Review Article

A narrative review of video-assisted thoracic surgery for geriatric patients: optimizing organ function and perioperative recovery

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Background and Objective: With rising numbers of elderly individuals undergoing video-assisted thoracic surgery (VATS)—and given the physiologic changes of aging that make major surgery more perilous for geriatric populations—it is more important than ever to implement best practices that may improve perioperative outcomes. A thoracoscopic approach offers well-characterized advantages in elderly patients, but uniform recommendations around the optimal care of elderly surgical candidates for VATS have not been defined. This review aims to identify and summarize evidence-based recommendations that may be employed to improve the perioperative recovery of geriatric patients undergoing VATS.

Methods: A narrative review of the literature was conducted using combinatorial terms including "VATS" or "thoracoscopy", "elderly" or "aging" or "geriatric", "thoracic surgery", "outcomes", "pulmonary complications" or "respiratory complications", "neurologic complications", and "brain health". A reverse lookup of relevant citing articles was performed to broaden the search parameters. Included studies were published after 1995 and were available in English.

Key Content and Findings: A growing number of studies exist to indicate that neurocognitive and pulmonary complications are of particular concern in elderly patients undergoing thoracic procedures. While VATS reduces the incidence of specific complications compared to open thoracotomy, a variety of preoperative, intraoperative, and postoperative measures may confer additional benefit with respect to organ function and overall recovery following surgery. We summarize these measures here.

Conclusions: Despite heterogeneity in the strength of the evidence, a working set of best practices can be identified in the perioperative management of geriatric patients undergoing VATS, particularly with respect to optimizing perioperative neurocognitive function and reducing pulmonary complications. However, there is an ongoing need for clinical investigation and multidisciplinary collaboration to improve the care of elderly patients requiring thoracoscopic procedures.

Keywords: Thoracic surgery; video-assisted thoracic surgery (VATS); frailty; perioperative outcomes; geriatrics

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Introduction

As the population ages, ever-increasing numbers of elderly patients will undergo thoracic surgery, particularly for the resection of cancerous or potentially cancerous pulmonary lesions. Furthermore, the expansion of the United States Preventive Services Task Force's guidelines on low-dose computed tomography may lead to a substantial increase in the number of patients identified as surgical candidates (1). Fortunately, video-assisted thoracic surgery (VATS) has paved the way toward a greater margin of safety

with excellent oncologic outcomes in the elderly, commonly defined as adults over 65 years of age.

Yet it is also known that the physiologic consequences of aging, in addition to frailty syndromes and comorbidities prevalent in elderly surgical patients, pose significant surgical and anesthetic challenges and increase the risks of perioperative cardiac, neurologic, and pulmonary adverse events. Though several institutional protocols have been developed to guide the perioperative care of patients undergoing VATS, evidence-based practices around safeguarding organ function following VATS have not been rigorously defined for the elderly. Given the high incidence of multiorgan complications after thoracic surgery—including VATS—a concise review of the available literature, coupled with actionable recommendations, is needed for surgical and anesthetic practitioners to optimize the care of elderly patients who are brought to the operating room for thoracic interventions.

Within this review, we aim to summarize key complications associated with thoracoscopic surgery that may be encountered by geriatric patients, focusing especially on perioperative neurocognitive disorders and pulmonary complications. We then review the evidence surrounding preoperative, intraoperative, and postoperative measures that may be implemented to reduce the incidence of these problems and accelerate functional recovery after VATS. We present the following article in accordance with the Narrative Review reporting checklist (available at https://vats.amegroups.com/article/view/10.21037/vats-22-47/rc).

Methods

This narrative review was conducted between October 1, 2022 and November 12, 2022 via query of MEDLINE®-indexed articles in the PubMed database maintained by the National Library of Medicine. Given the increasingly recognized prevalence of perioperative neurocognitive disorders in the elderly and the heightened risk of postoperative pulmonary complications (PPCs) following thoracic surgery, our review was targeted toward these concerns. Such adverse events, including prolonged postoperative air leak and delirium, have also been documented to occur at significantly higher rates in the elderly compared to younger patients undergoing VATS (2).

Combinatorial search terms included "VATS" or "thoracoscopy", "elderly" or "aging" or "geriatric", "thoracic surgery", "outcomes", "pulmonary complications" or "respiratory complications", "neurologic complications", and "brain health". A reverse lookup of citing articles published subsequently was also conducted to expand the search parameters. Studies without clear relevance to geriatric populations or perioperative outcomes were excluded from comprehensive review. In addition, included studies were published after 1995 and were available in English, with a significant majority of studies dated for publication after 2010. Of note, while VATS refers to a surgical technique that may be applied to a range of procedures with heterogeneous risk profiles, this search overwhelmingly yielded studies of VATS performed for lung resections. For a summary of the search strategy, see *Table 1*.

Defining the problem: impacts of thoracic surgery on the elderly

Frailty

One of the cardinal challenges of operative interventions in elderly patients is posed by frailty. "Phenotypic frailty" is a syndrome of quantifiable decline in physiologic reserve that commonly accompanies age. Hallmarks of phenotypic frailty include "*weakness*, *slow walking speed*, *low physical activity*, *fatigue or exhaustion*, *and unintentional weight loss*" (3). However, a unified set of criteria for frailty has yet to be established. Given the heterogeneity inherent in the diagnosis of frailty, the prevalence of the syndrome has also been estimated between 10–25% in most elderly adults living in community settings, with a clear correlation between incidence and advancing age (3,4). Interwoven with frailty is the concept of homeostenosis, defined by Fried *et al.* as an "*age-related decrease in the amount of physiological reserve that is available for responding to stressors*, *as a result of which older adults become vulnerable to the impact of stressors*" (3). Such stressors may impact virtually every organ system.

As thoracic operations and anesthetics often constitute profound physiologic insults, the benefits of any interventions must be weighed thoughtfully against the risk of irreversible postoperative functional decline. Frailty is a well-established risk factor for perioperative complications and persistent impairments, and this significantly elevated risk has been shown to extend to thoracic surgical populations (5-8). A large retrospective case-control study based on the National Surgical Quality Improvement Program (NSQIP) database demonstrated a clear correlation between metrics of frailty and an increased risk of perioperative morbidity and mortality (9). Another prospective cohort study of community-dwelling elderly

Table 1 Summary of the search strategy

Items	Specification
Dates of search	October 1, 2022 to November 12, 2022
Databases and other sources searched	PubMed database
Search terms used	"VATS" OR "thoracoscopy", "elderly" OR "aging" OR "geriatric", "thoracic surgery", "outcomes", "pulmonary complications" OR "respiratory complications", "neurologic complications", "brain health"
Timeframe	1998 to 2022
Inclusion and exclusion criteria	Inclusion: indexed in MEDLINE, published after 1995 (with most articles authored after 2010), available in the English language, subject relevant to geriatric populations undergoing thoracic surgery
	Exclusion: irrelevant to primary search terms, unavailable in English
Selection process	The two authors (LHM, XB) reviewed all candidate articles and selected studies for inclusion based on verbal consensus and the above predefined inclusion and exclusion criteria

VATS, video-assisted thoracic surgery.

adults indicated that frailty conferred a fourfold increase in 1-year mortality following major surgery (10).

Interestingly, a subsequent prospective cohort study of thoracic patients, which screened for phenotypic frailty based on criteria including strength, gait, nutritional status, and exercise capacity, found that a large proportion of patients classified as frail or pre-frail were ultimately deemed to be candidates for thoracic interventions—suggesting that frailty may be underdiagnosed in thoracic populations and perhaps underutilized as a tool for patient selection and preoperative intervention. The authors of this study, however, noted that the sequelae of cancer and phenotypic frailty criteria overlap substantially, with the most common symptom reported by frail and pre-frail patients being exhaustion or persistent fatigue (6). In addition, given that the most common indication for VATS in the elderly is the resection of suspicious nodules or confirmed lung malignancies, the benefits of proceeding with curative surgery even in frail adults may often outweigh the risks, and little concrete evidence exists to guide clinical decision-making in this area.

Various instruments are now available for the assessment of frailty, but none has demonstrated sufficient accuracy and precision to be considered a gold standard. Therefore, it may be recommended that a combination of frailty assessment scales be used in combination to better identify thoracic surgical patients who are at higher perioperative risk (11,12). Ultimately, effectively preoperative screening for frailty can facilitate meaningful discussions regarding risk-benefit considerations between patients and surgical teams, allow patients to be selected wisely for VATS and, if deemed to be potential candidates, to be targeted for preoperative interventions to counter physical and cognitive aspects of phenotypic frailty.

Perioperative brain health in geriatric patients

The aging process profoundly impacts the central nervous system. Imaging studies indicate that the cortical gray matter in the brain thins and retracts by up to 1% annually in elderly adults, perhaps as a function of decreased neuronal interconnectivity, reduced dendritic branching, and impaired metabolic regulation in nervous tissue (13). Regardless of the mechanism, it is established that cognitive agility, working memory, circadian regulation, and executive function decline with age. In addition, the fragility of the aging brain is increased with respect to systemic stresses produced by surgery as well as numerous medications that may be given in the perioperative period (14).

This progressive loss of neurologic reserve—especially when superimposed upon preexisting neurocognitive disorders—may significantly increase the risk of postoperative delirium (POD) and postoperative cognitive dysfunction (POCD) in elderly populations (15-17). POD manifests as a syndrome of inattention, confusion, and disorientation or impaired cognition with a waxing-waning course in the early postoperative period. POCD, by contrast, is diagnosable via neuropsychological testing at 3 months postoperatively and may manifest as worsened cognitive performance with variable recovery

over time. Collectively, these disorders have been found to occur postoperatively in at least 10% of elderly adults, and significant associations have been found between perioperative neurocognitive disorders and precipitous functional decline, long-term institutionalization, and increased morbidity after major surgery (18).

While minimally invasive approaches such as VATS have the potential to reduce surgical stress, improve pain control, and speed recovery, evidence that POD and POCD are reduced via the use of VATS remains sparse (19,20). In addition, given the documented associations between intraoperative hypoxemia and hypercapnia and the incidence of POD, thoracic procedures may substantially increase the risk of delirium compared to other surgeries as a result of one-lung ventilation (OLV), which often produces extended periods of shunt and impaired gas exchange (21). Uncontrolled pain as well as medication adverse effects (e.g., opioid-induced central nervous system depression) may further worsen postoperative brain function (22,23).

Geriatric pulmonary physiology and PPCs

Advancing age brings with it a host of adverse effects on pulmonary function, including both intrinsic structural changes to the lung parenchyma as well as extrinsic alterations to ventilatory control pathways and muscles of respiration. The compliance of the aging lungs increases with a progressive degeneration of elastin in the alveolar walls. At the same time, the chest wall stiffens, a process driven by calcification of the costal cartilages and exaggerated kyphosis of the thoracic spine. Therefore, although total lung capacity is generally preserved, residual volume tends to increase (24). The consequent reduction in vital capacity is often accompanied by a decrease in the measured functional expiratory volume in 1 second (FEV1), a function of increased collapsibility of the small airways and atrophy of the thoracic musculature in the elderly patient. Such collapsibility may further increase closing capacity above functional vital capacity, promoting the early closure of small airways and increasing the likelihood of postoperative atelectasis (24).

In addition, the sensitivity of peripheral and central chemoreceptors is also dampened as a function of aging (25). The result is a greater susceptibility to hypoventilation, which is potentiated when respiratory depressants such as opioids are administered perioperatively. In the presence of comorbid obstructive sleep apnea, the incidence of which increases further with age, significant hypoxemia and hypercapnia may be observed following thoracic surgery and anesthesia (24). All of these changes considerably increase the risks of PPCs for geriatric surgical patients at large.

In thoracic surgical populations specifically, PPCs are of even greater concern because of direct lung manipulation and surgical trauma, OLV, and the accumulated insults of underlying comorbidities such as tobacco smoking, pulmonary fibrosis, and chronic obstructive pulmonary disease. Surgical manipulation and lung collapse during VATS have the potential to worsen perioperative hypercapnia as well as atelectasis as a function of greater pressures exerted on the lung parenchyma during the operative period. Related to the above changes, varying degrees of baseline ventilation-perfusion mismatch, vascular disease, and pulmonary hypertension are common in the elderly and may reduce tolerance of OLV. Although the use of a VATS technique has been clearly linked to reduced pain scores compared to thoracotomy, port site incisions and the placement of a chest tube produce significant pain that may still exacerbate postoperative splinting and contribute to pulmonary complications beyond those observed after other forms of major surgery. To underscore the importance of risk mitigation strategies, patients developing PPCs after major surgery appear to be at increased risk for prolonged hospitalization, intensive pulmonary rehabilitation, and postoperative mortality (26,27).

VATS compared to open thoracotomy for the elderly

Intrathoracic surgical procedures, by their nature, carry risks of serious functional impairment, injury, and death, and this risk is clearly accentuated in the elderly. Fortunately, numerous studies now support the safety of video-assisted and minimally invasive thoracic surgical approaches in geriatric patients, particularly when compared to thoracotomy. Benefits of VATS over open procedures reported within the literature range from a reduced incidence of PPCs and pulmonary infections to shorter hospital stays, decreased resource utilization, and lower overall morbidity and mortality. These advantages are likely derived from a reduction in surgical stress and postoperative sympathetic arousal, which may be triggered by maneuvers such as rib-spreading as well as the increased tissue disruption associated with open thoracotomy (19,20,28-32). Such benefits extend across age groups, but they are most pronounced in elderly patients with diminished physiologic reserve.

At the same time, while concerns have been raised around lower tissue yields from lymph node dissection via VATS, oncologic outcomes appear equivalent (19,31). It is no surprise, then, that VATS is increasingly regarded as the gold standard approach to lung resection in elderly patients especially. Newer minimally invasive modalities may further improve perioperative outcomes, with one large retrospective study indicating that robotic-assisted lobectomy may be superior even to VATS lobectomy with respect to decreased transfusion rates, shorter hospital stays, and a lower likelihood of conversion to thoracotomy (33).

Of note, while advanced age is a risk factor for perioperative arrhythmias, studies indicate that VATS does not uniformly reduce the risk of common cardiovascular complications such as postoperative atrial fibrillation and atrial flutter compared to thoracotomy (34,35). Still, it is reasonable to extrapolate from other studies of minimally invasive procedures that reducing the extent of operative tissue disruption may lower the risks of major adverse cardiovascular events occurring due to surgical inflammation and systemic stresses (36).

Protecting the aging brain after VATS

Preoperative approaches

Numerous screening tools are available to assess neurocognitive function. It has been previously recommended that a screening tool be applied before surgery to assess baseline cognitive ability, which may assist in identifying patients with preexisting neurocognitive disorders and those at elevated risk of developing POD or POCD. While longer screening inventories have been validated, tools such as the two-part Mini-Cog© instrument, the clock-drawing test, and the Mini-Mental State Examination (MMSE) may be applied and scored within 10 minutes (15). Elderly patients found to have low scores on these assessments may warrant more deliberate preoperative discussion about the neurocognitive risks of thoracic surgery and anesthesia. Such patients may also be targeted for perioperative measures to prevent cognitive decline where possible. In general, a thorough preoperative discussion with the elderly patient and any caregivers to define goals of surgical treatment and to clarify advance directives is recommended for both surgical and anesthetic teams (15,37). This conversation is particularly important for elderly patients assessed to be at high risk of POD or POCD, as patients may lose the capacity to communicate medical decisions.

There is a mounting body of evidence that targeted multidisciplinary care coordination may improve neurocognitive outcomes in elderly adults undergoing specific surgical interventions, most notably hip fracture repair (38). One single-center randomized clinical trial (RCT) indicated that a cognitive prehabilitation intervention before noncardiac surgery reduced rates of POD with even minimal patient adherence, though further studies remain needed (39). In accordance with a prior randomized trial of comprehensive geriatric evaluations in vascular patients, a systematic review by Janssen *et al.* demonstrated that a multifaceted geriatric evaluation—coupled with appropriate referrals and targeted therapies for correction of preoperative anemia and cardiac comorbidities—may reduce the incidence of POD in a group of elderly vascular surgery patients (40,41). While no such care bundles currently exist for patients undergoing VATS, the successes of such pathways may argue for early involvement of specialists in geriatric and palliative care medicine for patients at elevated risk of perioperative neurocognitive disorders. The value of a geriatric consultant is underscored for particularly multimorbid surgical candidates or patients who may require longer perioperative hospital stays.

Intraoperative considerations

There has been enthusiasm to test specific surgical techniques or anesthetic strategies in the hope that they may prevent perioperative neurocognitive impairment. For example, a growing number of studies have compared non-intubated VATS, which is usually performed by maintaining spontaneous ventilation in an anesthetized patient, with conventional VATS relying upon mechanical ventilation. Despite early enthusiasm for non-intubated VATS at a few institutions—and limited evidence that VATS with spontaneous ventilation may reduce ICU admission and surgical blood loss—no convincing data have emerged to indicate that avoidance of intubation improves neurocognitive outcomes (42,43). A notable limitation of these studies with respect to neurocognitive function, however, is that patients in the non-intubated groups still received high doses of sedating medications.

Various pharmacotherapies to reduce the incidence of perioperative neurocognitive disorders have been studied, but very few appear to produce consistently meaningful results. For example, in one small randomized controlled trial, an intraoperative dexmedetomidine infusion at

0.5 mcg/kg/h reduced the incidence of early cognitive decline and improved postoperative sleep quality in elderly male patients undergoing VATS lobectomy (44). However, a subsequent trial was not able to replicate the reduction in POCD for thoracic surgical patients with low-dose dexmedetomidine, though pain scores and hospital length of stay were significantly reduced compared to placebo (45).

Indeed, no strong recommendations can be made with respect to the use of specific medications or anesthetic techniques during surgery to promote brain health. Ongoing research in this area may focus on optimizing pain control and sleep hygiene with appropriate drug therapies and nonpharmacologic interventions, such as continuous positive airway pressure (CPAP) in elderly patients with obstructive sleep apnea (16). By contrast, the avoidance of drugs with disorienting or destabilizing properties has long been associated with improved outcomes in elderly adults. Examples of drugs to avoid in geriatric populations are those with significant anticholinergic, sedative-hypnotic, or hypoglycemic effects (15).

The use of processed electroencephalography (pEEG) for guided titration of anesthetic depth has also been a matter of ongoing debate, particularly with respect to its efficacy in reducing POD and POCD incidence. While large-scale trials have yielded heterogeneous results, one recent randomized clinical trial in elderly thoracic patients demonstrated a positive outcome of EEG guided anesthesia for cognitive function (46). Implementing pEEG-based monitoring may therefore aid in targeting a lighter plane of sedation and thus avoiding a state of relative anesthetic overdose (47-49).

Normalizing a patient's oxygenation, temperature, and hemodynamics is more exquisitely important for geriatric patients undergoing thoracic surgery. Early studies demonstrated a link between cerebral hypoxia and postoperative cognitive decline in thoracic, cardiac, major abdominal, and orthopedic surgeries—a connection that has sparked a number of investigations into the use of cerebral oximetry to improve neurocognitive outcomes (50-53). As a result of the progressive loss of neurons and metabolic regulation within the aging brain, elderly patients are more susceptible to the hypoxic injury. Nevertheless, more research is needed to establish thresholds to minimize this risk.

While data on the relationship between intraoperative hypotension and POCD remain inconclusive, there is evidence to suggest that the duration and magnitude of low mean arterial pressures correlate with cognitive decline (54,55). The neurocognitive effects of sustained intraoperative hypotension may be further exacerbated in elderly patients with chronic hypertension and impaired cerebral autoregulation. As such, it would be recommended that elderly patients undergoing VATS should be managed with attention to ensuring sufficient cerebral perfusion and oxygenation, perhaps with increased blood pressure targets during periods of OLV to compensate for the relative hypoxemia arising during these periods.

Postoperative strategies

To date, there is sparse evidence to suggest that any isolated postoperative intervention can effectively reduce the incidence of POD or POCD. However, routine care measures to reduce the incidence of delirium are still frequently recommended, including normalization of sleep cycles, early mobilization, and aggressive nutritional and functional rehabilitation (15,16).

One randomized trial of elderly patients undergoing abdominal surgery focused on implementing a nursing-led regimen of "orienting communication, oral and nutritional assistance, and early mobilization". While this study was able to demonstrate a substantially reduced risk of POD, particularly within the first 8 days postoperatively, widespread uptake of such intensive interventions has been slow (56). Early removal of chest tubes and avoidance of urinary catheters unless clearly indicated may also be advocated for patients to avoid the potentially deliriogenic effects of indwelling lines and drains (57).

The use of antipsychotic drugs, particularly haloperidol and quetiapine, to treat and prevent states of delirium also remains common, with some evidence suggesting that such medications may reduce the incidence of delirium compared to placebo (57). However, such findings are not uniform, and specific studies have directly contradicted these outcomes. Enthusiasm around the use of antipsychotics has also been tempered by the findings of various adverse effects in geriatric populations, notably sedation, hypotension, and electrocardiographic changes such as prolongation of the QT interval (58).

In elderly patients undergoing VATS, due attention to pain control, circadian regulation, and accelerated mobilization may be particularly effective interventions, particularly given the interplay between pain, delirium, and agitation in hospital patients. In the future, multidisciplinary protocols or care bundles may be shown effective in geriatric individuals undergoing minimally invasive thoracic procedures, though further study is needed.

Table 2 Recommendations with respect to brain health for elderly patients undergoing VATS

Setting	Recommendation	Comments
Preoperative	Apply a validated neurocognitive screening tool to assess baseline brain function and vulnerability	The use of a simplified tool such as the Mini-Cog© or clock drawing test is often most expedient
	Thoroughly discuss neurocognitive risks with patients and families	Couple with advance care planning and identification of a healthcare proxy
	Involve multidisciplinary specialists and teams in the perioperative care of the patient	–
Intraoperative	Avoid unnecessary medications with anticholinergic or sedative effects	–
	Avoid prolonged hypoxemia, hypotension, and temperature derangements	Consider a higher blood pressure or oxygenation target in elderly patients during OLV
	Consider the deliberate use of processed EEG to avoid anesthetic overdose	Mixed evidence exists regarding efficacy, though potential for harm is minimal
Postoperative	Target early mobilization and rehabilitation	–
	Remove chest tubes, urinary catheters, and indwelling drains when no longer indicated	–
	Reorient patients frequently and normalize sleep	–
	Consider cautious use of dexmedetomidine or antipsychotic medications	May treat or reduce refractory POD
	Ensure adequate coverage of postoperative pain	Multimodal strategies may aid in reducing sedation and avoiding adverse effects

VATS, video-assisted thoracic surgery; OLV, one-lung ventilation; EEG, electroencephalography; POD, postoperative delirium.

The approaches discussed above are summarized in *Table 2*.

Optimizing lung function in the elderly after VATS

Preoperative approaches

To optimize perioperative lung function, preoperative smoking cessation counseling is perhaps of greatest importance in elderly thoracic surgical populations. This is because active smoking of tobacco products has been pinpointed as the strongest independent risk factor for PPCs (26). Benefits of early and sustained preoperative smoking cessation include a reduction in carboxyhemoglobin levels, reduced airway reactivity, and preserved pulmonary secretion clearance and immune function. Most sources currently recommend preoperative tobacco cessation at least 4–8 weeks prior to major surgery, as a transient increase in bronchorrhea is often observed in the initial weeks following discontinuation of smoking. There is also evidence that smoking cessation for at least several weeks improves pain control after thoracoscopy compared to smoking cessation within 3 weeks preoperatively (59).

Beyond simply improving pain control, preemptive regional analgesic interventions have been shown to confer numerous benefits such as improved functional recovery, decreased rates of POD, and lower levels of neuroinflammatory markers after VATS (60-63). Compared to open thoracotomy, VATS produces lower levels of postoperative pain and is associated with a lower incidence of post-thoracotomy pain syndrome. Yet VATS may still be associated with moderate to severe postoperative pain in at least 15% of patients, likely because healing port sites and indwelling chest tubes may continue to irritate and inflame the chest wall (64). These pain foci may be covered by a variety of regional anesthetic techniques. Consideration should be given to the placement of thoracic epidural catheters or single-shot paravertebral, serratus anterior plane, erector spinae plane, or intercostal blocks in elderly patients at high risk of postoperative pulmonary compromise (65).

Some evidence suggests that geriatric patients undergoing VATS for lung resection, particularly those

with marginal baseline pulmonary function, may benefit from a pulmonary "prehabilitation" program targeted at improving respiratory strength, offering physical therapy, and smoking cessation (66). Such a program may be most beneficial when coupled with interventions designed to address malnutrition and baseline frailty, such as nutritional supplementation and continuation of clear liquid intake up to 2 hours prior to surgery (67). Such programs may even enhance operability, allowing patients initially deemed poor candidates for surgery to undergo curative surgery with fewer complications (68). Identification and correction of preoperative anemia is also of utmost importance in patients undergoing VATS, as uncorrected anemia has been closely linked to adverse outcomes and increased mortality in patients undergoing cardiothoracic procedures (69).

Intraoperative considerations

Because of the ubiquitous need for OLV during VATS, optimization of ventilatory parameters is the ideal starting point for prevention of PPCs associated with thoracoscopic surgery. At least one retrospective study has indicated that tidal volumes maintained during OLV are inversely associated with the risk of respiratory complications in the presence of low positive end-expiratory pressure (PEEP) (70). The same study indicated that each increase in the driving pressure by 1 cmH_2O was associated with a 3.4% increase in perioperative morbidity. The judicious application of PEEP may also improve oxygenation during OLV, though caution must be taken to optimize PEEP based on measurable endpoints. Studies indicate that techniques such as PEEP titration to observed respiratory system compliance or using electrical impedance tomography (EIT) may be particularly helpful in the elderly (71,72). The importance of individualized ventilatory parameters is underscored by the increases in closing capacity, lung compliance, and heterogeneity of ventilation-perfusion matching observed in the elderly.

By avoiding neuromuscular blockade and positive-pressure ventilation, a non-intubated VATS approach has been associated with decreased release of inflammatory mediators, shorter lengths of stay, and lower rates of postoperative pulmonary complications in dedicated centers (73). However, in elderly patients, the benefits of this approach do not appear to be as significant. Two recent studies also indicated that maintenance of spontaneous ventilation may increase chest tube indwelling time with a corresponding increase in total chest tube drainage volume (42,43). Given the lack of conclusive pulmonary benefits demonstrated with spontaneous ventilation, further investigations are required for firm recommendations to be made.

Fluid therapy during thoracic procedures has also been closely examined. Aggressive fluid resuscitation with greater than 6 mL/kg/h has been linked to an increased risk of pulmonary edema (74). In one recent study, an approach involving target-directed fluid therapy during OLV appeared to be effective in reducing pulmonary inflammation and infection, but other clinical impacts of this approach did not achieve significance (75). Studies also suggest that an overly restrictive fluid administration strategy should be avoided in thoracic surgical patients, with a deliberate goal of giving fluid to a near-zero net fluid balance perhaps producing the fewest overall complications (76). A targeted approach toward restoring and maintaining euvolemia, preferably with balanced crystalloid solutions, should therefore be preferred perioperatively (67).

Other evidence-based approaches to safeguard postoperative lung function include appropriate antibiotic prophylaxis and the rational use of both mechanical and chemical venous thromboembolism (VTE) prophylaxis in elderly patients (67). Geriatric patients, particularly those undergoing VATS for known malignancy and those with baseline mobility impairments, may present with higher baseline risks of VTE.

Postoperative strategies

Postoperative pulmonary rehabilitation may promote enhanced recovery of lung function after VATS. There is now mounting evidence that a multicomponent intervention encouraging incentive spirometry, regular coughing, and early mobilization may reduce the need for postoperative ventilatory support and shorten hospital stays. However, individual modalities to support pulmonary rehabilitation, including incentive spirometry and time-limited non-invasive positive pressure ventilation modes used in isolation, have not universally been shown to benefit geriatric patients (77-79). For patients with significant obstructive sleep apnea, however, any existing nighttime positive-pressure ventilation modes should be continued postoperatively, and patients may be instructed to bring in their own CPAP devices from home when feasible (67).

Early chest tube removal, when clinically appropriate, may facilitate earlier ambulation and reduce postsurgical

Table 3 Recommendations with respect to lung recovery for elderly patients undergoing VATS

Setting	Recommendation	Comments
Preoperative	Encourage smoking cessation efforts	Tobacco cessation 4–8 weeks prior to surgery may produce the greatest benefit
	Consider thoracic epidural analgesia or peripheral nerve blockade	VATS may be associated with significant pain treatable with a variety of regional anesthetics
	Consider regimented prehabilitation programs	Most recommended for frailty, malnutrition, or marginal lung function
	Screen for and correct preoperative anemia	–
	Consider development of a multidisciplinary care pathway for VATS patients	–
Intraoperative	Target fluid therapy toward euvolemia	Avoid overly restrictive fluid management
	Utilize lung-protective ventilation strategies, especially during periods of OLV	Individualize PEEP and avoid excessive driving pressures
	Administer appropriate perioperative antibiotics	No special coverage needed for pathogens associated with pneumonia
	Give mechanical and/or chemical prophylaxis against venous thromboembolic disease	Geriatric patients may be at higher risk, particularly in the setting of malignancy or baseline immobility
Postoperative	Combine pulmonary hygiene interventions to promote lung recovery	Regular incentive spirometry, coughing exercises, and chest physiotherapy may be more effective in combination than alone
	Minimize chest tube use and remove these as early as feasible	–
	Strive for tight control of PONV	Identify and treat risk factors with combinations of antiemetic agents
	Provide consistent and effective analgesia throughout the postoperative period	–

VATS, video-assisted thoracic surgery; OLV, one-lung ventilation; PEEP, positive end-expiratory pressure; PONV, postoperative nausea and vomiting.

pain. There is some evidence that early discontinuation of indwelling chest tubes, defined in one set of guidelines as removal of chest tubes as soon as serous output is decreased to less than 500 mL over 24 hours, may confer benefit. Similarly, leaving only one chest tube in place whenever possible—already a common practice in many VATS procedures—is also recommended (67). Regardless of the chest tube management approach selected, early mobilization and physical therapy are essential in promoting adequate lung excursion and return of function.

Diligent control of postoperative nausea and vomiting (PONV), particularly in patients at risk for concomitant neurocognitive dysfunction, is also strongly recommended to further avoid aspiration syndromes and delayed mobilization. Patients at high likelihood of developing PONV may be easily identified via the simplified Apfel score, which includes four key risk factors: female sex, prior PONV or motion sickness, nonsmoking status, and postoperative opioid consumption (80). It is also well established that patients benefit from perioperative antiemetic prophylaxis, with combinations of pharmacotherapies from differing classes conferring additive and substantial benefits (56).

Especially for patients who are deemed ineligible for preoperative or intraoperative regional anesthetic techniques, the use of multimodal analgesic strategies—ideally incorporating the use of non-steroidal anti-inflammatory drugs (NSAIDs) and acetaminophen—may improve postoperative pain control and reduce splinting while mitigating opioid-related adverse effects.

The approaches discussed above are summarized in *Table 3*.

Conclusions

It has been thoroughly established that geriatric patients are at a significantly elevated risk of developing complications associated with thoracic surgery. Much of this risk is derived from the physiologic changes and the accumulation of comorbidities that often accompany the aging process, creating challenges for surgical and anesthetic teams aiming to treat thoracic disease. Fortunately, VATS provides numerous substantial benefits over open thoracotomy, allowing more elderly and multimorbid patients to undergo thoracic interventions safely.

Given the aging worldwide population and the constantly increasing numbers of elderly patients undergoing VATS, the need to identify perioperative organ-protective strategies has never been more acute. While this narrative review provides a working overview of strategies to improve organ recovery in the elderly after VATS, rigorous investigations of multifaceted interventions for geriatric patients undergoing thoracic surgery remain lacking. It must also be noted that the available evidence is most abundant with respect to VATS lung resections. Therefore, the needs of geriatric patients undergoing other VATS procedures may differ. These limitations highlight the ongoing need for robust research as well as interdisciplinary collaboration between surgeons, anesthesiologists, and allied healthcare professionals to optimize the care of elderly patients undergoing thoracoscopic procedures.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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