Precise anesthesia in thoracoscopic operations

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Purpose of review
The current review focuses on precise anesthesia for video-assisted thoracoscopic surgery (VATS) with the goal of enhanced recovery.

Recent findings
VATS has become an established and widely used minimally invasive approach with broad implementation on a variety of thoracic operations. In the current environment of enhanced recovery protocols and cost containment, minimally invasive VATS operations suggest adoption of individualized tailored, precise anesthesia. In addition to a perfect lung collapse for surgical interventions with adequate oxygenation during one lung ventilation, anesthesia goals include a rapid, complete recovery with adequate postoperative analgesia leading to early discharge and minimized costs related to postoperative inpatient services. The components and decisions related to precise anesthesia are reviewed and discussed including: letting patients remain awake versus general anesthesia, whether the patient should be intubated or not, operating with or without muscle relaxation, whether to use different separation devices, operating with different local and regional blocks and monitors.

Conclusion
The determining factors in designing a precise anesthetic for VATS operations involve consensus on patients’ tolerance of the associated side effects, the best practice or techniques for surgery and anesthesia, the required postoperative support, and the care team’s experience.

Keywords
intercostal nerve block, thoracic anesthesia, vagal nerve block, video-assisted thoracoscopic surgery

INTRODUCTION
The major advance in video-assisted thoracoscopic surgery (VATS) procedures is related to the major pulmonary resections. With advances in endoscopic, robotic and endovascular techniques, VATS can be performed in a minimally invasive way in the management of most pulmonary [1–3], mediastinal, and pleural diseases. By avoiding a thoracotomy incision, VATS allows a shorter operating time and less postoperative morbidity [1,4]. Recently, uniportal VATS lobectomy combined with mediastinal lymphadenectomy has been reported to be a safe and feasible technique [5]. Substantial benefits of uniportal VATS in various operations [6,7,8,9] include less postoperative pain, blood loss, drainage time, and postoperative hospital stay [10,11]. Moreover, in selected patients, it was reported that tubeless VATS was feasible [12]. The application of these less invasive VATS techniques has prompted similar advancements in anesthetic management. A faster recovery with a best-fit postoperative analgesia and earlier return to normal activity have become new goals of anesthetic management above and beyond the conventional goals of satisfactory surgical fields and oxygenation during one lung ventilation (OLV). Therefore, added to an enhanced recovery after surgery protocol [13], precise anesthesia for VATS operations can play a major role in recovery.

THE CONSIDERATIONS FOR PERFORMING PRECISE ANESTHESIA
The considerations of precise anesthesia include all the potential factors affecting recovery (age, smoking, male, cardiovascular disease, American Society of Anesthesiologists (ASA) status, preoperative lung function), surgical factors (operation fields, greater...
KEY POINTS

- With advances in endoscopic, robotic and endovascular techniques, VATS can be performed in a minimally invasive way through less ports with less drains.

- A faster recovery with a best-fit postoperative analgesia and earlier return to normal activity has become the new goal of anesthetic management for VATS operations.

- Thoracoscopic vagal nerve blocks can be performed precisely by surgeon under direct vision to facilitate anatomical resection in nonintubated VATS.

- Anesthesiologists can perform a tailored anesthesia using a combination of general anesthetics and regional blocks with optimal airway management for different patients with less invasive monitors.

The choices of general anesthesia and drugs applied to perform general anesthesia

General anesthetics, including intravenous anesthetics, inhalational agents, and narcotics, along with muscle relaxants and mechanical ventilation, have long been considered the standard approach for VATS operations. However, the concept of precise anesthesia can be summarized as the balance between the adverse effects of general anesthesia and the patients’ preexisting pulmonary and cardiac diseases. Reduced ventilation and depressed cardiovascular functions are concerns with general anesthesia in this patient population. The functional residual capacity (FRC) is reduced soon after anesthesia [15] and there is a cephalad shift of the diaphragm because of a loss of the diaphragmatic end-expiratory tone. Patients who were paralyzed with muscle relaxants exhibited a greater cephalad shift of the diaphragm. When the FRC falls below the closing capacity, lungs tend to collapse and airways tend to close. Consequently, hypoxemia develops easily, particularly in the elderly [16] and those patients with chronic obstructive pulmonary disease. As noted in previous reports, keeping patients awake to avoid those adverse effects was favorable in some particular operations [17,18]. However, most patients want to be sedated because of the discomfort from apneic sensations during surgical pneumothorax. With adequate monitoring, a precise sedation can be performed and adjusted [19].

Controlled ventilation with muscle relaxants carries the risks of mechanical ventilation associated lung injuries [20] and residual muscle relaxation. Postoperative residual neuromuscular blockade not only delays the clinical recovery [21] but also increases the accidental awareness [22]. For rapid respiratory recovery and the necessity of respiratory rehabilitation, neuromuscular monitoring [21] or sugammadex [23] is strongly suggested to prevent residual muscle relaxation.

Some anesthesiologists believed that ideal candidates for awake or nonintubated VATS (NIVATS) are patients with multiple comorbidities [24]. However, the surgical needs should be taken into anesthetic consideration. For procedures not involving lung parenchyma, Katlic [25] has reported on more than 500 patients receiving VATS without intubation and muscle relaxants. In contrast, for anatomical resection requiring lobectomy or segmentectomy, a quiet smooth operation field with complete lung collapse is needed. Therefore, inhibition of the cough reflex is necessary for surgeons manipulating the airways and hilum during anatomical resection. In addition to intravenous narcotics, intrapulmonary or extrapulmonary vagal nerve blocks can suppress the cough reflex [26]. Thoracoscopic vagal nerve blocks can be performed precisely by surgeon under direct vision [27]. The injection sites of left and right thoracoscopic vagal nerve blocks are different and illustrated in Fig. 1. The recovery from unilateral vagal nerve blocks can be monitored with cough performance and phonation without hoarseness.

The intraoperative opioid should also be chosen both based on duration of action and possible side effects. The continuous infusion of remifentanil set with target-controlled infusion (TCI) guarantees effective intraoperative analgesia and rapid extubation times with rapid recovery [28]. In recent years, postoperative narcotics requirement has been reduced with the popularity of regional blockades, even in pediatric patients [29], and there has been less analgesic requirement after minimized invasive surgeries.

The host’s immune defense mechanisms and the effects on cancer progression are impacted by surgical stress, anesthesia, and perioperative analgesia [30]. Although inhalational agents were reported as preferred for better intraoperative microcirculation [31],
and less postoperative complications [32**]. Large-scale investigations have shown better survival rates for patients receiving total intravenous anesthesia (TIVA) [30*]. As there is a trend of less invasiveness in thoracic operations and selecting regional blocks for postoperative analgesia, the impact of oncologic outcomes associated with operations and anesthesia will be limited in the future.

### The choice of different local and regional blocks

Local and regional anesthesia has a fundamental role in maximizing all potential advantages of minimally invasive techniques like VATS. Thoracic epidural analgesia (TEA) remains to be the intraoperative and postoperative gold standard for thoracotomy. However, although epidural anesthesia was reported not to disturb respiratory or parenchymal functions [33], TEA leads to the development of bilateral sympathetic nerve block with reduced cardiac output (CO) [34] and a high risk of hypotension. Recently, regional blocks with less incidence of hypotension such as intercostal nerve blockades [35] and paravertebral blocks [36] are chosen more often for VATS operations with combination of sedation. These nerve blocks remain a good component of postoperative multimodal analgesia especially for minimally invasive VATS operations. As a result, the determining factors in selecting the regional technique of choice include the consensus on best practice or technique, the tolerance of the associated side effects, and the anesthesiologist’s experience.

### The choice of tracheal intubation and lung separation instruments

Satisfactory surgical fields with complete lung collapse is mandatory for VATS operations. Although spontaneous negative breathing facilitates lung collapse in NIVATS, the spectrum of indication contains procedure-dependent and patient-dependent factors. While choosing intubated VATS, OLV via lung separation and isolation plays a key role in airway management. Techniques on inserting lung isolation instruments such as double-lumen tubes (DLTs) or bronchial blockers [37–39] and knowledge in tracheobronchial anatomy by fibroptic bronchoscopy (FOB) is routinely requested for anesthesiologists [40]. Recently, a new VivaSight DL (EF-View Ltd, Misgav, Israel) with a camera embedded in the tube’s right side has been reported to intubate to the correct position without FOB [41] minimizing insertion injuries and continually monitoring the position of the lung separation device. In addition, there are also reports on how to select the best-fit DLTs to minimize DLT-associated injuries, especially for small-sized Asian people [42]. With recently developed easily inserted rigid-angle bronchial blockers, the role of FOB has also changed to be effective on directing bronchial blockers to the target side but not ensuring satisfaction of surgical fields [43].

NIVATS has been transformed from awake VATS to monitored VATS [19] and can be performed under general anesthesia with supraglottic airway devices [44*]. There are more and more NIVATS performed for different VATS operations all over the world [17–19] in minor operations [44*] as well as in major operations [45], even for geriatric patients [46]. The key role of anesthesiologists on NIVATS is to provide a well controlled anesthesia combined with optimal regional blocks and optimal sedation. Optimal anesthetic depth is essential to maintain oxygenation, CO₂ elimination, and a smooth respiratory movement for safe surgery. Bispectral index (BIS) monitoring allows advantages to fit the fluctuation in anesthetic requirement with regional anesthesia.

**FIGURE 1.** The injection site of left and right thoracoscopic vagal nerve blocks. SVC, superior vena cava.
and surgical manipulation. It also reduces the recovery time after waking, mainly by reducing the administration of general anesthetics as well as the risk of adverse events [47].

The choices of anesthetic management during one lung ventilation

To achieve adequate oxygenation during OLV, the main issues are to maintain adequate CO2 and to reduce the ventilation/perfusion mismatch. In addition to avoiding the cardiovascular depression of general anesthesia, fluid therapy needs to be administered critically to avoid overload. The application of minimally invasive monitors based on ventilation-induced pulse pressure variations has its limitations in protective ventilation strategies [48] and low tidal volume ventilation during OLV [49]. In addition, ‘volume responsiveness’ should not be equated to volume deficiency. So, minimal discontinuation of oral hydration and early feeding should be encouraged [50]. In addition to maintaining CO2 during anesthesia, there are ways to reduce the ventilation/perfusion mismatch during OLV such as supplying oxygen to the nondependent lung, boosting the oxygen content in the shunt, and increasing oxygen reserve [51,52]. Respiratory management of ventilation during VATS, including during OLV, needs to be optimized to prevent not only intraoperative hypoxemia, but also postoperative acute lung injury.

CONCLUSION

As VATS operations become more popular and less invasive on various surgical procedures, precise anesthesia should be performed to improve short-term and long-term outcomes. By considering the patients and the surgical factors with clear recovery goals, anesthesiologists can perform a tailored anesthetic using a combination of general anesthetics and regional blocks with optimal airway management for different patients with less invasive monitors.

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Conflicts of interest

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- of special interest
- of outstanding interest

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