Non-Intubated Video-Assisted Thoracic Surgery

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Abstract

Non-intubated VATS (NIVATS) is a surgical method that is performed under the patient's spontaneous respiration without tracheal intubation. NIVATS reduces adverse effects such as ventilator-induced lung injury from mechanical ventilation and induces a faster recovery. In order to safely perform NIVATS, appropriate patient selection, assessment, and a multidisciplinary team approach are required.

19.1 Introduction

Video-assisted thoracoscopic surgery (VATS) has been evolved by technical innovations and instrumental developments. Thus, most of thoracic surgeries were initiated under thoracoscopic settings, even requiring complex procedures. Moreover, reduced port surgery has been demonstrating efficacy with acceptable outcomes, compared to multi-port VATS or thoracotomy. In accordance with minimally invasive trends, non-intubated thoracoscopic surgeries has also been increasingly employed with VATS experiences. Non-intubated VATS (NIVATS) which comprises maintenance of spontaneous respiration without tracheal intubation for one-lung ventilation has revealed feasibility and benefits of less invasiveness [1, 2]. Expected rewards are explained by removal of adverse effects from mechanical ventilation, which includes intubation injury or lung damages. Moreover, adequate loco-regional block has been offered grants, avoiding potential harmful effects of neuromuscular blockade, that rapid recovery is observed with reduced usage of sedative and analgesics [3]. Shortened induction and recovery time enables reduced total operation time that urinary catheter and central venous catheter can be omitted. Finally, fast postoperative recovery facilitates patients discharge earlier with better quality of life, compared to intubated VATS [4]. Routine drainage tubes also can be deleted for entirely tubeless VATS settings to decrease postoperative pain [5]. To initiate and set up the NIVATS protocol, proper indications and experienced team approach are mandatory. With flexibility, NIVATS should be changed to intubation settings whenever surgeons or anesthesiologist demands to keep on safety operations. Understanding basic steps and strategy is essential to recognize NIVATS, as a promising alternative for conventional intubated VATS.

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K. Kim et al. (eds.), *Techniques in Minimally Invasive Thoracic Surgery*,
https://doi.org/10.1007/978-981-19-2472-9_19

19.2 Pathophysiological Changes During NIVATS

In the spontaneous respiration cycle, the lung expands due to the negative pressure in the closed chest cavity during inspiration. During NIVATS, the concept is to allow the creation of a "surgical pneumothorax" as the surgeon opens the chest [6]. Once thorax cavity is opened with surgical incision, the negative pressure is lost. Therefore, the lung cannot expand during spontaneous breathing, resulting in lung collapse. Further lung collapse is promoted by the external atmospheric pressure. This can provide excellent lung isolation without the need for positive pressure ventilation on the dependent lung. However, respiratory and hemodynamic derangement may also occur due to two major physiologic changes after surgical pneumothorax. First, both lungs are not completely separated during NIVATS. Therefore, part of the air inside the non-operated lung enters into the surgical lung during expiration, causing CO_2 rebreathing. Converse flow occurs during inspiration, and it contributes to lung collapse of surgical site. This is called "paradoxical respiration," which commonly makes hypoxia and hypercapnia during NIVATS [7]. Second, mediastinal structure swings according to the respiratory cycle and moves downward by gravity, which may cause hemodynamic instability and decrease the dependent lung to offer efficient tidal volume.

Oxygenation in NIVATS is well maintained in properly selected patients because *V*/*Q* mismatch is reduced with hypoxic pulmonary vasoconstriction, the lateral position, and relatively preserved FRC and the diaphragm function. Hypoxia may occur in patients with impaired pulmonary function, but most of them improve with increasing oxygen flow. Hypercapnia is a more common problem because CO_2 rebreathing occurs during paradoxical respiration and respiratory depression is caused by the use of sedative and opioid. However, the concept of permissive hypercapnia is applied to one-lung ventilation, and it is considered safe to reach 70 mmHg $PaCO_2$. Breathing increases with postoperative awakening, and CO_2 concentration is restored to normal range.

19.3 Challenging Indications

Patients having poor pulmonary functions have been selectively decided for VATS under spontaneous ventilation to avoid ventilator-induced lung injury [8, 9]. With evolving NIVATS procedures, variety of thoracic procedures have been reported under non-intubated settings with modifying VATS approaches, simple procedures for pleural disease, hyperhidrosis, pneumothorax, pulmonary nodules, and mediastinal tumors [10–12]. Nowadays, VATS has become the standard surgical modality for early lung cancers. Oncologic advantages after lung cancer surgery under NIVATS have also been endorsed [13, 14]. Moreover, technically demanding cases of tracheal resection and sleeve lobectomy were also reported [15, 16]. However, any unstable conditions of patient intolerance may happen by surgical or anesthetic events with inexperience. Above all, surgical team should recognize the physiology of non-intubated anesthesia. Proper selection is emphasized of patients with ECOG performance status less than 1, anesthesiologist standard (ASA) grade less than II, and low BMI less than 25 kg/m^2 [17]. Patients with expected difficult airway are absolutely contraindicated because of the high incidence of hypoxemia and the possibility of intraoperative intubation failure. Previous history of pleural infection or thoracic surgery having possibility of dense adhesions might be relatively contraindicated because it is difficult to perform intraoperative intercostal block. Patients with significant cardiopulmonary dysfunction or neurologic deficit also will be excluded due to possibility of hemodynamic collapse with severe hypercarbia. In planning difficult thoracic procedures, cooperation with anesthesiologist under cautious monitoring is more essential, and underlying morbidities should be discussed with consultants preoperatively. With experienced team settings, tubeless, uniportal VATS has been introduced in lung cancer surgery [18, 19].

19.4 Anesthetic Perspectives

General evaluation studies are compatible with traditional VATS under one-lung ventilation. Pulmonary function test, echocardiography, and arterial blood gas analysis on resting status are listed for checkup. Especially, anticipated difficult airway, obesity, and expected extensive pleural adhesions due to history of severe infectious disease or prior thoracic surgery are thoroughly assessed for proper patient selection [20].

In addition to standard monitoring (included non-invasive blood pressure, SpO_2, and ECG), end-tidal CO_2 ($ETCO_2$) and invasive arterial blood pressure monitoring are in place to monitor real-time respiration and hemodynamic changes. Bispectral index (BIS) is highly recommended for evaluation of sedation level and advanced judgement of anesthetic depth, aiming for BIS over 40–60. The level of sedation should be selected according to the patient's condition and type of surgery. Simple procedures (i.e., lung biopsy or pleurodesis) in patients with poor pulmonary function may be performed under full awake state with neuraxial block. Moderate or deep sedation is necessary for the patient's comfort, especially in the prolonged procedure like lobectomy, which makes it intolerable to maintain same position for several hours. Omitting endotracheal intubation, total intravenous anesthesia is introduced for sedation without use of muscle relaxant under loco-regional block with modifications [21]. Continuous infusion of propofol with/without remifentanil using target-controlled infusion (TCI) would mostly create a balanced status with sufficient sedation and ventilatory/hemodynamic stability. Dexmedetomidine can be used as a good alternative or adjuvant for continuous infusion. In the case of sedation, we should monitor the level of consciousness and the pattern of breathing with BIS and $ETCO_2$, respectively. The goal of ventilation management is to maintain a smooth and non-effort respiratory pattern with respiratory rate over 12–20 times/minute for providing a satisfactory surgical field. Meticulous modification of infusion rate or adjuvant administration of fentanyl, midazolam, and ketamine is required to maintain proper range of BIS and breathing [22]. Various loco-regional anesthesia is used for analgesia covering chest cage and parietal pleura. Thoracic epidural block, paravertebral nerve block, and thoracoscopic intercostal nerve blocks are useful in intrapleural analgesia. Vagus nerve block can minimize irritating sensation from visceral pleura and prevent cough reflex during surgical manipulation.

Oxygenation could be facilitated with O_2 supplement by nasal cannula or by facial mask (Fig. 19.1). In patients with poor pulmonary function requiring deep sedation, supraglottic

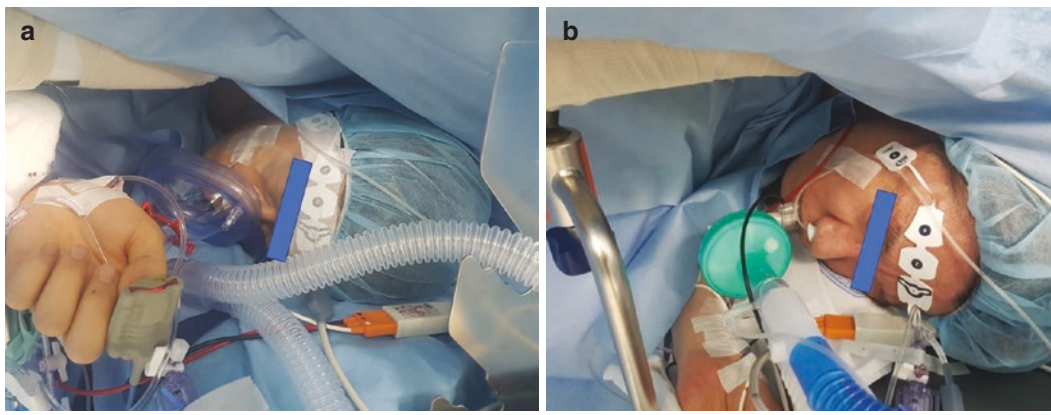

Fig. 19.1 Oxygenation with facial mask (**a**) or laryngeal mask (**b**)

device such as laryngeal mask airway (LMA) can be useful. If SpO_2 drops to below 90% or $PaCO_2$ increases over 60 mmHg, infusion rates of anesthetic agents are modified, and temporary mechanical or assisted ventilation is applied. When unstable condition is not controlled, conversion to endotracheal intubation should be assessed. Position change for semi-lateral decubitus or supine position is required to assess adequate airway management. Single lumen tube with bronchial blocker or double-lumen endotracheal tube can be replaced under guidance of video-laryngoscope and/or fiberoptic bronchoscope. Intubation related oral, tracheal, and tooth injuries might be occurring that should be announced preoperatively.

19.5 Surgical Perspectives

Thoracoscopic procedures are usually equivocal to conventional intubated VATS according to surgeon's preferences. Under lateral decubitus positioning with sterilization, transparent draping between surgical field and anesthesiologist offers benefits for cooperative monitoring. Ultrasound-guided paravertebral (or epidural) block is made preoperatively. Preemptive anesthetic local injection is given in placing thoracoscopic working wound with ports placement, avoiding compression of the thoracic cage (Fig. 19.2a). Entering the thoracic cavity, surgical pneumothorax was identified, and intercostal (T2–T9 levels) nerve block is introduced under lung collapse if preoperative neuraxial block is not performed (Fig. 19.2b). Vagal nerve block is applied over the mediastinal pleural region around the trachea above the azygos vein for right sided, and below the aortic arch for the left sided to prevent cough reflex (Fig. 19.2c, d). Local anesthetic spray on pharyngeal cavity, inhaled lidocaine or satellite ganglion block also may be applied. Irritations to intrathoracic structures increase the risk of coughing reflex causing mediastinal or diaphragm bulging. Thus, gentle manipulation during pulling or retraction of the lung, bronchial tree, and hilum is essential for surgeons and assistants. During procedures, additional vagal block or regional anesthesia over pleural surfaces might be required if the surgical field is not suitable due to persistent coughing or excessive lung movement from deep breathing. After completing the thoracic procedure, the anesthesiologist performs manual positive pressure ventilation with mask fitting to achieve both lung inflation, allowing an air leak test or two lung ventilation. Air vent is more attained using temporary negative pressure maneuver through the drainage tube or catheter for lung recruitment. During sealing the VATS wounds, the chest tube can be placed with continuous negative pressure or can be removed after tightening of last suturing immediately for chest tubeless VATS. Postoperatively, NIVATS preserves physiologic cardiopulmonary function and neurologic status that stable fast recovery can be realized with less common nausea or vomiting symptoms. Atelectasis or effusion may occur due to mucus plugging in bronchial airways and incomplete lung expansion. Encouraging deep breathing and cough is mandatory as alike as conventional VATS for respiratory toileting.

In cases requiring irritating manipulation causing refractory cough reflex, decision should be made whether to continue NIVATS with sedation control, or to convert into endotracheal intubation. If abrupt inflation of the lung or sudden mediastinal bulging continues, withdrawals of thoracoscopic instruments from the surgical fields be promptly executed to avoid intrathoracic organ or intercostal injury. Minor bleedings or injuries can be managed with suturing, coagulation or sealing materials as preferred thoracoscopic techniques. Conversion is required for treating invasive tumor characteristics or severe pleura and hilar adhesions with anthracosis. Smooth conversion is properly carried out under hemostatic compression, and situations of major bleeding may need emergent thoracotomy. This also have to be settled in respiratory distress with intractable arrhythmia despite of modifying ventilation setting [23]. Continuing NIVATS should be reassessed for time-consuming unsafe procedures, not to make catastrophic situa-

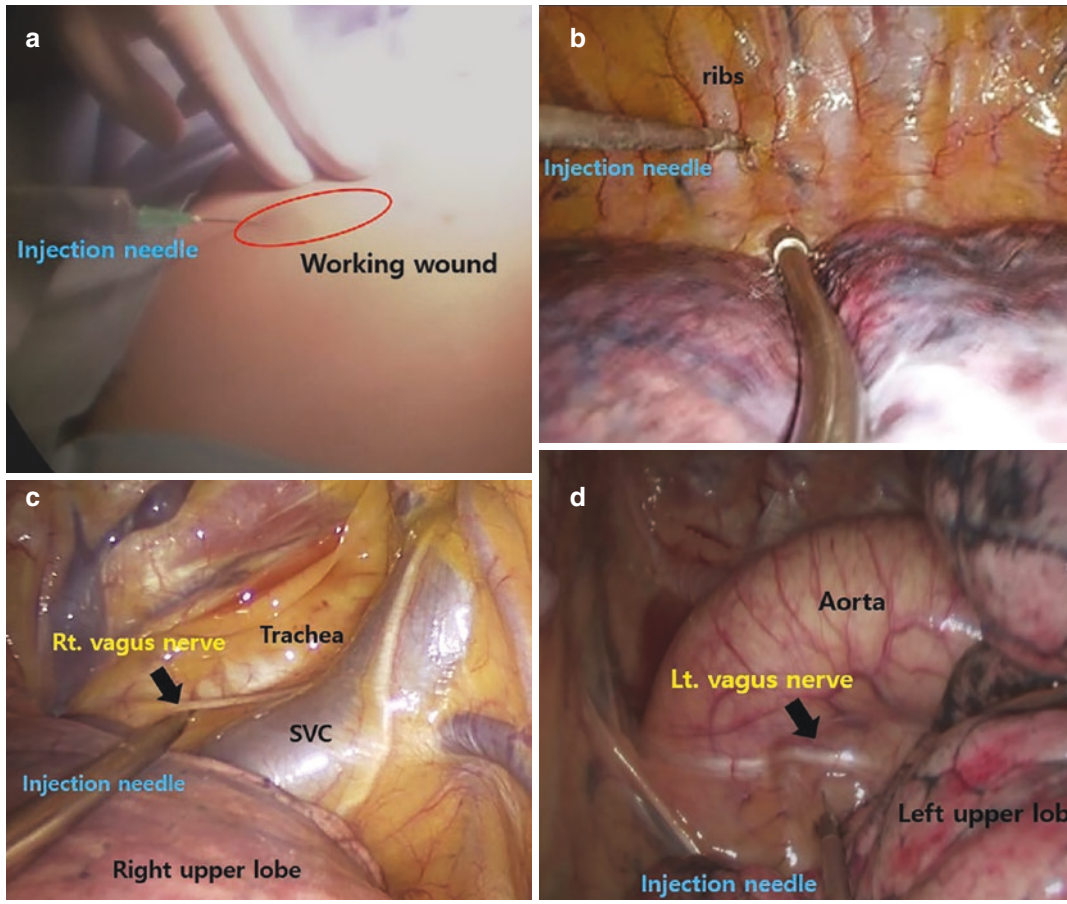

Fig. 19.2 Preemptive anesthetic local injection (**a**) and intercostal nerve block (**b**) and right sided (**c**) and left sided (**d**) vagal block during uniportal approach

tions of major vessel bleeding and to complete complex procedures [24]. Developing NIVATS techniques with proper patient selections have been demonstrated as effectively applicable substitutes or modification to conventional VATS that promisingly suggested [25]. Focus in performing NIVATS is continuous interactions with the anesthesiologist, as dedicated team surgery. Educational simulation program under protocol is essential to avoid uneventful situations, even for simple procedures by proper selection criteria. Resonable consensus protocol is still expected to reveal the exact role of NIVATS on morbidities and oncological issues with extended indications for thoracic diseases.

19.6 Conclusion

NIVATS has revealed effectiveness as alternative, less invasive procedure in treating variable thoracic diseases. Reduced postoperative complication and faster recovery have proved its feasibility and efficacy compared to conventional intubated VATS. To set up and conduct NIVATS safely, dedicated team approach and patient-specific assessment are important in both thoracic surgery and anesthetic fields.

Conflict of Interest No potential conflict of interest relevant to this article was reported.

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