Non-intubated Airway Surgery

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KEYWORDS

• Non-intubated • Airway surgery • Resection • Reconstruction

KEY POINTS

- Non-intubated airway surgery is an option for tracheal tumors or stenosis, diagnosed through various imaging modalities.
- Supraglottic airway devices and short-acting anesthetics allow for surgery without endotracheal intubation, reducing complications and promoting recovery postoperatively.
- Different surgical approaches are adopted based on the location of the airway pathology, such as cervical tracheal reconstruction, cervicothoracic junction reconstruction, and intrathoracic tracheal reconstruction.
- Surveillance bronchoscopy, computed tomography (CT), MRI, and PET/CT aid in evaluating outcomes and detecting complications.

INTRODUCTION

Airway resection and reconstruction is an intervention frequently performed for tracheal tumor or stenosis. Tracheal tumors are not common, located at upper respiratory system, with the diagnosis and assessment by bronchoscopy, MRI, computed tomography (CT) scan, and PET/CT.[1] Tracheal stenosis may be caused by prolonged endotracheal intubated ventilation, [2] neoplasms, [3] or trauma.[4] The resection of stenotic airway segments may significantly improve the patient's quality of life. However, anesthetic management for both tracheal neoplasms and stenosis procedures is challenging. Tracheal resection and reconstruction is a therapeutic option for patients with tracheal tumors or tracheal stenosis.[5] However, airway surgery is still a technically complex task for both thoracic surgeons and anesthesiologists.

Airway surgery has traditionally been performed under general anesthesia with endotracheal intubation to secure the airway and facilitate mechanical ventilation. Although this approach has been the standard practice for decades, it carries inherent risks such as airway trauma, vocal cord injury, and other postoperative respiratory complications. Additionally, the use of general anesthesia and endotracheal intubation may not be feasible or desirable in certain patient populations, such as those with significant comorbidities, or difficult airway anatomy. Cross-field intubation was usually used for intraoperative ventilation as well.[6] Once the trachea is transected, a sterile endotracheal tube would be inserted into the distal trachea and connected to a breathing circuit across the surgical field for a ventilation guarantee. However, the endotracheal tube inevitably affects the operative view as well as a precise suturing for anastomotic stoma.[7] High-frequency ventilation connected through a small-size orotracheal catheter has been reported in some institutions.[8] During the procedure, once the airway is opened, adequate ventilation may not be ensured, resulting in dynamic hyperinflation and hypercapnia.[9,10]

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In recent years, to address the problems mentioned, there has been growing interest in the development and refinement of techniques for nonintubated airway surgery (NAS), [11] also known as spontaneous ventilation anesthesia. Progressive evolution of supraglottic airway devices and short-acting anesthetics has allowed for nonintubated anesthesia tracheal surgery. Laryngeal mask airway (LMA),[9] a supraglottic airway device, obviates the need for endotracheal intubation anesthesia maintained by total intravenous anesthesia. Patients' spontaneous ventilation is maintained, and respiratory depression is prevented because muscle relaxant is avoided and the bispectral index monitor is used during the operation. This innovative approach allows for surgical intervention on the airway without the need for endotracheal intubation or general anesthesia.

NAS represents a paradigm shift in the management of airway pathology, offering several potential advantages over the traditional intubated techniques. Our prior study[12] demonstrated that nonintubated procedures may reduce the risk of perioperative complications, minimize airway trauma, and expedite postoperative recovery. Additionally, the avoidance of positive pressure ventilation may be beneficial in patients with compromised cardiopulmonary function or preexisting lung disease and reducing the use of muscle relaxant, which may enhance recovery after surgery.

This article aims to provide a comprehensive overview of NAS, including the technical considerations and perioperative management strategies, with the hope of contributing to the understanding and adoption of NAS as a safe and effective approach for the management of airway operation.

PATIENT EVALUATION OVERVIEW

The selection of appropriate candidates for NAS is paramount to ensuring safety, efficacy, and optimal outcomes. Previously, Zhou and colleagues.[11] had summarized the indications for nonintubated upper tracheal surgery, including (1) surgical approach via cervical incision, (2) age ranging from 16 to 70 year, (3) American Society of Anesthesiologists standard grade of $\leq$ III, (4) body mass index (BMI) less than 28 kg/m^2, (5) lack of clinically relevant dyspnea, (6) no massive hemoptysis, (7) lack of arrhythmia (frequent atrial fibrillation or premature ventricular contractions), (8) lack of coronary artery disease (CAD), and (9) normal cardiac function (ejection fraction greater than 50%).

In addition, patient evaluation encompasses a comprehensive assessment of the medical history, physical examination findings, airway anatomy, respiratory function, and psychological factors. Herein, we provide an overview of the key considerations in the evaluation of patients undergoing NAS.

1. Medical history: A detailed medical history is essential to identify underlying medical conditions, previous surgical interventions, allergies, medications, and lifestyle factors that may impact surgical candidacy. Specific attention should be paid to respiratory disorders (eg, asthma, chronic obstructive pulmonary disease), cardiovascular disease, neurologic conditions, and previous adverse reactions to anesthesia.
2. Airway assessment: Evaluation of airway anatomy is critical to assess the feasibility and safety of nonintubated techniques. Factors such as Mallampati score,[13] thyromental distance, and presence of anatomic abnormalities should be considered. Imaging studies such as neck and chest CT scan and MRI may be rapidly effective for a detailed assessment of airway anatomy.
3. Respiratory function: Assessment of baseline respiratory function helps identify patients at risk of perioperative respiratory complications and guides perioperative management strategies. Pulmonary function tests provide objective measures of lung function, whereas arterial blood gas analysis assesses oxygenation and ventilation status.
4. Cardiovascular evaluation: Patients undergoing the procedure should receive cardiovascular evaluation to assess cardiac function and identify any underlying cardiovascular disease (such as CAD) that may impact perioperative management. Electrocardiography, echocardiography, and cardiac stress testing may be indicated in candidate cases.
5. Preoperative counseling and psychological assessment: Preoperative counseling plays a crucial role in preparing patients for NAS. Patients should be adequately informed and educated about the nature of the procedure, expected sensations, potential risks, and postoperative recovery. Clear communication and realistic expectations help alleviate a patient's psychological pressure and improve a patient's cooperation during the perioperative care.
6. Multidisciplinary assessments: Optimal patient evaluation for NAS requires tight collaboration between surgeons, anesthesiologists, nursing staffs, and other health care providers. Multidisciplinary discussions facilitate comprehensive assessment, individualized treatment planning, and shared decision-making, ensuring the best possible outcomes for patients.

SURGICAL TREATMENT OPTION (PROCEDURES)

Based on the anatomy of the airway, it can be divided into 3 main parts: the cervical trachea, the cervicothoracic junction of trachea, and the intrathoracic trachea (including the carina). Different surgical incisions and corresponding surgical approaches distinguish various choices for surgeons, depending on segmental distribution of the trachea.

TUBELESS CERVICAL TRACHEAL RECONSTRUCTION

The patient should be placed in the neck hyperextension position, and the LMA should be applied. An arc incision in alignment with the skin creases in the neck is made.[14] The trachea is carefully dissociated to avoid any injury to the recurrent laryngeal nerve. Bronchoscopy is used to decide the resection scope. Dissection is carried out in a standard way, and, after identification of the upper airway, the trachea is infiltrated with lidocaine sprayed on the tracheal mucosal surface to avoid cough reflex. A circumferential dissection (**Fig. 1**) of the stenotic tract or tumor is performed to preserve the recurrent nerves and tracheal vascularization. During the procedure, oxygen being delivered through laryngeal mask, cross-field or jet ventilation is seldom used unless a patient's oxygenation is extremely poor, especially less than 80%, and vital signs are not stable. After the reconstruction, anastomotic leak test is performed using sterile saline. The neck incision will be closed after confirmation of no anastomotic leak or active bleeding.

Tracheal anastomotic sutures will be placed as described previously. The neck will be removed from extension and flexed under the support of a pillow. The chin sutures, also called guardian stitch, will be pulled toward each other to relieve tension, and the tracheal sutures will be tied tightly starting from the anterior tracheal wall. In addition to a standard anterior tracheal release technique, supraglottic release will be performed if any tension is present on the sutures. The endotracheal tube will be advanced and positioned distal to the anastomosis. After closure of the incision, the chin stitch will be placed and held for 1 week to avoid inadvertent patient neck extension.

TUBELESS INTRATHORACIC TRACHEAL RECONSTRUCTION

The patient will be placed in the lateral decubitus position after being anesthetized. Incisions will be made according to the lesion length after administration of local anesthetics at the area.[15] Under thoracoscopy, the azygos vein will be separated and stapled with a vascular stapler. After the mediastinal pleura are opened, the vagus nerve will be dissected and suspended. Subsequently, the trachea will be divided from the level of the suprasternal notch to the carina. After the trachea has been exposed, the operator will carry out needle-guided bronchoscopy to reconfirm the extent of tumor margins and then open the trachea (**Fig. 2**). Reconstruction will be initiated after a review of the frozen sections confirms that the margins on both sides are negative. Reconstruction will begin from the membranous area of the upper trachea using 4-0 absorbable sutures utilizing the parachute technique.

During the NAS procedure, the key to maintain spontaneous ventilation is to achieve an optimal balance between sedation and spontaneous respiration. Agents such as propofol and dexmedetomidine are preferred for their sedative properties and minimal respiratory depression. Regional anesthesia techniques, including intercostal nerve

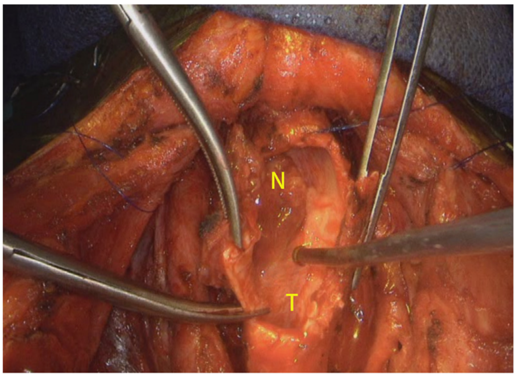

Fig. 1. NAS for upper (laryngotracheal) tracheal reconstruction. N, neoplasm; T, trachea.

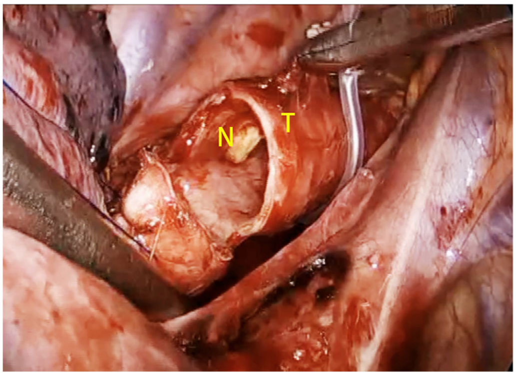

Fig. 2. NAS for video-assisted thoracic surgery (VATS) intrathoracic tracheal reconstruction. N, neoplasm; T, trachea.

blocks and thoracic epidural anesthesia, provide effective analgesia without compromising respiratory function. Without the endotracheal tube or cross-field ventilation, the operative view will be improved considerably and the anastomosis will be completed smoothly and rapidly. After an anastomotic leak and active bleeding have been excluded, 4-0 absorbable suture for intermittent suture reinforcement will be used to enhance the anastomosis. An intrathoracic chest drainage tube will be inserted, and the incision will then be closed.

To prevent ischemia, the authors suggest the following: (1) the normal trachea should be preserved as long as possible and devascularization should be kept to a minimum, especially the tracheal membrane; (2) the tissues surrounding the trachea should be protected.

TUBELESS CARINAL RECONSTRUCTION

A right-side position will be preferred and the surgical incisions will be selected as follows: (1) observation port: in the sixth intercostal space at the anterior axillary line; (2) auxiliary operation port: at the posterior line; and (3) main operation port: in the fourth intercostal space between the anterior axillary line and midaxillary line.[16,17]

Incision lengths will be decided according to the tumor's length. Local anesthesia with lidocaine will be performed before incision creation. After entering the pleural cavity, the authors will block the intercostal nerve and the vagus nerve using ropivacaine (0.75%) and lidocaine (2%). The hilar structures will be released first, during which the azygos vein will be transected, and the connective tissues at the lower trachea and around the left and right main bronchus will be dissociated. During the surgery, the blood supply of the trachea will be carefully protected, and any injury to the vagus nerve will be avoided. Before opening the airway, the surgical field must be kept clean. The right and left main bronchus will be transected at the site according to the tumor position (Fig. 3). Intraoperative frozen-section histopathology will be performed to ensure that there is no tumor cell infiltration at the stumps.

During the carinal reconstruction, the lower segment of the trachea and the posterior wall of the main bronchus will be continuously anastomosed using 3-0 nonabsorbable continuous sutures, followed by the anastomosis of the anterior wall (Fig. 4). Then, the other main bronchus and the orifice will be continuously anastomosed using 3-0 nonabsorbable continuous sutures in the same way. Because there will be no tracheal tube, the surgical field will be clearly exposed, making the anastomosis less difficult. An air-leak test using normal saline will prove the integrity of the anastomosis. One or two chest tubes would be placed in the upper and lower pleural cavity after the surgery.

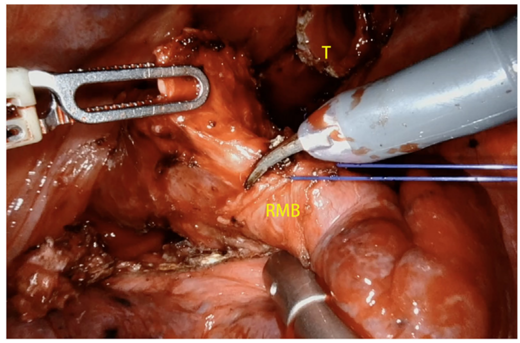

Fig. 3. NAS for roboted-assisted thoracic surgery (RATS) carinal reconstruction RMB, right main bronchus; T, trachea.

POTENTIAL COMPLICATIONS OF NONINTUBATED AIRWAY SURGERY

In accordance with our experience, the timing for NAS converting to intubated anesthesia mainly includes the following parts: (1) Excessive and uncontrollable bleeding intraoperatively, with blood entering the airway. Maintaining the airway clean and clear is critical to prevent obstructions, with meticulous dissection and adequate hemostasis intraoperatively being essential. (2) The occurrence of a pneumothorax complication in the contralateral thoracic cavity during the surgical process, leading to a decrease in oxygen saturation, unable to maintain adequate oxygenation without intubation. (3) When the patient has severe pleural adhesions. (4) Hypercapnia due to insufficient ventilation, requiring intubation for mechanical ventilation.

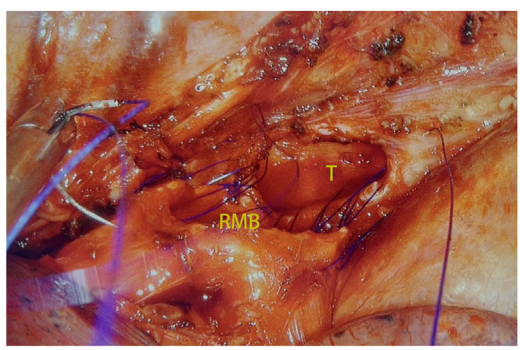

Fig. 4. NAS for video-assisted thoracic surgery (VATS) carinal reconstruction. RMB, right main bronchus; T, trachea.

CLINICAL OUTCOMES AND LONG-TERM RECOMMENDATIONS

Some studies have proved the benefits and surprising clinical outcomes. NAS has been found to be a safe technique for patients with interstitial lung disease, who seem to benefit from NAS due to the avoidance of positive pressure ventilation.[18,19] Another study exploring the surgical outcomes of NAS found that this approach resulted in shorter durations of anesthesia induction and surgery, higher intraoperative Pa_{O_2} levels, reduced intraoperative blood loss, and shorter postoperative hospital stays and chest tube retention times.[20,21] Due to the reduced use of anesthetics, patients' postoperative gastrointestinal motility is not being significantly inhibited, allowing for faster food intake postoperatively, so that patients reach a faster postoperative recovery. According to our experience, NAS avoids endotracheal intubation minimizing the occurrence of laryngeal edema as much as possible, especially during laryngotracheal anastomosis. Moreover, in robotic-assisted thoracic surgery, NAS can maintain good intraoperative oxygenation without relying on extracorporeal membrane oxygenation (ECMO).

SUMMARY

- Despite its potential benefits, NAS presents unique challenges and considerations for both surgeons and anesthesiologists. Techniques for airway anesthesia and sedation must be carefully tailored to each patient's individual needs and the specific requirements of the surgical procedure. Furthermore, meticulous patient selection, comprehensive preoperative evaluation, and close intraoperative monitoring are essential to ensure safety and optimize outcomes.
- The selection of patients suitable for NAS is a critical first step. A thorough medical history, airway assessment, respiratory function tests, cardiovascular evaluation, and psychological assessment are essential components of patient evaluation. Multidisciplinary collaboration is key to ensuring a comprehensive and individualized treatment plan.
- The surgical procedures described are intricate and vary based on the location of the airway pathology. Cervical tracheal reconstruction, cervicothoracic junction reconstruction, and intrathoracic tracheal reconstruction are detailed, with emphasis on techniques that minimize trauma, such as the use of LMA and avoidance of positive pressure ventilation. Carinal reconstruction is also discussed, highlighting the meticulous suturing required to ensure the integrity of the anastomosis.
- NAS offers significant benefits: safety for patients with lung disease, shorter surgery times, improved oxygenation, reduced bleeding, and expedited postoperative recovery. It also minimizes laryngeal edema and maintains oxygenation without ECMO in robotic surgery. Not using CO_2 insufflation may decrease the risk of perioperative hypercapnia and subcutaneous emphysema.
- In conclusion, NAS presents a promising option for patients with tracheal tumors or stenosis.

CLINICS CARE POINTS

- Non-intubated surgery benefits: Non-intubated airway surgery (NAS) reduces airway trauma and postoperative complications by avoiding endotracheal intubation.
- Supraglottic devices: Use of supraglottic airway devices like the laryngeal mask airway with short-acting anesthetics maintains spontaneous ventilation, facilitating surgery and enhancing postoperative recovery.
- Surgical approach customization: Tailoring surgical approaches based on the airway lesion's location is crucial, with options like cervical tracheal reconstruction, cervicothoracic junction reconstruction, and intrathoracic tracheal reconstruction.
- Imaging for evaluation: Utilization of surveillance bronchoscopy, computed tomography (CT), MRI, and PET/CT for precise evaluation of outcomes and early detection of complications.
- Patient selection criteria: Careful patient selection based on criteria such as age, American Society of Anesthesiologists grade, body mass index, and absence of significant comorbidities ensures the safety and efficacy of nonintubated surgery.
- Multidisciplinary teamwork: Collaboration between surgeons, anesthesiologists, and other health care providers is essential for comprehensive patient assessment and treatment planning.
- Postoperative surveillance: Regular follow-up and surveillance with bronchoscopy and imaging studies are vital for evaluating the surgical outcome and detecting late-onset complications.

- Pitfalls to avoid:
  - Anesthesia risks: General anesthesia and endotracheal intubation carry risks such as airway trauma, vocal cord injury, and respiratory complications, which non-intubated surgery aims to mitigate.
  - Cross-field intubation issues: The use of cross-field intubation can obstruct the surgical view and hinder precise suturing, a pitfall avoided in nonintubated surgery.
  - High-frequency ventilation challenges: Potential difficulties in ensuring adequate oxygenation and the risk of hyperinflation and hypercapnia with high-frequency ventilation.
  - Patient evaluation oversights: Failing to conduct a thorough medical history, airway assessment, and cardiovascular evaluation could compromise patient safety and surgical outcomes.
  - Surgical technique errors: Imprecise dissection, causing injury to nerves or disrupting blood supply, can lead to complications such as tracheomalacia or anastomotic leaks.
  - Postoperative complications: Inadequate monitoring and management can result in severe complications such as hemorrhage, fistulas, and infections, which necessitate timely interventions.
  - Long-term follow-up neglect: Failure to provide regular long-term follow-up increases the risk of undetected late-onset complications, impacting patient recovery and quality of life.
  - Overlooking pharmacologic treatment: Neglecting the role of medical treatments like chemotherapy, targeted therapy, and immunotherapy in the management of malignant tracheal stenosis.

DISCLOSURE

The authors have nothing to disclose.

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