

The non-intubated anesthesia for airway surgery

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Abstract: Surgical treatment for lung cancer including airway resection following reconstruction is typically performed under general anesthesia with single-lung ventilation because it is necessary to maintain a sufficient working space and to adjust the airway pressure for the leak test. However, non-intubated thoracic surgery has been gradually developed in recent years for thoracoscopic surgery, due to its lower rate of postoperative complications, shorter hospitalization duration, and lower invasiveness than the usual single-lung anesthesia. Initially, only minor thoracoscopic surgery, including wedge resection for pneumothorax and the diagnosis of solitary pulmonary nodules, was performed under waking anesthesia. However, major thoracoscopic surgery, including segmentectomy and lobectomy, has also been performed under these conditions in some institutions due to its advantages with respect to the postoperative recovery and in-operating room time. In addition, non-intubated thoracic surgery has been performed for tracheal resection followed by reconstruction to fully explore the advantages of this surgical modality. In this article, the merits and demerits of non-intubated thoracoscopic surgery and the postoperative complications, perioperative problems and optimum selection criteria for patients for thoracic surgery (mainly airway surgery) are discussed.

Keywords: Non-intubated; thoracoscopic surgery; airway surgery; feasibility; safety

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Introduction

Thoracoscopic surgery has become a standard surgical approach for a variety of thoracic diseases. This approach is regarded as minimally invasive surgery and is performed under tracheal intubation with double lumen tube or bronchial blocker to achieve single-lung ventilation under general anesthesia. Recently, thoracoscopic surgery without tracheal intubation under local and regional anesthesia has been reported to be safe and less invasive for lung, pleura and mediastinum operations than intubated methods. The operative procedures suitable for non-intubated anesthesia have been expanding to include tracheal resection followed by reconstruction. We herein report the feasibility and safety of non-intubated airway surgery.

History of non-intubated anesthesia

Non-intubated thoracoscopic surgery under local and regional anesthesia is an alternative method for treating patients in whom general anesthesia is inappropriate with a poor pulmonary reserve. In such cases, it is difficult to maintain the cardio-pulmonary function with single-lung intubation under general anesthesia.

A double-lumen tube is widely used for single-lung ventilation during thoracic surgery to provide a quiet surgical working space with pulmonary collapse. Before the development of this anesthesia technique, Buckingham *et al.* (1) first reported the use of thoracic epidural analgesia (TEA) to perform awake thoracic procedures in 1950. However, performing awake thoracic surgery is

more technically challenging than the same procedures under general anesthesia, so thoracic surgery is typically performed under general anesthesia with single-lung intubation. In the 1990s, thoroscopic surgery replaced thoracotomy because of the lower invasiveness and earlier post-operative recovery. With this background, the appropriateness of local and regional anesthesia for thoracic surgery is being investigated once again. Indeed, improvement has been seen in the efficacy of local and regional anesthesia for performing waking surgery. Given that general anesthesia with a double lumen endo-tracheal tube may lead to complications, including accidental airway trauma, hyperinflation of the dependent lung and unilateral ventilator-induced lung injury, alternative methods of achieving anesthesia are awaited.

Techniques of non-intubated anesthesia

Non-intubated thoracic surgery is more technically challenging than thoracic surgery under general anesthesia, but it helps avoid the complications associated with intubation and mechanical ventilation injury (2,3). Several methods combining local and regional anesthesia techniques have been proposed, including local wound infiltration, serratus anterior plane block, selective intercostal nerve blockade, thoracic paravertebral blockade, TEA and lidocaine administration in the pleural space (4). Considering the need for post-operative analgesia, a catheter placement is an even more useful method.

As premedication before anesthesia, intramuscular midazolam and atropine are used for sedation and secretion reduction. During the operation, continuous intravenous sedation and analgesia are needed to relieve patients' anxiety, especially for more invasive and time-consuming procedures. Remifentanyl administered as total intravenous anesthesia is useful because of the short context-sensitive half-time of 3 min (4).

With regard to the complications associated with local and regional anesthesia, physicians should be alert for potential lidocaine addiction. Complications associated with epidural anesthesia include dural puncture, neurological injury and paraplegia. The planning of the local and regional anesthesia before each procedure is very important. The procedure and incision site, the expected operation time and the condition of the patient, including their mental situation, should be considered. A continued infusion of sedation and analgesia drugs is administered in order to achieve adequate sedation under spontaneous respiration

and avoid excessive patient hyper-reactivity, apnea or carbon dioxide retention.

Advances in surgical techniques, anesthesia techniques and sedation drugs have enabled thoracic surgery to be performed under non-intubated anesthesia conditions. While this is challenging for anesthesiologists and surgeons, it allows patients to undergo less invasive procedures.

Non-intubated minor thoroscopic surgery

Since the late 1990s, non-intubated thoroscopic surgery has been performed as a less invasive procedure for pneumothorax and small nodule resection. Nezu *et al.* (5) reported thoroscopic wedge resection of blebs with a stapling device under local anesthesia with sedation in 34 consecutive patients with spontaneous pneumothorax. They compared the non-intubated patients' clinical course with that of 38 patients who underwent the procedure under general anesthesia during the same period and concluded that thoroscopic wedge resection under local anesthesia did not induce an increase in the rates of any perioperative complications and additionally resulted in a shorter hospital stay. In the same period, Mukaida *et al.* (6) reported the usefulness of TEA for the thoracic management of secondary pneumothorax in high-risk patients contraindicated for general anesthesia. Noda *et al.* (7) reported the benefits of awake thoroscopic surgery in patients with secondary spontaneous pneumothorax using propensity score matching and compared the surgical results between TEA and general anesthesia. They found that the duration of the operating room stay was shorter in the non-intubated group than in the intubated group ($P=0.006$), and the incidence of postoperative respiratory complications, including pneumonia and acute respiratory distress syndrome, was lower in the non-intubated group than in the intubated group ($P=0.02$).

Pompeo *et al.* reported on the outcomes of non-intubated surgery for wedge resection of solitary pulmonary nodules, pneumothorax and non-resectional lung volume reduction (8-10). They also performed a randomized study of thoroscopic surgery with talc pleurodesis using TEA or general anesthesia (11). They emphasize the safety and feasibility of non-intubated thoroscopic surgery. In each analysis, they concluded that non-intubated thoroscopic surgery reduced the hospital stay, morbidity rate and procedure-related costs relative to the procedures performed with general anesthesia.

Regarding other reports of non-intubated thoroscopic

surgery, Mineo *et al.* (12) performed a case-matched study of pleurodesis for malignant pleural effusion comparing the outcomes between non-intubated and intubated thoracoscopic surgery. Liu *et al.* (13) performed a randomized control trial in 354 patients (167 patients in the non-intubated group and 180 in the control group) comparing the outcomes between non-intubated and intubated thoracoscopic surgery. The surgical procedures included bullae resection, pulmonary wedge resection and lobectomy. The non-intubated group had markedly lower rates of postoperative mortality (6.7% *vs.* 16.7%, $P=0.004$) and respiratory complications (4.2% *vs.* 10.0%, $P=0.039$) than the intubated group. They emphasized the merits of non-intubated anesthesia as a shorter hospital stay and lower cost.

Non-intubated major thoracoscopic surgery

Thoracoscopic surgery has expanded globally as a minimally invasive alternative to thoracotomy because of its low invasiveness and painless aspect following surgery (14). This technique has also been applied in lobectomy for early-stage lung cancer. To further improve these surgical procedures, Chen *et al.* (15,16) reported on the outcomes of lobectomy for lung cancer patients performed as non-intubated thoracoscopic surgery. Non-intubated anesthesia for major thoracoscopic surgery is limited to the non-problem cardiopulmonary function and pursue the minimum invasive surgery. As such, non-intubated anesthesia cannot be adapted for major thoracoscopic surgery in the same way as for minor thoracoscopic surgery. Chen *et al.* evaluated the feasibility and safety of non-intubated thoracoscopic lobectomy using TEA, intrathoracic vagal blockade and sedation. They found that the patients who underwent non-intubated surgery had lower rates of sore throat ($P=0.002$) and earlier resumption of oral intake ($P<0.001$) than those who were intubated. Patients undergoing non-intubated surgery also tended to have better non-complication rates and shorter postoperative hospital stays than those who were intubated (15). They additionally reported the outcomes of 36 consecutive elderly patients with stage I and II non-small cell lung cancer who underwent thoracoscopic lobectomy under non-intubated anesthesia, confirming the safety and feasibility of non-intubated anesthesia even in elderly patients (16).

However, several issues remain to be resolved regarding the use of non-intubated TEA for major pulmonary resection. Careful patient selection is needed in order to avoid complications of hypoxia and hypercapnia. To avoid perioperative respiratory failure, non-intubated

TEA is usually performed only in certain patients, namely those who can tolerate an estimated operation time of up to 3 hours and have ASA grade I-II, body mass index <25 , and a good cardiopulmonary function (17). Chen *et al.* (15) reported that 3 patients (out of 30) in the non-intubated group required conversion to intubated single-lung ventilation because of persistent hypoxemia, poor pain-control and bleeding. Non-intubated thoracoscopic segmentectomy for lung tumors has also been reported, and the rapid recovery after surgery and reduced anesthesia costs have been confirmed (18-20).

Non-intubated surgery for the upper trachea

Especially for upper airway surgery, tracheal surgery is usually performed under general anesthesia, with the cessation of spontaneous breathing, and cross-field intubation with intermittent ventilation is the most common method for resection and reconstruction of the trachea. Macchiarini *et al.* (21) reported the feasibility of upper airway surgery under awake anesthesia and spontaneous respiration. They managed patients with upper tracheal stenosis through cervical epidural anesthesia and conscious sedation with atomized local anesthesia. They experienced only one case who required a nasotracheal tube for 36 h after the surgical procedure. They treated the patients with idiopathic or postintubation upper tracheal stenosis and concluded that awake and tubeless upper airway surgery is feasible and safe and has a high level of patient satisfaction. They emphasized that non-intubated airway surgery not only avoids general anesthesia with tracheal intubation and mechanical ventilation but also provides an ideal surgical field without any intraoperative tubing systems. Furthermore, the maintenance of spontaneous breathing makes airway reconstruction more anatomical and enables checking the movement of vocal cords during the surgical procedure, with an earlier recovery. Liu *et al.* (22) reported a case of non-intubated tracheal resection and reconstruction for the treatment of a mass in the upper trachea via neck incision. The resection of adenoid cystic carcinoma (ACC) was done under intravenous anesthesia plus cervical plexus local anesthesia using a laryngeal mask. The patient remained awake during the surgery, and the depth of anesthesia was measured using the electroencephalogram bispectral index. They emphasized the following merits of non-intubated tracheal resection: the patient retained spontaneous breathing, endo-tracheal intubation was not necessary and the time of tracheal suture was shorter than

in cases requiring operative field intubation.

For upper tracheal surgical procedures under local and regional anesthesia, switching to general anesthesia and intubation in the operating field is quite easy if preparations have been made in advance, as the operation field for the upper trachea is closer and wider than with an intrathoracic approach for the lower trachea.

Non-intubated surgery for the lower trachea

Bronchial sleeve resection has emerged as an effective but complicated thoracoscopic approach to avoid pneumonectomy and maintain the left lung function in order to reduce the procedure-related mortality and morbidity rates. Shao *et al.* (17) reported a case of complete endoscopic bronchial sleeve resection of right lower lung cancer under non-intubated epidural anesthesia. Intramuscular midazolam and atropine were administered 30 min before anesthesia. Epidural anesthesia was administered into the T7-8 intervertebral space, with the epidural catheter tip pointed towards the head and fixed after confirming successful placement, and an adequate dose of the drug was administered. To keep the airway open in order to supply oxygen, a laryngeal mask airway (LMA) was inserted, and the anesthesia machine was connected to provide simultaneous intermittent mandatory ventilation. To suppress the cough reflex caused by lung tissue stretching during the intra-thoracic procedure, an intrathoracic vagus nerve block was added. Part of the intermediated bronchus was resected, and the right middle lobular bronchus was joined with the right intermediated bronchus. The operation time was 165 min, and it took 25 min to perform bronchial anastomosis. Maintaining oxygenation while the intermediate bronchus is open seems difficult. It is therefore necessary to prepare the intra-operative field properly or switch to endo-tracheal intubation and general anesthesia for this procedure.

Non-intubated surgery for the carinal reconstruction

Carinal resection and reconstruction is one of the most difficult and challenging surgeries for thoracic surgeons. Peng *et al.* (23) reported the outcome of non-intubated complete thoracoscopic surgery for carinal reconstruction in a patient with ACC of the trachea. Pre-anesthesia preparation included the use of midazolam and atropine 30 min before surgery. TEA was performed at the T6-7

level, and intravenous anesthesia was performed using remifentanyl, dexmedetomidine and propofol as sedation to maintain spontaneous breathing. To keep the airway open in order to supply oxygen, an LMA was inserted, and local anesthesia with lidocaine, an intercostal nerve block and a vagus nerve block were also used. Peng *et al.* concluded that carinal reconstruction under non-intubated anesthesia is a feasible and safe method of anesthesia for certain patients, but they could only draw conclusions based on their single experience of carinal reconstruction under local and regional anesthesia. The feasibility and safety should therefore be confirmed in more patients in order to establish appropriate criteria for identifying candidates for this procedure.

Problems with non-intubated airway surgery

There are several issues that must be addressed with airway surgery under non-intubated anesthesia. The first issue concerns the management of hypoxia, especially after cutting open the airway. High-flow oxygen has been delivered via a laryngeal mask to maintain a high oxygen concentration in the pleural cavity, but this technique has limitations. The burst by using electro-surgical knife should be aware during such situation. The second issue concerns the management of hypercapnia and continuous measurement of the carbon dioxide level during airway reconstruction. The third issue concerns how to perform the air-leak test after reconstruction, as adequate positive pressure management is impossible under non-intubated conditions. Fourth, blood and secretions dropped into the airway during reconstruction cannot be removed via suctioning under non-intubated conditions. Peng *et al.* reported that the operator must perform adequate hemostasis before anastomosis in order to ensure that the surgical field is clean. Fifth, and the most important issue, coughing during airway construction must be prevented, as severe complications may occur due to patient movement during airway suturing. Shao and Peng have described the effectivity of the vagus nerve block in the intra-thoracic field to suppress the cough reflex (22,23). Finally, airway surgery is still an extremely risky operation, and the outcomes of few cases have been reported. Educating younger surgeons is an important duty for experienced surgeons.

Safety and guidelines for non-intubated thoracoscopic surgery

Non-intubated thoracic surgery is challenging. To perform

lobectomy and airway surgery under spontaneous respiration, the team (surgeons, nurses and anesthesiologists) should have experienced the same procedure under general anesthesia as well as have performed the easier method of thoracoscopic surgery before, including wedge resection and pleural infiltration cases. The entire team must be aware of the complications that can happen during awake thoracic surgery, with potential risks including hypoxemia, uncontrolled cough and severe bleeding. If the patient must be emergently intubated during non-intubated thoracic surgery, the anesthesiologist must be trained in lateral intubation. Navarro-Martinez *et al.* (24) reported that they trained themselves to intubate in the lateral position using scheduled-surgery patients. They emphasized that responses to surgical and medical emergencies during non-intubated thoracoscopic surgery must follow the crisis resource management guidelines. Before beginning non-intubated surgery, the surgical team should confirm the criteria for conversion to general anesthesia and not hesitate with such conversion.

Conclusions

Cases of non-intubated airway surgery are not very frequent, and the merits of non-intubated airway surgery over intubated surgery remain unclear, especially for carinal reconstruction and lower tracheal resection and reconstruction. The mortality rate for tracheal resection and reconstruction is still high, and few cases have been reported. This dearth of reports hampers the widespread application and further development of the technique. At present, we can cite no overwhelming benefit to non-intubated airway surgery outweighing the associated risks. As such, non-intubated thoracoscopic surgery should be limited to lobectomy for the time being.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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