Case Report

A simple and practical intraoperative ventilation technique for uniportal video-assisted thoracoscopic tracheal reconstruction: a case report

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Background: Cross-field endotracheal intubation is typically performed during tracheal anastomosis to maintain single-lung ventilation. To minimize obstruction of the surgical field by the cross-field tube, special equipment such as high-frequency jet ventilation (HFJV) and extracorporeal membrane oxygenation (ECMO) or advanced techniques such as non-intubated ventilation have been proposed. Here, we describe a simple and practical airway management strategy that requires only conventional ventilators and techniques. Our operation is completed under uniportal video-assisted thoracoscopic surgery (VATS).

Case Description: We report a case of tracheal adenoid cystic carcinoma (ACC) presenting with cough with bloody sputum in a 53-year-old man. Computed tomography (CT) and flexible bronchoscopy revealed an irregular polypoid neoplasm attached to the right wall of the distal trachea, which almost completely blocked the tracheal lumen. To relieve the symptoms, transbronchoscopic resection of the tumor, followed by curative resection via uniportal VATS under general anesthesia was performed. To maintain single-lung ventilation during tracheal reconstruction, we took advantage of a thin suction tube [internal diameter (ID) 3 mm; external diameter (ED) 4 mm], which was connected to a conventional ventilator. Specifically, by introducing the suction tube into the distal left main bronchus through the endotracheal tube and blowing 100% oxygen, we achieved satisfactory oxygenation throughout the anastomotic process; and the blood CO_2 partial pressure was also acceptable. The view of the anastomotic site was far less obstructed owing to the small diameter of the suction tube, and the anastomotic process was smooth and accurate. Postoperative recovery was good, and no stenosis of the reconstructed trachea was observed at the 3-month follow-up.

Conclusions: Our technique proves to be safe and feasible for selected patients with tracheal tumors, and can be a practical choice for medical centers that are not equipped with HFJV or ECMO.

Keywords: Tracheal tumor; airway management; one-lung ventilation (OLV); video-assisted thoracoscopic surgery (VATS); case report

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Introduction

Primary tracheal tumors are a rare disease with an estimated incidence of 2.6 cases per 1,000,000 patients per year (1). Surgical resection is the only curative choice for these patients and is typically performed via thoracotomy (2). With advances in surgical techniques and minimally invasive instruments, tracheal resection followed by end-to-end anastomosis with video assistance through multiple small incisions, or even a single small incision, has become feasible (3,4). For both open and thoracoscopic surgeries, a clear surgical field is important for performing tracheal anastomosis. However, cross-field intubation, which is typically used to maintain ventilation during the procedure, can interfere (5). This is particularly true when a uniportal approach is applied. Herein, we describe a simple and practical airway management strategy that provides satisfactory intraoperative ventilation without disturbing the surgical field during uniportal thoracoscopic tracheal resection with reconstruction. We present the following case in accordance with the CARE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-21-6215/rc)

Case presentation

A 53-year-old man with no history of smoking presented to our hospital with a 3-month history of hemoptysis. Enhanced chest computed tomography (CT) showed a 1.9 cm × 1.1 cm mass located in the distal trachea, with a clear margin and slight heterogeneous enhancement (*Figure 1A,1B*). The right wall of the trachea was thickened, where the mass was attached. Multiple left tracheoesophageal groove lymph nodes were noted, with the largest having a diameter of 0.6 cm. No enlarged mediastinal or hilar lymph nodes were observed. Enhanced CT of the maxillofacial and abdominal organs showed no abnormalities. Brain magnetic resonance imaging and whole-body bone scans did not reveal any suspicious lesions. A flexible bronchoscopy showed that there was an irregular polypoid neoplasm attached to the right wall of the trachea, about 2.5–3.5 cm above the carina, and the tumor almost completely blocked the tracheal lumen (*Figure 1C*). Pulmonary function examination revealed a moderately restrictive spirometric pattern; the forced expiratory volume in the first second (FEV_1) was 2.64 L (71.1% of the predicted value). Physical examination and routine laboratory tests revealed no abnormalities. To alleviate the patient's respiratory symptoms, transbronchoscopic resection of the tumor was performed using an electrosurgical snare (*Figure 1D*). The pathological results were positive for adenoid cystic carcinoma (ACC). Since tracheal wall invasion and regional lymph node metastasis could not be excluded, we decided to perform tracheal segment resection with end-to-end anastomosis using video-assisted thoracoscopic surgery (VATS) via a single incision. All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

After the placement of American Society of Anesthesiologists (ASA) standard monitors and pre-induction arterial line, general anesthesia was gradually induced with 0.05 mg/kg midazolam, 2 mg/kg propofol, 0.3 μg/kg sufentanil and 0.6 mg/kg rocuronium and maintained with 4–8 mg/(kg·h) propofol and 0.05–2 μg/(kg·min) remifentanil to maintain the bispectral index (BIS) between 40 and 60. The muscle relaxant, rocuronium, was administered intermittently under neuromuscular blockade monitoring. A single-lumen endotracheal tube combined with a bronchial blocker was used for one-lung ventilation (OLV) and provided a satisfactory oxygen supply prior to tracheotomy. The patient was placed in the left lateral decubitus position. A single incision of approximately 4 cm was made in the 4th intercostal space along the right midaxillary line and was protected with a wound protector. Thoracic examination revealed dense pleural adhesions in the chest cavity. After sharp dissection of the adhesions with electrocautery, the right lung gradually collapsed. The mediastinal pleura was then cut open, and the trachea from the level of the suprasternal notch to that of the carina was dissociated. Care was taken to protect the bronchial arteries and vagus nerves. Mediastinal lymph nodes, including the subcarinal, paratracheal, retrotracheal, and right tracheal-bronchial lymph nodes, were dissected. Intraoperative frozen-section analysis confirmed that the left tracheoesophageal lymph nodes were negative for tumor cells. The inferior pulmonary ligaments were divided. The azygos vein was dissected and transected with a linear stapler. The right vagus nerve was isolated and suspended for protection, whereas the distal trachea was looped with sterile cotton tape for traction. Since the tumor had been removed preoperatively, the resection segment was confirmed using bronchofiberscopy during surgery. Immediately before the tracheotomy, the

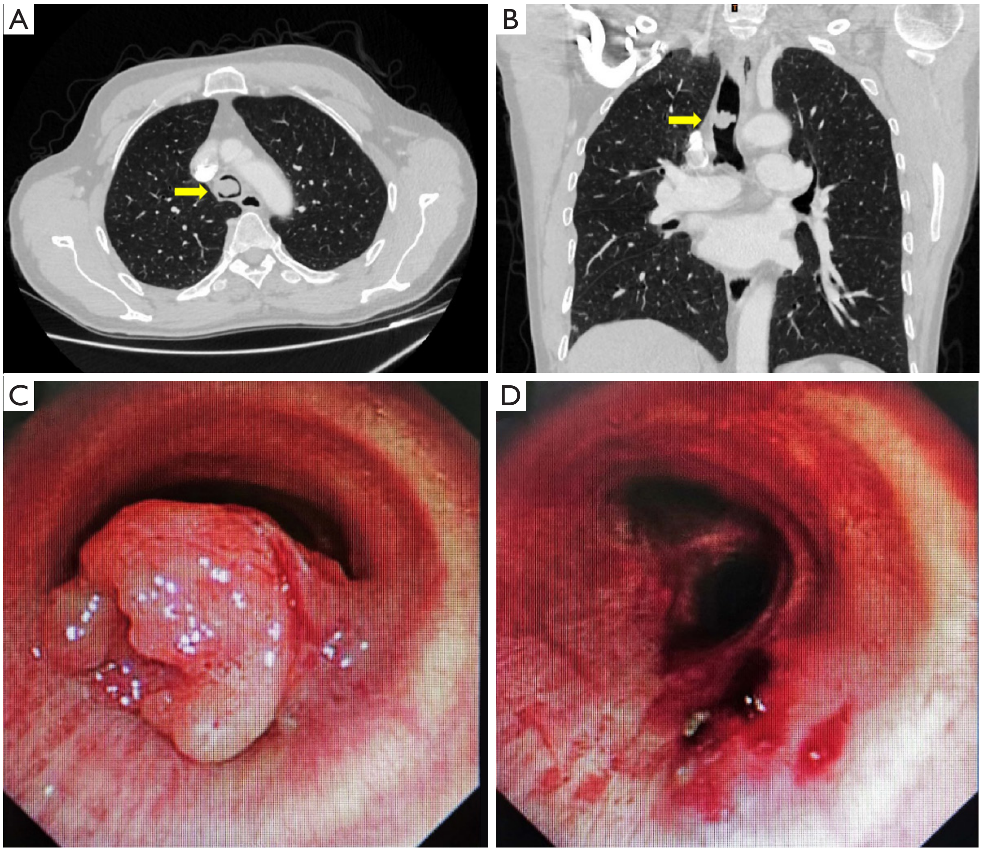

Figure 1 Presentation of the mass in the lower trachea. Chest CT image shows a mass in the lower trachea (arrow) on (A) axial view and (B) coronal view. View of the lower trachea through fibrobronchoscopy (C) before and (D) after the mass was resected using an electrosurgical snare.

distal tip of the endotracheal tube was retracted to the upper trachea. Simultaneously, the bronchial blocker was withdrawn from the trachea. After the distal end of the trachea, which was approximately 1.0 cm away from the base of the resected tumor, was transected, a sterile cuffed single-lumen tracheal tube [internal diameter (ID) 6.0 mm] was placed into the distal left main bronchus via the thoracic cavity. Subsequently, a cross-field OLV was initiated. Meanwhile, the patient was placed in a 15° Trendelenburg position to prevent oozing blood from flowing distally into the tracheobronchial tree. The trachea was transected at the proximal end of the tumor to completely remove the tracheal segment. The resected segment was about 2 cm in length. Both sides of surgical margins were confirmed negative by intraoperative frozen section analysis. Once the preparation for anastomosis was completed, the cross-field tube was withdrawn, and, a thin single-lumen suction tube [ID 3 mm; external diameter (ED) 4 mm] (*Figure 2A*) that was connected to the breathing circuit of the anesthesia machine (*Figure 2B*) was inserted through the endotracheal tube to the proximal end of the tracheostomy site (*Figure 2C*). The breathing mode of the anesthesia machine was set to manual, and the limit pressure of the APL valve was set to 25 cmH_2O. Subsequently, 100% oxygen was continuously blown in, and the fresh gas flow was set to be greater than 5 L/min. This maintained the fingertip blood oxygen saturation (SaO_2) above 95% for approximately 5 min; when SaO_2 dropped below 95%, the suction tube was further inserted to the distal end of the tracheotomy site and the distal tip was placed approximately 2 cm away from the opening of the left bronchus under thoracoscopic guidance (*Figure 2D*). Anastomosis was performed using a continuous 3-0 Prolene running suture from the posterior to anterior region. Starting from the left joint of the membranous and cartilaginous parts, the left half of the trachea was first closed, followed by the right half (*Figure 2E*). Without

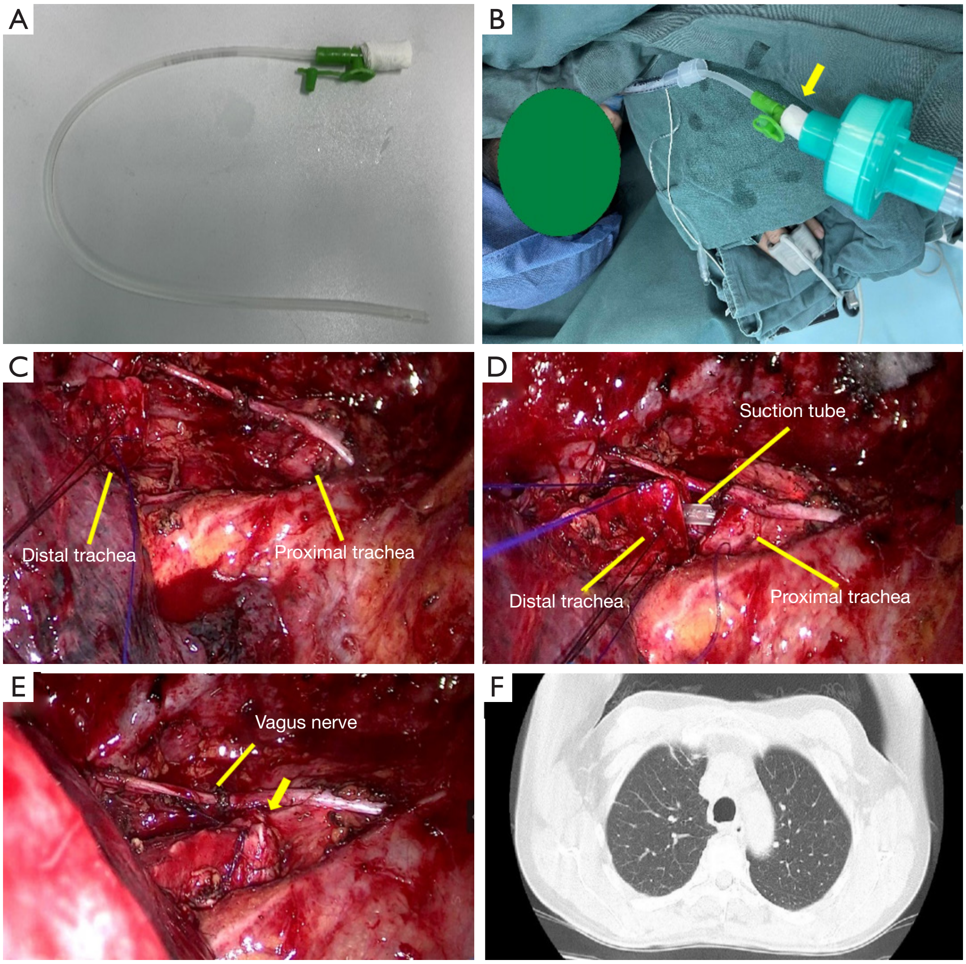

Figure 2 Demonstration of the proposed OLV technique. (A) The suction tube (ID 3 mm; ED 4 mm) we used to support OLV during tracheal anastomosis. (B) The tube was connected to a breathing circuit. We used tapes (arrow) to tackle the discrepancy in the caliber between the tube and the breathing circuit. (C) Running suture with the suction tube placed at the proximal tracheotomy site. (D) Running suture with the suction tube inserted into the left main bronchus. (E) Tracheal anastomotic stoma (arrow). (F) Postoperative CT showed that no stenosis existed. OLV, one-lung ventilation; ID, internal diameter; ED, external diameter.

interference from the cross-field tube, the entire end-to-end anastomosis process was smooth and accurate, and the time for tracheal reconstruction was approximately 30 min. During the anastomotic phase, the aforementioned cross-field tube was prepared on the operating table for rescue use. Indeed, the fingertip blood SaO_2 of the patient was consistently above 96%, and the blood gas analysis of the patient without ventilation during tracheal anastomosis was acceptable (*Table 1*). Once anastomosis was completed, the endotracheal tube was repositioned 21 cm away from the incisors. The chest incision was closed after it was confirmed that there was no active intrathoracic bleeding or air leakage, and a 15-Fr chest tube was placed posterior and toward the apex of the thoracic cavity through the incision for drainage. The patient's vital signs remained stable throughout the surgery. After surgery, the endotracheal tube was removed in the operating room and spontaneous breathing was fully restored.

This operation took 335 min (117 min were spent dissecting the pleural adhesions) with approximately 100 mL of blood loss. Chest radiography on postoperative day 1 showed that the right lung was well re-expanded with no sign of pneumothorax. The patient occasionally presented with cough and sputum production. He did not have any significant symptoms until he complained of shortness of breath and fever on postoperative day 5. Chest radiography

Table 1 Blood gas analysis of the patient without ventilation during the tracheal anastomosis

Time point	PO_2/mmHg	PCO_2/mmHg	HCO_3^-/mmol/L	BE/mmol/L	SO_2
Before anastomosis	352	46	27.8	2.4	100%
5 min after anastomosis	72	52	27.9	1.3	95%
15 min after continuously blow in oxygen	93	67	28.1	–0.7	96%
30 min after continuously blow in oxygen (the anastomosis just ended)	128	78	29.1	–1.0	98%

PO_2, oxygen partial pressure; PCO_2, partial pressure of carbon dioxide; BE, base excess; SO_2, oxygen saturation.

revealed pleural effusion, primarily in the right lower lobe. To facilitate drainage, the chest tube placed during surgery was withdrawn and replaced by a 7-Fr drainage catheter, which was inserted through the 6th intercostal space along the scapular line under ultrasound guidance. Approximately 500 mL serous pleural fluid was drained, and his body temperature gradually returned to normal. The catheter was removed on postoperative day 14 and the patient was discharged the next day. Pathological results confirmed tracheal ACC without lymph node involvement. According to the patient, the postoperative recovery was satisfactory during the 3-month follow-up. The patient did not visit our hospital for further consultation because of his economic status. CT scans of the reconstructed trachea performed at a local hospital showed no stenosis (*Figure 2F*) and no signs of local tumor recurrence.

Discussion

Tumors originating in the trachea are relatively uncommon. Surgery is typically the treatment of choice and is performed to resect the tumor and restore the airway by end-to-end anastomosis. However, this can be a challenging procedure even when performed under open thoracotomy for majority of medical centers because of the high rates of postoperative morbidity and mortality (6).

Airway management and reconstruction, as the key and most difficult issue of tracheal surgery, require careful coordination between the surgical and anesthesia teams. Several ventilation techniques have been developed to provide a sufficient oxygenation for the patient during airway excision and anastomosis. One of the classic methods is cross-field ventilation (5), in which a sterile endotracheal tube is inserted into the distal trachea by the surgeon once the trachea has been transected to directly ventilate a single lung. The major advantage is that it allows for unrestricted positive pressure ventilation and provides aspiration protection throughout the procedure. In our case, the cross-field tube was also used after the distal trachea was transected before anastomosis and for rescue purpose during anastomosis. However, the disadvantage is also explicit in that the cross-field tube can obstruct the view of the reconstruction site, requiring periodic retraction of the tube during anastomosis to improve exposure.

To minimize the obstruction of the cross-field tube to the surgical field, we used a tube with a smaller diameter to sustain the OLV. SaO_2 was maintained above 98% and the blood CO_2 partial pressure was also acceptable. Because of the small diameter of the suction tube, the view of the anastomotic site is far less obstructed, the process of anastomosis is smooth and accurate, and no retraction of the tube is needed. Indeed, a similar technique was proposed over a decade ago by Macchiarini (7). To maintain hyperoxygenation during anastomosis, a 10-F catheter was introduced into the contralateral main bronchus across the surgical field in that study. In our case, the small tube was introduced through the endotracheal tube, and tracheal reconstruction was accomplished with a single surgical port on the chest wall, minimizing trauma to the patient.

Another conventional technique is high-frequency jet ventilation (HFJV). Similar to our strategy, HFJV also uses a small-diameter catheter for ventilation; however, it requires special equipment and has potential risks of air trapping and barotrauma (8,9). It has been reported that HFJV use could be a risk factor for the development of acute respiratory distress syndrome (ARDS) (10).

Recently, the non-intubation technique has been successfully used in tracheal surgery (11) in which regional anesthesia is typically used and a spontaneous single-lung breathing status is maintained. Compared with intubated general anesthesia, a completely open surgical field is achieved, and early results suggest a faster postoperative recovery and lower overall complication rate (12). However, it should be noted that not all patients are suitable for non-intubated surgery and advanced anesthetic techniques, and that extensive experience in airway management is required to control the considerable physiological derangements during the procedure. In addition, concerns such as cough control, distal airway protection, and inability to perform air-leak tests should also be addressed (12).

Cardiopulmonary bypass (CPB) and extracorporeal membrane oxygenation (ECMO) are alternative, but more invasive approaches for tracheal reconstruction (13). They provide effective respiratory support and hemodynamic stability and the surgical site is unaffected. However, they require special equipment and are associated with potential complications and high cost (5).

Although our case proves safe and feasible, the results of our study should be interpreted with caution. First, switching the anesthesia machine to the manual mode can increase the risk of hypercapnia. In our case, the blood CO_2 partial pressure increased to 78 mmHg when the tracheal anastomosis was completed within 30 min. If more time is spent on this procedure, cross-field intubation may be applied to manage hypercapnic acidosis. Second, because the 3-way suction tube was not designed to be connected to the breathing circuit, their calibers were not matched. This might have affected the connection stability, thus affecting the continuity of ventilation. We used medical tape as a temporary solution to address the discrepancy in the caliber of the two ends (*Figure 2B*). Third, the flexibility of the plastic suction tube to some extent increases the difficulty of manipulation, particularly inside the bronchus. Furthermore, the single-lumen suction tube failed to provide aspiration protection. To ensure safety, rescue techniques should always be prepared for emergency use. Finally, the results of only one case are not adequate to prove its safety and feasibility for all tracheal tumors. For now, we can only speculate that this technique can be safely applied to selected patients with ASA I-II, and more cases are needed to optimize the procedure and verify the reliability and effectiveness of this technique.

Conclusions

In conclusion, our proposed ventilation strategy for tracheal reconstruction using uniportal VATS is simple and feasible. It provides satisfactory oxygenation without significantly disturbing the surgical field and should be a good practice for both thoracic surgeons and anesthesiologists with experience in intraoperative ventilation management in tracheal surgery. Moreover, for medical centers that are not equipped with HFJV or ECMO, our method can be a practical choice.

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Footnote

Reporting Checklist: The authors have completed the CARE reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-21-6215/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-21-6215/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

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