studies reporting the use of VATS at the VA: operative details

Study	Approach and operation	Operative time	Blood loss (cc)	Operative details (P value)
Cajipe *et al.*, 2012	Open *vs.* VATS lobectomy	No difference (P=0.17)	No difference (P=0.9)	No differences in: nodes resected (0.70), N2 stations (0.30), R0 resection (0.36), Central tumors (0.86), tumor size (0.47), pathologic stage (0.55), %AC (0.43), %SCC (0.61), and % other pathologies (0.76)
DeArmond *et al.*, 2012	VATS lobectomy	VA with longer operative time (237 *vs.* 196 min, P=0.002)	–	Higher incidence of pathologies other than NSCLC in non-VA population (0.04), no difference in rate of conversion to open (1.0), pathologic stage (0.26), patients with post-operative event (0.14)
Maiga *et al.*, 2019	Lobectomy (77.5%) or wedge (22.5%); 64.5% open, 35.5% VATS	–	–	VATS with higher rate benign pathology than open (8.9% *vs.* 4.9%, OR 0.53; 95% CI: 0.45–0.62; P<0.001);
Holleran *et al.*, 2022	VATS lobectomy	Shorter operative time with no pulmonary complications (3.6 *vs.* 4 hours, P<0.001)	–	–
Holleran *et al.*, 2021	Transsternal (63.3%), VATS, including robotic (19.0%) VATS, transcervical (17.7%)	VATS and transsternal cases with shorter operative time than transcervical 2.7, 2.9, 3.2 hours, P=0.006)	–	Transsternal with higher proportion of 1+ complications (13.6% *vs.* 6.2% and 4.8%, P=0.008), higher rate pulmonary complications (7.5% *vs.* 0.9% and 1.9%, P=0.006)
Skancke *et al.*, 2017	Open (67%, transhiatal or Ivor Lewis) *vs.* minimally invasive (33%, Ivor Lewis)	No difference (P=0.81)	Open approach with higher blood loss (822 *vs.* 222 mL, P=0.001)	More nodes harvested in minimally invasive cohort (10 *vs.* 4, P=0.001), no difference in positive margins (R1, P=0.21), MIE with greater rate of pathological upstaging (33% *vs.* 0%, P=0.016)
Dyas *et al.*, 2022	Open, VATS, robotic lobectomy	–	Open approach with higher EBL (67 *vs.* 28 mL VATS *vs.* 58 mL robotic, P<0.001)	No subgroup difference in intraoperative complications (0.32), MI (0.75), vascular injury (0.21)
Holleran *et al.*, 2022	VATS: uniportal and multiportal	Uniportal shorter (1.7 *vs.* 3.1 hours, P<0.001)	–	–
Napolitano *et al.*, 2022	Open, VATS, robotic pulmonary resection	No difference (P=0.31)	No difference (P=0.12)	–
Cornwell *et al.*, 2018	VATS lobectomy, SBRT	–	–	All VATS patients achieved R0 resection; seven patients (18.9%) who received VATS had pathologic upstaging; SBRT total dose: 50–56 Gy, 4–5 fractions, 86.5% complete response, 5.4% partial response, 8.1% no change

VATS, video-assisted thoracic surgery; VA, veterans affairs; AC, adenocarcinoma; SCC, squamous cell carcinoma; NSCLC, non-small cell lung cancer; MIE, minimally-invasive esophagectomy; EBL, estimated blood loss; MI, myocardial infarction; SBRT, stereotactic body radiotherapy.

the VATS and the open surgery groups experienced similar blood loss, surgical time, number of lymph nodes resected, number of N2 stations dissected, percentage of complete resections, median tumor size, pathological stage, and percentage of centrally located tumors (*Table 3*). This suggests that using the VATS technique resulted in an equivalent oncologic operation. VATS patients also had chest tubes removed 1 day earlier on average than patients who underwent thoracotomy (P<0.001), had shorter length of hospital stay (LOS) by three days (P=0.02), and suffered fewer postoperative complications (30% *vs.* 58%, P=0.009), including pulmonary complications (24% *vs.* 48%, P=0.01) (*Table 4*). On multivariate analysis, VATS approach was an independent predictor of reduced complications (OR =0.359; 95% CI: 0.13–0.96; P=0.04) (*Table 4*). These improved outcomes support the more widespread use of VATS procedures in veteran populations. However, the authors did note that these patients experienced higher complication rates and longer hospital stays than had been observed in similar analyses with non-veteran populations. This may be accounted for, though, by the poorer health status in their population, as well as the inclusion of stage 2 and centrally located disease.

Given the expedient rate at which medical technology develops, the feasibility and ease of implementation for new approaches is often limited. One study by DeArmond *et al.* focused on comparing the implementation of VATS lung resections at VA and non-VA centers, in this case a university-affiliated county hospital, a community hospital, and a Veterans Administration hospital (4) (*Table 2*). As noted above, the veteran population has an inherently different risk profile than a civilian population, which can limit the interpretation of these results. In this case, patients at the VA were in overall poorer health than their non-VA counterparts: they had a higher number of preoperative risk factors (P=0.006), a higher percentage of current smokers (68% *vs.* 35%, P=0.02), and a lower diffusing capacity for carbon monoxide (DLCO; 56 *vs.* 70, P=0.046) (*Table 2*). By surgical notes, procedures at the VA hospital were longer (237 *vs.* 196 min, P=0.002), involved more concurrent procedures (P=0.004), and had more documented cases of pleural adhesions or hilar lymphadenopathy (53% *vs.* 19%; P=0.01) (*Table 3*). However, there was no difference between groups with respect to intraoperative conversion to thoracotomy, 30-day mortality, number of postoperative events, rate of postoperative atrial fibrillation, or number of days within the ICU (*Table 4*). These results demonstrate that VATS is equally feasible to implement in VA centers, and that it can be as safe as open resection, even for a population with poorer baseline health status.

These results are encouraging, and so there has understandably been a growing interest in determining if surgical approach (i.e., VATS) can independently predict improved rates of pulmonary complications after pulmonary resections. This interest has been investigated in both veteran and civilian hospitals, since pulmonary complications are themselves independently associated with worsened patient outcomes (22,23). In a review of VA VATS cases, Holleran *et al.* specifically queried patients via the Veterans Affairs Surgical Quality Improvement Program (VASQIP) database who underwent VATS lobectomy between 2008 and 2018 looking at the rates of pulmonary complications in the perioperative period (*Table 2*) (24). They identified 4,216 non-emergent cases; 11.3% of these developed at least one pulmonary complication, which was in turn associated with increased mortality (12.1% *vs.* 0.8%; P<0.001) and longer length of stay (12.0 *vs.* 6.8 days; P<0.001) (*Table 4*). This is consistent with rates found in civilian populations, which can range from 3% to 14% (25-27).

Although the Holleran study did not make any comparisons to non-VATS procedures; one contemporary study by Geraci *et al.* (14) did find increased rates of postoperative pneumonia in VA patients when comparing propensity matched VA and academic medical center populations (11% *vs.* 1.2%, P=0.01), but similarly did not perform any sub-analyses comparing surgical approaches. However, the same surgical group did perform an analysis on a separate civilian population, comparing patient outcomes after muscle-sparing thoracotomy *vs.* VATS resection (28). In this case, the authors found no association between surgical approach and postoperative complications, disease-free survival, or overall survival. Unfortunately, the evidence remains mixed, with yet other studies demonstrating improvements in rates of postoperative pulmonary complications after VATS procedures when compared with open thoracotomy (29-32).

Other studies, like the one by Maiga *et al.* in 2019 (33), have performed analyses deliberately tracking the use of thoracoscopic techniques over time. This retrospective study using the VASQIP database included a total of more than 11,000 veterans between 2002 and 2015 who underwent open *vs.* VATS resection for known or suspected lung cancer (*Table 2*). Encouragingly, the proportion of VATS procedures increased steadily from 15.6% system-wide in 2002 to 50.6% by 2015 (Pearson r=0.97; 95% CI: 0.91–0.99; P<0.001) (*Table 4*). However, uptake of VATS varied widely across regions, (P<0.001), with higher volume regions using VATS more frequently (Pearson r=0.35; 95% CI: 0.15–0.52; P<0.001) (*Table 4*). This is consistent with a contemporary analysis of utilization and outcomes in civilian cases (34), which demonstrated less common use of VATS in similar regions, particularly in the Western US. The study demonstrates that the implementation of VATS still lags in less populated areas of the country and at some

Table 4 Summary of studies reporting the use of VATS at the VA: postoperative outcomes

Study	Postoperative complications/outcomes (P value)	Length of stay	Outcomes (P value)
Cajipe *et al.*, 2012	VATS patients had fewer complications (30% *vs.* 58%, P=0.009), shorter chest tube duration (3 *vs.* 4 days, P=0.0001);	VATS shorter LOS (7 *vs.* 10 days, P=0.02)	Operative mortality: no difference (0.2); multivariate analysis: VATS was an independent predictor of reduced complications (OR =0.36, 95% CI: 0.13–0.96, P=0.04)
DeArmond *et al.*, 2012	No difference in: days with chest tube (0.15), ICU days (0.07)	longer LOS for VA patients (6.4 *vs.* 3.6 days, P=0.022)	No difference in 30-day mortality (1.0)
Maiga *et al.*, 2019	–	–	VATS use increased over time, from 15.6% in 2002 to 50.6% in 2015; VATS use by facility ranged from 0% to 81.7%, with higher volume correlated with increased VATS use (Pearson r=0.35; 95% CI: 0.15–0.52; P<0.001)
Holleran *et al.*, 2022	–	–	Complication cohort with higher prevalence of COPD (49.0% *vs.* 38.6%; P<0.001), subjective dyspnea (33.5% *vs.* 24.4%; P<0.001), ASA class >3 (20.8% *vs.* 12.4%; P<0.001), unhealthy alcohol consumption (20.8% *vs.* 12.4%; P=0.016), and hyponatremia (9.4% *vs.* 6.9%; P=0.048); no differences in proportions of smokers between cohorts (0.265); multivariate analysis- the following risk factors were associated with higher odds of pulmonary complication after VATS lobectomy: COPD [aOR =1.37 (1.12–1.69); P=0.003], subjective dyspnea [aOR =1.33 (1.06–1.66); P=0.013], ASA class >3 [aOR =1.67 (1.29–2.17); P=0.001], and hyponatremia [aOR =1.50 (1.06–2.11); P=0.021]. Unhealthy alcohol consumption was independently associated with pulmonary complication on a trend level [aOR =1.31 (1.00–1.73); P=0.052]; smoking within 1 year preoperatively not associated with 30-day pulmonary complications [aOR =0.90 (0.73–1.11); P=0.325]
Holleran *et al.*, 2021	–	Transsternal with longer LOS (4 *vs.* 2 *vs.* 2 days, P<0.001)	VATS use increased from 0% in 2008 to 61% of case volume in 2019; multivariable analysis showed transsternal correlated with more than 13 times higher adjusted odds of pulmonary complications (aOR, 13.29; 95% CI: 1.20 to 146.93; P=0.035)
Skancke *et al.*, 2017	No difference in anastomotic leak (P=0.70)	no difference in LOS (P=0.22)	No difference in 30-day mortality (0.49)
Dyas *et al.*, 2022	No subgroup difference in intrahospital complications (0.39), including arrhythmia (0.28), pneumonia (0.34), UTI (0.57), SSI (0.75), reintubation (0.57), reoperation (0.34), stroke (0.75)	open with longer LOS (7 *vs.* 2 days VATS *vs.* 5 days robotic, P<0.001)	No 30-day mortalities observed
Holleran *et al.*, 2022	Uniportal with higher rate of superficial wound infection (2.8% *vs.* 0.8%, P=0.017), clostridium difficile (1.7% *vs.* 0.4%, P=0.044)	uniportal longer (6 *vs.* 5 days, P=0.04)	No difference in 30-day mortality (P=0.76)
Napolitano *et al.*, 2022	Open approach with higher rates of: return to operating room (7.3% *vs.* 4.8%, P<0.001), cardiac arrest (1.5% *vs.* 0.8%, P<0.001), failure to wean from the ventilator (5.4% *vs.* 3.2%, P<0.001), pneumonia (8.0% *vs.* 5.5%, P<0.001), reintubation (7.1% *vs.* 4.3%, P<0.001), acute renal failure (0.8% *vs.* 0.4%, P=0.007), progressive renal insufficiency (0.9% *vs.* 0.4%, P=0.002), superficial wound infection (1.2% *vs.* 0.7%, P=0.014), UTI (1.6% *vs.* 1.1%, P=0.021), sepsis (3.7% *vs.* 2.6%, P<0.001), return to operating room (7.3% *vs.* 4.8%, P<0.001)	Open approach with longer LOS (7 *vs.* 5 days, P<0.001)	No difference in 30-day mortality (P=0.112); proportion of VATS increased over time (24.2% cases in 2008 and 69.9% cases 2018) Decrease in complication rates for both approaches. Specifically for VATS: 8% lower rate of major complications in 2008, 2018 with 58% lower rate of complications (P<0.001). Composite pulmonary complications decreased significantly over time in both VATS and open groups (P<0.001)
Cornwell *et al.*, 2018	VATS: 24.3% had complications, none greater than grade 2; SBRT: 24.3% late toxicity	–	VATS: no operative, 30-day, or 90-day mortality; SBRT: no operative, 30-day mortality, 2.7% 90-day mortality; overall Survival worsened with SBRT (3.1 *vs.* 8 years, P=0.0016); 1-year overall, 3-year overall, and 3-year recurrence-free survivals were 89.2%, 52.9%, and 38.5% after SBRT and 94.6%, 85.7%, and 82.8% after VATS (P<0.005 for all); SBRT independently predicts poorer overall survival and recurrence rates (mortality OR =11.6, P=0.019; recurrence OR =9.9, P=0.031)

VATS, video-assisted thoracic surgery; VA, veterans affairs; LOS, length of stay; ICU, intensive care unit; COPD, chronic obstructive pulmonary disease; ASA, American Society of Anesthesiologists classification; aOR, adjusted odds ratio; UTI, urinary tract infection, SSI, surgical site infection; SBRT, stereotactic body radiotherapy.

VA hospitals.

The benefits of VATS have led to it becoming the predominant technique used in VA pulmonary resections. In one recent study, Napolitano *et al.* identified patients who underwent VATS resection (including wedge or segmental resection, lobectomy, or pneumonectomy) at the VA between 2008 and 2018 (*Table 2*) (35). Analysis of propensity matched groups, which included 5,748 patients each, demonstrated that use of a VATS approach was associated with lower rates of cardiac complications (P<0.001), prolonged ventilation (P<0.001), pneumonia (P<0.001), reintubation (P<0.001), acute renal failure (P=0.007), progressive renal insufficiency (P=0.002), superficial wound infection (P=0.014), urinary tract infection (P=0.021), sepsis (P<0.001), and a return to the OR (P<0.001), as well as a 2-day reduction in hospital stay (P<0.001) (*Table 4*). The authors demonstrated that while 76% of lung resections were performed using an open approach in 2008, nearly 70% of procedures were performed using VATS by 2018. Additionally, while total complication rates decreased in both groups over time, undergoing VATS lung resection in 2018 was associated with a 58% reduced risk of major complications than thoracotomy (P<0.001), compared with an 8% lower risk of major complications in 2008 (*Table 4*). These results are encouraging. Not only do they demonstrate overall improved outcomes for lung resection patients at the VA over the last decade, but they also demonstrate the increased utilization of what is now becoming standard of care, minimally invasive techniques in this unique population.

Other areas of VATS application

There is less literature on the utilization of VATS techniques for other types of thoracic surgery procedures within the VA system. However, the available studies demonstrate increased use of VATS approaches over the last decade, with equivalent or improved perioperative outcomes. In one analysis, Holleran *et al.* compared the use of thoracoscopic *vs.* open approaches for thymectomy cases within the VA between 2008 to 2019 (*Table 2*) (36). Similar to the trends seen with contemporary VATS pulmonary resections, the authors demonstrated a large increase in the proportion of thymectomies performed using VATS, and transsternal thymectomy decreased from 90.2% of operative volume in 2008 to 22.2% of operative volume in 2019 (*Table 4*). VATS thymectomy increased from 0% of cases in 2008 to 61.1% of operative volume in 2019. There was a downtrend in complication rate across all cases from 17.7% in 2008 to 5.6% in 2019 (P=0.014). However, patients undergoing VATS had better outcomes than their open-surgery counterparts, including decreased LOS (2 *vs.* 4 days; P<0.001), decreased complications overall (6.2% *vs.* 13.6%; P=0.008), and fewer pulmonary complications (0.9% *vs.* 7.5%; P=0.006) (*Table 3*). On subgroup analyses, there were no differences in survival between surgical groups for patients undergoing procedures for thymic cancer, and no differences in perioperative morbidity or mortality for patients with myasthenia gravis.

These favorable results demonstrate the potential for improved patient outcomes with the use of thoracoscopic techniques outside the sphere of pulmonary resections. This has the potential to greatly influence not only outcomes, but patient selection for VATS and surgical planning. Additionally, the absence of oncologic staging data further limits the interpretation of this study, as the extent of locoregional disease also influences surgical approach and has the potential to significantly impact perioperative outcomes.

The VA has also seen an increase in the use of minimally invasive techniques to treat esophageal malignancy (37,38). The integration of VATS techniques at the VA for these procedures is both feasible and safe (38), and has positively impacted patient outcomes. In one retrospective analysis by Skancke *et al.* comparing minimally invasive to open techniques (*Table 2*) (37), VATS esophagectomy patients lost less blood intraoperatively (222 *vs.* 822 mL, P<0.001), had a larger number of lymph nodes harvested (10.33 *vs.* 2.72, P<0.001), and experienced equivalent anastomotic leak rates (11% *vs.* 17%, P=0.703) and equivalent postoperative mortality (0% *vs.* 6%, P=0.490) (*Table 3*).

The next step: uniportal VATS and robotics

Uniportal VATS

As VATS has become more widespread, further efforts have focused on reducing the number of ports used in these procedures. Uniportal VATS wedge resection was first described by Rocco *et al.* in 2004 (39), and there is some evidence to suggest that the use of only one port decreases patients' postoperative pain, reduces length of hospital stay, and improves patient satisfaction when compared with multi-port VATS (40-42). Other studies have demonstrated noninferior oncologic outcomes with uniportal approaches (43,44).

In one study comparing uniportal and multiportal lung resection at the VA, Holleran *et al.* found that a uniportal technique was associated with shorter operative time (1.7 *vs.* 3.1 hours, P<0.001) and no difference in 30-day mortality (P=0.76) (*Table 4*) (45). However, it was also associated with longer length of stay (LOS; 6 *vs.* 5 days, P=0.04) and higher rates of superficial surgical site infection (SSI; 2.8% *vs.* 0.8%, P=0.017) and postoperative clostridium difficile infection (1.7% *vs.* 0.4%, P=0.044) (*Tables 2,3*). The study had some significant limitations, though, as all of the uniportal procedures were performed at one center by one surgeon. Indeed, there are fewer surgeons using the uniportal technique within the VA system, and so there is limited data available regarding its utility and outcomes for the VA population. As more evidence becomes available regarding the use of uniportal VATS at civilian hospitals, it may be worth considering the increased use of this approach in VA patients.

Robotics

Robotic thoracic surgery approaches have also demonstrated significant improvements in patient outcomes compared to open thoracotomy (46). Additionally, robotic surgery provides multiple ergonomic and technical advantages to surgeons, including the neutral positioning of the console, the three-dimensional operating field, and the use of wristed instruments which circumvent the fulcrum effect of most laparoscopic tools (47-49). However, numerous comparative studies have failed to find any improvement in patient outcomes when comparing robotic surgery to VATS (50,51).

In one study, Dyas *et al.* hypothesized that initiation of a robotics program at a VA medical center would decrease length of stay and complication rates (*Table 2*) (52). To do this, they reviewed cases from a 5-year period spanning both pre- and post-robotic thoracic surgery integration. After implementation, robotic operations accounted for 53% of cases of lung resections. This period also saw a large rise in the overall use of minimally invasive approaches (85% *vs.* 42%, P<0.001). Minimally invasive surgery was also associated with shorter LOS (4 *vs.* 7 days, P<0.001), lower estimated blood loss (EBL) (50 *vs.* 100 mL, P<0.001), and more discharges to home (OR 13.00, 95% CI: 1.61–104.70, P=0.02) (*Table 4*). However, on subgroup multivariate analysis, both VATS and robotic approaches were independent predictors of shorter LOS for patients (P<0.001 and P=0.009, respectively), with use of robotics predicting no outcomes advantages for patients over the use of VATS.

Still, the novelty of robotic surgery at many VA centers should not be ignored when drawing conclusions from these studies. Robotic surgery within the VA is relatively new, as the VA center with the highest case volume only started their program in 2017 (53). Surgeons, staff, and care facilities are still learning the best ways to care for these patients. Patient outcomes are likely to improve as the use of robotic surgery becomes more routine, and so the relative benefits of robotic surgery when compared to other approaches is also likely to shift as this happens. Thus, further investigation comparing robotic-assisted and VATS procedures focusing on their respective benefits and drawbacks will be important to ensure that patients continue to receive optimal, cost effective care.

VATS vs. stereotactic body radiotherapy (SBRT)

Other competing technologies have also emerged for the treatment of early-stage lung cancer. SBRT, in particular, has begun to gain traction for stage I non-small cell lung cancer (NSCLC), particularly in patients who are not operative candidates (54). There is increasing evidence that the procedure is safe and effective (55,56), and a number of patients have begun to choose SBRT over surgical therapy as a way to avoid more invasive treatment (57,58). However, studies directly comparing surgical and SBRT approaches have not been encouraging, with VATS often out-performing SBRT regarding long-term patient outcomes (59). Evidence within the veteran population is limited. One study by Cornwell *et al.* reviewed data from a propensity-matched cohort of patients with clinical stage I NSCLC who underwent either SBRT (n=56) or VATS resection (*Table 2*) (22). The authors demonstrated that not only was overall survival worsened with SBRT (3.1 *vs.* >8 years, P=0.0016), the 1-year overall, 3-year overall, and 3-year recurrence-free survivals were 89.2%, 52.9%, and 38.5% after SBRT and 94.6%, 85.7%, and 82.8% after VATS (P<0.005 for all), respectively (*Table 4*). The authors also demonstrated on multivariate analysis that SBRT treatment was an independent predictor of poorer overall survival and recurrence rates (mortality OR =11.6, P=0.019; recurrence OR =9.9, P=0.031). Ergo, surgical resection at this juncture remains vital in ensuring optimal oncologic outcomes for patients who are operative candidates.

Conclusions

VATS procedures decrease perioperative pain and disability, improve patient outcomes, and are feasible to perform within the VA system. Minimally invasive procedures should be considered in patients who meet criteria, particularly at centers which already have experience performing VATS procedures. It is critically important that the VA continue to incorporate minimally invasive techniques in an effort to optimize care for the veteran population and its unique set of needs. As the field of thoracic surgery continues to move towards the standardized use of advanced technologies, this will likely require a proactive effort in order to remain up to date with the most recent developments in evidence-based care.

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Footnote

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