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REVIEW

# Nonintubated Anesthesia in Video-assisted Thoracoscopic Surgery

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**ABSTRACT**

The standard anesthesia method in intubated patients during thoracoscopic surgery is one-lung ventilation (OLV). Accumulated experience in video-assisted thoracoscopic surgery (VATS) has remarkably advanced minimally invasive techniques in thoracic surgeries, a progress that has prompted anesthesiologists to pursue different and alternative methods. The desire to avoid possible general anesthesia side effects, such as intubation-related airway trauma, mechanical ventilation-induced lung damage, residual neuromuscular blockade, and postoperative nausea and vomiting, has led to the introduction of nonintubated anesthesia techniques as an alternative anesthesia method in thoracic surgery. Nonintubated techniques are established to preserve the patient's spontaneous breathing during iatrogenic pneumothorax created by the surgeon during VATS and the atelectasis on the side to be operated on, providing sufficient surgical field of view and allowing successful completion of the surgery. Although this does not compete with continuing traditional thoracic anesthesia, in the future, nonintubated techniques will gain greater acceptance for VATS with appropriate patient selection and increased experience. This article reviews nonintubated anesthesia techniques used in VATS, including their advantages, disadvantages, appropriate patient selection, and complications.

**Keywords:** Anesthesia, non-intubated, video-assisted thoracoscopic surgery

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## Introduction

Traditionally, in thoracoscopic surgeries, one-lung ventilation (OLV) under general anesthesia has been a standard anesthesia method which provides a good safety profile and optimal conditions. The development of uni- and multiportal video-assisted minimally invasive techniques in thoracic surgery has become a springboard for the use of minimally invasive approaches in anesthesia techniques for thoracic surgery to the fore. Since thoracoscopic surgeries conducted under local, regional, or general anesthesia with the aid of subglottic devices in spontaneously breathing patients produce successful results, especially in selected patients, the routine use of these techniques has gained widespread interest.[1,2] Minor and major video-assisted thoracoscopic surgeries (VATS) can be safely performed under regional anesthesia or general anesthesia with subglottic devices in nonintubated spontaneously breathing patients.[3,4] The most important factor limiting their standardization in daily routine use is the risks involved in these anesthesia techniques, especially in major surgical procedures.

In thoracic surgery, non-intubating techniques present challenges and potential advantages for both the anesthetist and the surgeon. This article aimed to review nonintubated anesthesia techniques in VATS.

## Brief History

Until the adaptation of an inflatable cuff to an endotracheal tube described by Guedel et al.[5] in 1928, ether or chloroform anesthesia with mask was the most popular anesthesia technique. In the early 1900s, metal endotracheal tubes were designed and later rubber tubes were placed in the absence of laryngoscopy; however, these applications were not widely accepted because these required expertise and skill in blind placement and had to be performed under deep anesthesia. The advent of cuffed tubes was a turning point. Cuffed tubes protected the lungs from gastric aspiration and allowed controlled breathing through the suppression of spontaneous breathing with controlled hyperventilation, while concurrently achieving anesthesia levels deep enough to provide diaphragmatic immobility and apnea.

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In thoracic surgery, cuffed tubes prevented pneumothorax and suppressed the patient's spontaneous breathing; however, contamination from the diseased lung to the healthy lung and the inability to isolate a single lung remained important obstacles in these surgeries. In 1931, Gale et al.[6] described selective one-lung ventilation. In this technique, after patient intubation with a cuffed endotracheal tube, the cuff was advanced to the east of the bronchus of the intact lung and then inflated. Hence, while the healthy lung continued to ventilate, the other lung was deflated. The definition of modern laryngoscopes and the subsequent emergence of the Macintosh laryngoscope blades in 1943, still used today, provided convenience and accuracy in endotracheal tube placement.[7] With the definition of bronchial blocker by Archibald in 1935 and double-lumen tubes (DLT) by Carlens in 1949, great advances in thoracic anesthesia were achieved.[8,9]

Pompeo et al.[10] used epidural anesthesia for solitary pulmonary nodule resection in an awake patient in 2004. In 2007, Al-Abdullatief et al.[11] elucidated that some major surgeries and even lung resections were possible with minimal sedation in a nonintubated patient.

Presently, advancements in VATS allow the use of less invasive anesthesia techniques in these surgeries.

## Advantages of Nonintubated Techniques in Vats

Avoiding the risk of possible general anesthesia complications is one of the most significant advantages of nonintubating techniques. In patients undergoing mechanical ventilation under general anesthesia, the incidence of postoperative nausea, vomiting, pulmonary complications, and residual block has been reported as high.[12–14] Difficulty in DLT placement highlights bronchial blocker preference, especially in patients with difficult airways.[15] These difficulties can be overcome with the development and increasing use of flexible bronchoscopies; however, it has been reported that both DLTs and bronchial blockers may be associated with complications, such as sore throat and hoarseness, including very serious airway complications such as arytenoid dislocation and rupture.[16–19] The limited number of studies and meta-analyses comparing non-intubating techniques with traditional intubated OLV techniques in VATS has demonstrated that non-intubated techniques are associated with shorter hospital stays and shorter anesthesia and operation times and thus lower costs, including lesser incidence for hoarseness and sore throat. It has been also demonstrated that non-intubated techniques provide less nursing care and shorten postoperative fasting time.[20–29]

Existing literature has not elucidated whether nonintubating techniques are superior to traditional intubated methods in terms of survival, but it has been reported that they are less efficacious in inflammatory cytokine and lymphocyte responses and stress hormone levels, especially in the postoperative period.[30–32] In patients with comorbidities such as chronic obstructive pulmonary disease who may require intensive care in the postoperative period, nonintubated techniques should be considered as an alternative to conventional OLV.[33]

## Disadvantages of Nonintubated Techniques in Vats

Patients can maintain spontaneous breathing during nonintubated VATS. Hypoventilation develops with iatrogenic pneumothorax created during the procedure, which causes pulmonary perfusion decline. Functional residual capacity decreases and hypercapnia develops.[34]

Maintaining airway safety in an emergency is one of the most important problems in nonintubated patients, especially patients in the lateral decubitus position. Although VATS is a safe surgical procedure featuring small incisions, encountering major complications that are difficult to manage is possible.[35] One of the most important complications requiring urgent intervention is bleeding that originates from the pulmonary artery. Emergency thoracotomy may be required for uncontrolled bleeding. In this case, the patient should be intubated in the lateral decubitus position or quickly placed in the supine position. However, where intubation is expected to be difficult, attempting intubation in the lateral decubitus position may render the situation extremely challenging.[36]

Although some conditions such as obesity, emphysema, excessive movement of the diaphragm or mediastinum, or cough render non-intubation techniques difficult to employ, they may not be definite contraindications. Anesthesiologists who will use nonintubated techniques should have experience in this field and the ability to address problems that may occur intraoperatively.

## Patient Selection

More often, nonintubated techniques have been used in minor thoracic surgeries involving low-risk patients; however, advancements in technology and increased experience have demonstrated that these techniques are safe and applicable in more complicated procedures for selected and high-risk patients. Their good safety profile has been shown in surgeries such as pulmonary nodule resections,[4,10,37,38] pleural and pericardial effusions,[39] pneumothorax,[40–42] biopsies,[43–45] thymectomy,[46–48] volume reduction surgeries,[29,49] segmentectomy,[50,51] and lobectomy.[26,52,53]

In the past, patients with American Society of Anesthesiologists grades 1–2, body mass index of <30, cardiopulmonary

**Table 1.** Contraindications for nonintubated techniques

| |
|---|
| **General contraindications** |
| The patient declines |
| Patients with an ASA score ≥4 |
| Obesity |
| **Anesthesia-related contraindications** |
| Difficult airway expectation |
| Preoperative $FEV_1$ <30% |
| Situations where isolation is necessary to protect the contralateral lung from contamination (acute lung infection, tbc, etc.) |
| Presence of persistent cough or excessive secretions |
| Gastric reflux, risk of regurgitation |
| Presence of phrenic nerve paralysis on the opposite side |
| Severe cardiopulmonary dysfunction |
| Hemodynamic instability |
| Coagulopathy |
| Neurological disorders (risk of seizures, inability to cooperate), increased intracranial pressure |
| Presence of hypoxia ($PaO_2$ <60 mmHg) and/or hypercapnia ($PaCO_2$ >50 mmHg) during resting |
| Situations resulting in contraindications for regional anesthesia |
| **Surgical-related contraindications** |
| Large pleural adhesions |
| History of pulmonary resection or ipsilateral thoracic surgery |
| Pulmonary artery bleeding |

ASA: American Society of Anesthesiologists; $FEV_1$: Forced expiratory volume in one second; $PaO_2$: Arterial partial pressure of oxygen; $PaCO_2$: Partial carbon dioxide pressure

stability, and no expectation for difficult airway were preferred for nonintubated techniques.[10,28,54] At present, these techniques can be used safely in high-risk patients.[11,45,55–57] Thus far, despite the absence of a definite consensus, similar contraindications for nonintubated techniques are mentioned in the literature.[2,54,58,59] Table 1 summarizes the contraindications for nonintubated techniques. Moreover, in the table, recommendations are presented including what should be considered in the context of surgery and anesthesia team's experience and current patient risk factors.

## Anesthesia Management

### Preoperative Evaluation

During the preoperative evaluation, patients who are candidates for nonintubated techniques should be educated regarding the surgical procedure to be conducted and the anesthesia method to be employed. Particularly where regional anesthesia techniques are utilized, patients should be warned of the discomforts that may result from staying in the lateral position and the temporary respiratory problems that may occur during iatrogenic pneumothorax.

As premedications, antagonizable agents should be selected. Benzodiazepines may be an optimal option, especially since they can be antagonized with flumazenil to eliminate cooperation disorder and hypoventilation that may occur prior to and during the procedure. It has been reported that complementary techniques such as hypnosis decrease preoperative anxiety and present as an alternative premedication methods for respiratory depression prevention secondary to pharmacological agents.[60,61]

### Intraoperative Monitoring

Intraoperative monitoring may differ in accordance with the patient's existing comorbidities and surgical procedure. Routine monitoring should include an electrocardiogram (ECG) with a minimum of three channels, pulse oximetry, and noninvasive blood pressure monitoring (depending on the patient's condition, invasive blood pressure monitoring may be preferred). Central venous line and urinary catheter placement can be decided based on the patients' conditions, the selected anesthesia method, and surgical procedure.

When non-intubating techniques are employed, the lung exposed to atmospheric pressure is vulnerable to atelectasis due to the surgical opening of the parietal pleura during spontaneous breathing, and OLV begins. Hypoxia that may occur in this situation can usually be prevented by a face mask or nasally administered supplemental oxygen, unless the patient has an additional pulmonary comorbidity. Hypercapnia that may emerge during OLV should not be ignored.

Generally, this "persistent hypercapnia" is well tolerated by patients. However, end-tidal carbon dioxide ($EtCO_2$) assessment is vital for monitoring the patient's breathing pattern, rate, and hypercapnia that may occur during sedation and OLV. In the nonintubated patient, $EtCO_2$ can be monitored through specially designed nasal cannulas, an oxygen mask, or breathing circuit in patients via a subglottic device. Depth of anesthesia monitoring using the bispectral index (BIS) or patient state index (PSI) guides the appropriate depth of anesthesia to protect and maintain spontaneous breathing in the presence of sedation or subglottic device.

## Anesthesia Method Selection

Nonintubating techniques render the surgical procedure possible in the absence of endotracheal intubation. Thereafter, various methods are then employed. The surgical procedure can be performed while the patient is fully awake, under mild sedation, under deep sedation, or under general anesthesia. Regional anesthesia or subglottic device use are also possible alternatives for these surgical procedures.

### Regional anesthesia methods

Thoracic epidural anesthesia (TEA) is a well-known established technique among non-intubating techniques.[10] While reducing the myocardial oxygen demand, its advantages include blood flow improvement, left ventricular function enhancement, pulse rate and arrhythmia frequency reduction, ventilation and peak expiratory flow rate enhancement, pulmonary vascular resistance reduction, and diaphragmatic contractility improvement. However, disadvantages also exist, including hypotension, block failure, postdural headache, and, if opioids are used, respiratory depression and urinary retention.[11]

Placement of an epidural catheter between T1–T8 and preferably at T4–T5 level allows a T1–T8 block to provide an adequate anesthesia level while maintaining diaphragmatic respiration.[10] Short-acting or long-acting and low- or high-concentration local anesthetics may be preferred, considering the onset of the effect or surgery duration. However, since the patient may experience pain during intrathoracic manipulations, the use of low-concentration and very high-concentration local anesthetic solutions should be avoided, as this may cause a tidal volume decline due to motor block formation.[62] Maintenance can be provided as a bolus or continuous infusion. The use of infusion may be preferred as it can provide better hemodynamic stability and pain control compared to bolus administration.[59]

#### *Paravertebral block*

Paravertebral block (PVB), the regional anesthesia method frequently used as an alternative to TEA among nonintubated techniques, is associated with decreased hypotension and postoperative pulmonary complications and creates a unilateral block without bilateral sympathectomy. It may serve as an alternative to TEA in sepsis, coagulopathy, neurological disorders, and vertebral disorders where epidural catheter placement is difficult or contraindicated.

In the paravertebral space, fatty tissue, dorsal ramus, intercostal nerves, blood vessels, hemiazygos vein, and sympathetic nerve trunks are present. Since the intrathoracic fascia does not encompass this space, the nerves here are more sensitive to the effects of local anesthetics.[63] Although large-scale randomized studies evaluating PVB efficacy in nonintubated thoracic surgeries are warranted, a limited number of studies with small sample sizes report that PVBs added to nonintubated techniques using subglottic devices can provide effective and safe anesthesia.[64–67]

#### *Intercostal nerve block*

Intercostal nerve blocks (ICB) are a simple and safe method of anesthesia and can be employed intraoperatively under direct vision. ICB is reported to offer advantages in terms of pain control and analgesic consumption in nonintubated VATS and can be used in major surgeries, especially with developments in uni-portal VATS techniques.[52,68,69]

#### *Serratus anterior plane block*

In serratus anterior plane blocks (SAPB) a local anesthetic is injected in the plane between the serratus anterior and latissimus dorsi and between the chest wall and the serratus anterior muscles and are generally effective in T2–T9 dermatomes. Although a randomized controlled study is not available in the literature, a few case reports support the view that SAPB may be a suitable alternative in minor nonintubated VATS procedures.[70–73]

#### *Erector spina plane block*

While studies exist demonstrating the postoperative analgesic efficacy of erector spina plane block (ESPB) in thoracic surgeries,[74] few case reports exist mentioning ESPB efficacy in nonintubated VATS.[75,76]

### Subglottic devices

Currently, anesthesia management, in which spontaneous breathing is preserved under the subglottic device such as laryngeal mask (LMA) and with the addition of regional anesthesia, is becoming very popular among non-intubating methods.[4] The requirement for sedation, especially due to anxiety, can sometimes suppress the awake patient's spontaneous breathing. Such cases benefit from deeper sedation that afford spontaneous breathing and the use of subraglottic airway devices for airway protection, particularly in combination with regional techniques.

In 2019, the consensus was reached in that the combination of intravenous anesthesia after LMA placement, ICB, superficial local anesthesia to the visceral pleura, and vagus nerve block was the optimal approach for nonintubated VATS.[54] The procedure is initiated with induction using propofol and fentanyl/remifentanil, followed by LMA placement once the BIS value is <60 or the PSI value is <50. To maintain anesthesia, propofol, remifentanil, and/or dexmedetomidine infusions are used. Dexmedetomidine infusion may be terminated during pleural cavity closure, and propofol and remifentanil infusions may be terminated during skin closure. With LMA, spontaneous breathing is allowed and oxygen is administered at 50% concentration with a flow rate of 2–3 L/min. The oxygen concentration should be titrated according to the patient's tolerance. If necessary, synchronized intermittent mechanical ventilation (SIMV) modes are preferred both for allowing spontaneous breathing and maintaining ventilation in the event of possible respiratory depression. Decreases in $SpO_2$ or increases in $EtCO_2$ can be solved through SIMV mode adjustments or via manual ventilation. Although it varies by patient, it is recommended that the $SpO_2$ value is >90 and the $PaCO_2$ value is <55–60 mmHg. This method also supplies a smoother intubation without the need for both preoxygenation and additional anesthetic agents except for a muscle relaxant during a possible need for intubation. Figure 1 demonstrate the standard anesthesia monitorization and adequacy of surgical view in a patient undergoing nonintubated VATS using LMA.

## Complications

### Hypoxia

In the event of surgeon-induced iatrogenic pneumothorax during non-intubating techniques, hypoxia may occur. However, this resulting hypoxia is minimal and a nasal cannula or mask with oxygen support can usually be employed to address this. If a subglottic device is used under general anesthesia that affords spontaneous breathing, manual ventilation in hypoxia situations or mechanical ventilation with low tidal volume in SIMV mode can be utilized. If the lung on the operated side has completely collapsed, airway resistance will be higher on the surgical side. During low tidal volume ventilation, most of the ventilated air will be diverted to the contralateral lung owing to this resistance. For this reason, the surgical side will swell only negligibly, and this will minimally affect the surgery.

### Hypercarbia (hypercapnia)

Hypercapnia usually occurs due to hypoventilation and may be exacerbated by the effects of sedation or general anesthetic drugs. Generally, $EtCO_2$ values may be higher during nonintubation techniques compared to general anesthesia. Thus, caution should be exercised in patients with high pulmonary or intracranial pressure or arrhythmias. An accepted ventilation technique during thoracic surgery is permissive hypercapnia and is generally well tolerated and improves rapidly after the surgery.[77,78] In cases where $PaCO_2$ exceeds 60 mmHg, it can be intervened through manual ventilation or SIMV mode. Adjustment of the infusion speeds of the anesthetic agents is another option.

### Cough

During non-intubating techniques, cough is the most common problem encountered. Sudden onset of cough will cause both the patient and the lungs to mobilize and render it difficult for the surgeon to complete the surgery. Insufficient blockade or sedation can cause hyperactivity and cough, and despite appropriate blockade and sedation, the cough reflex can be stimulated through manipulation of the bronchi. The cough reflex is primarily controlled by the vagus nerve. If awake thoracic surgery is conducted with epidural anesthesia, vagal tone predominance after sympathetic blockade following epidural anesthesia can theoretically increase bronchial tone and reactivity.

Different methods can induce cough reflex suppression; however, none are absolutely reliable.[79] Sedation with remifentanil may aid in suppressing the cough reflex but should be used with caution, as high doses can cause apnea and respiratory depression.[68] Intravenous lidocaine infusion may be an option, but toxicity is possible. Lidocaine nebulization of 2%–4% administered 30 min prior to surgery may be beneficial for intraoperative cough.[80] Nerve blockade may be introduced through the application of a local anesthetic in the Nervus vagus vicinity under direct thoracoscopic vision.[79,81] Despite all these possible applications, in some patients, the cough reflex may not be suppressed.

### Intraoperative Intubation Requirement

In the literature, the rate of conversion from nonintubated technique to intubation varies between 2% and 11% for thoracic surgeries.[82] The most important factor for conversion to intubation is mediastinal mobility secondary to respiration, as it will lead to injuries that may result in surgical complications. Undesirable bleeding during non-intubating techniques is usually caused by an unexpected respiratory effort, cough reflex, or an insufficiently collapsed lung that obscures the surgeon's vision. Intubation reduces surgical stress by controlling breathing and protecting the contralateral lung.

Another important factor for intubation is the prolonged hypoxia or hypercapnia. Although there are no definitive criteria, intubation should be considered when oxygen saturation is 85% or less for more than 5 min or if $PaO_2$ is <60

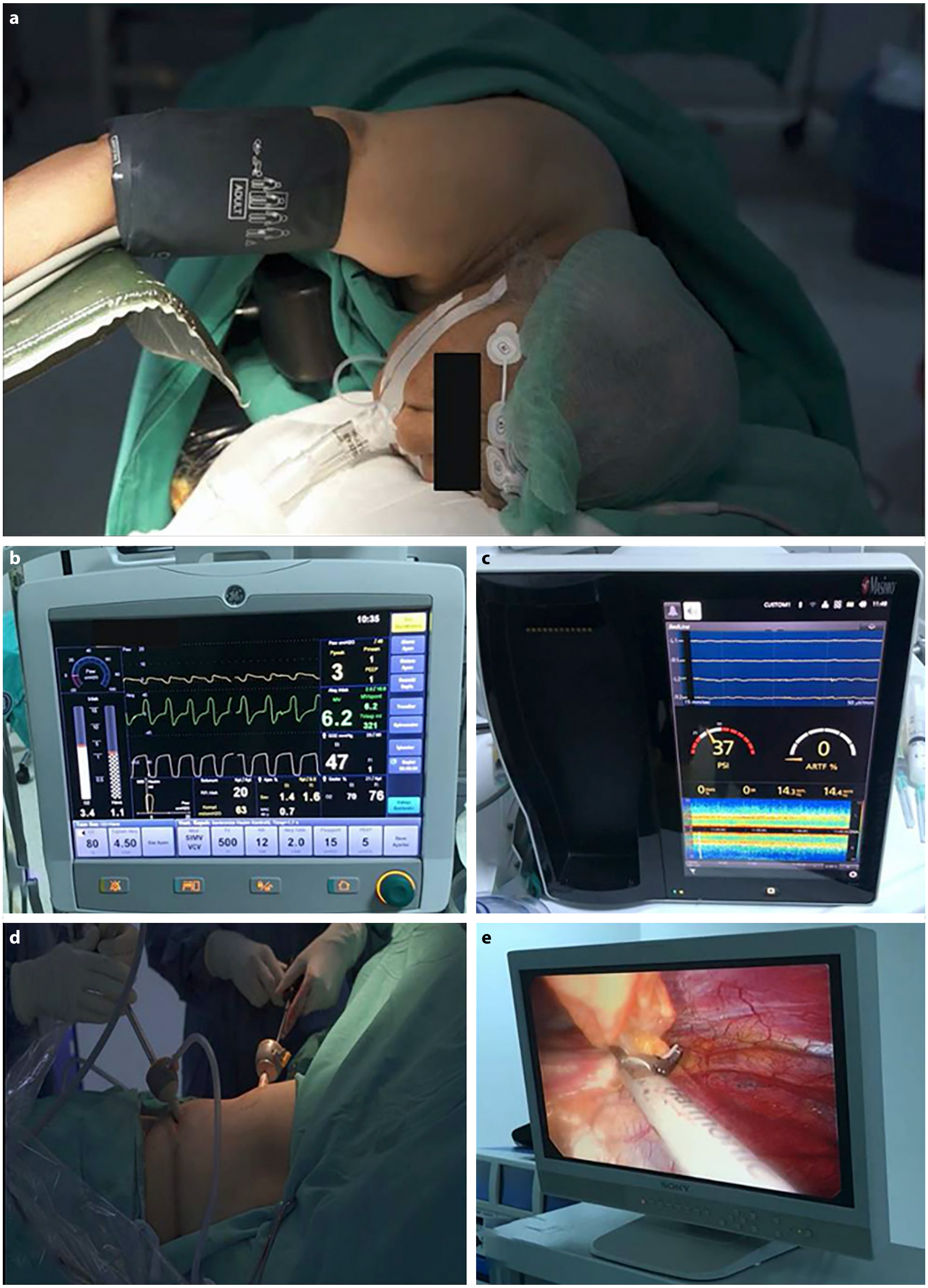


**Figure 1. (a)** Nonintubated video assisted thoracoscopic surgery under general anesthesia with laryngeal mask in a patient placed in the lateral decubitus position. **(b)** Spontaneous ventilation monitoring during one-lung ventilation. Patient is spontaneously breathing with tidal volumes of about 320 ml, a respiratory rate of 20 and minute ventilation of 6.2 L/min. **(c)** Patient state index (PSI) value is between 25 and 50. **(d)** The surgeon and the camera assistant are in the appropriate position for the surgery. **(e)** Sufficient surgical field of view is provided for the operation.

mmHg or $PaCO_2$ is >80 mmHg. Additionally, arrhythmias and hemodynamic changes accompanying these values may also affect the decision for intubation.[54]

For the conversion to intubation, it is essential that the surgeon and anesthesiologist evaluate the patient together to arrive at a decision. Patients may be in the lateral decubitus position during surgery and emergent intubation may need to be performed in this position. Some authors suggest that intubation can be performed in the lateral decubitus position, while others suggest that the patient be immediately covered with sterile drapes and intubated while in the supine position.[58] Here, the joint decision and the anesthesia and surgical team experience should direct the course of action. The combination of single-lumen endotracheal tube and bronchial blocker for intubation in the lateral decubitus position may be a more feasible option than DLTs.[68,77]

## Conclusion

In thoracic surgery, nonintubating techniques are innovative procedures that can be conducted and managed safely and successfully by experienced anesthesia teams. Although their long-term results have not been clearly elucidated yet, these techniques should be considered as an alternative to thoracoscopic surgery under OLV, especially in patients with a high intubation risk. The challenges encountered in the initial application of this technique can be overcome through sufficient training and experience. Video-assisted thoracic surgeries in nonintubated patients are increasingly popular. Nevertheless, more studies are warranted to determine which patient groups will benefit these techniques and to investigate their effects on morbidity and mortality.

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