

TECHNICAL NOTE

Extracorporeal membrane oxygenation (ECMO)-assisted intratracheal tumor resection and carina reconstruction: A safer and more effective technique for resection and reconstruction

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Introduction

Primary tracheal malignant tumors are rare, with an incidence of 0.1 to 0.2 per 100 000 people, accounting for approximately 0.2% of respiratory tumors.^{1,2} There are no obvious symptoms at an early stage and tumors progress slowly. When the tumor enlarges to > 75% of the cross-sectional area of the trachea, obvious symptoms of respiratory obstruction, such as dyspnea, appear.³ At present, surgical resection and tracheal reconstruction are the main treatment methods for tracheal tumors. When a tumor is located in the tracheal carina, it is necessary to surgically remove the carina and reconstruct it.⁴ The trachea is not only the surgical site, but also an important

Abstract

Carina resection and reconstruction is required when a tracheal tumor invades the tracheal carina. It is a relatively complicated surgical procedure that requires complex reconstruction to maintain airway continuity. The technical difficulty lies in minimizing the influence of anesthetic endotracheal intubation and maintaining good ventilation function during surgery by establishing appropriate ventilation channels, which are contradictory in many cases. Therefore, in order to achieve the optimal surgical outcome, we performed intratracheal tumor resection and carina reconstruction with the help of extracorporeal membrane oxygenation.

channel to ensure ventilation and maintain oxygenation during surgery. Otherwise, hypoxia can easily occur and affects multiple organ function. Therefore, tracheal tumor resection and tracheal reconstruction, particularly carina reconstruction, is complicated and high-risk. It is known as the most complicated and difficult thoracic surgery, and has the highest requirements for anesthesia and the highest risk. In order to reduce the risk and simplify the surgical procedure, we stopped the patient's mechanical airway ventilation with the assistance of extracorporeal membrane oxygenation (ECMO), and performed tracheal tumor resection and carina reconstruction without the obstruction of tracheal intubation.

Methods

A 53-year-old man was referred to our hospital after experiencing a year of progressive dyspnea. Fiberoptic bronchoscopy revealed a mass in the anterior wall of the lower trachea. The tumor pedicle was wide and obstructed most of the lumen. The electron microscope could not enter the distal end and the tumor could not be removed under endoscopy. Biopsy results suggested parotid-derived tumors (low malignancy). Computed tomography (CT) revealed that the upper level of the tracheal carina was occupied, the corresponding lumen was narrow, the lesion was broadly based, and no extra-tracheal tumor invasion was observed. After multidisciplinary consultation, it was decided: (i) the position of the tracheal tumor was too low to perform a tracheotomy; (ii) because of the size of the tumor, an anesthesia cannula could not pass through the tumor site, and the risk of sudden suffocation to death during anesthesia is high; thus (iii) a Thompson Surgical procedure (tracheal carina resection and reconstruction) was required, as it would be difficult to intubate both the left and right main bronchi to ensure single-lung

ventilation, and tracheal intubation seriously affects the surgical field, as well as obstructing anastomosis (Fig 1).

After obtaining informed consent from the patient, we performed tracheal tumor resection and carina reconstruction with the aid of ECMO. The patient was placed in a supine position for general anesthesia. A single lumen reinforced endotracheal tube with an inner diameter of 8 mm was inserted orally. Venovenous (VV) ECMO intubation of the right femoral vein-right internal jugular vein was established rapidly after heparinization.

The specific surgical process was as follows. Before intubation, heparin 1.0 mg/kg was administered by intravenous injection. After five minutes, the activated clotting time (ACT) was 230 seconds (target range: 200–250 seconds). Two thoracic surgeons then performed intubation and one in vitro perfusionist performed ECMO pipe prefilling. With the assistance of ultrasound, a 17Fr femoral vein cannula (CB96670-017, Medtronic, Shanghai, China) was placed in the right femoral vein as an extracorporeal drainage tube to draw venous blood out of the body, and a 17Fr femoral artery vein cannula (CB96570-017, Medtronic) was placed in the right internal jugular vein as a cardiac

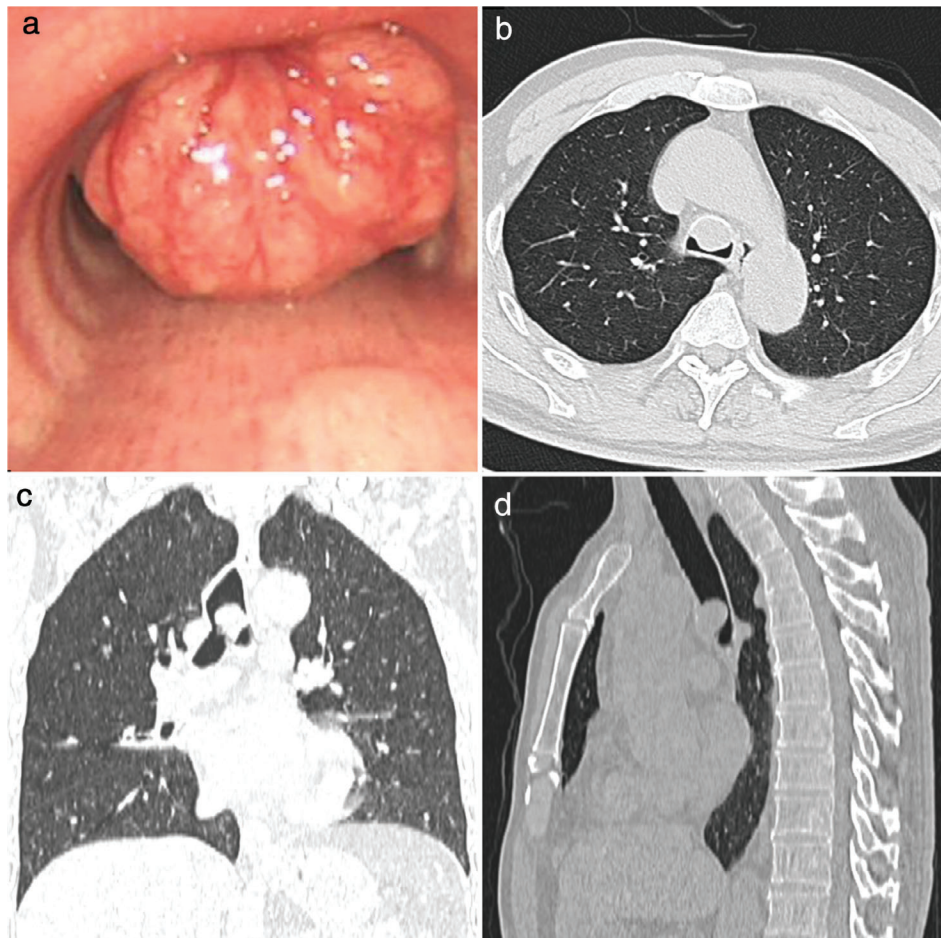
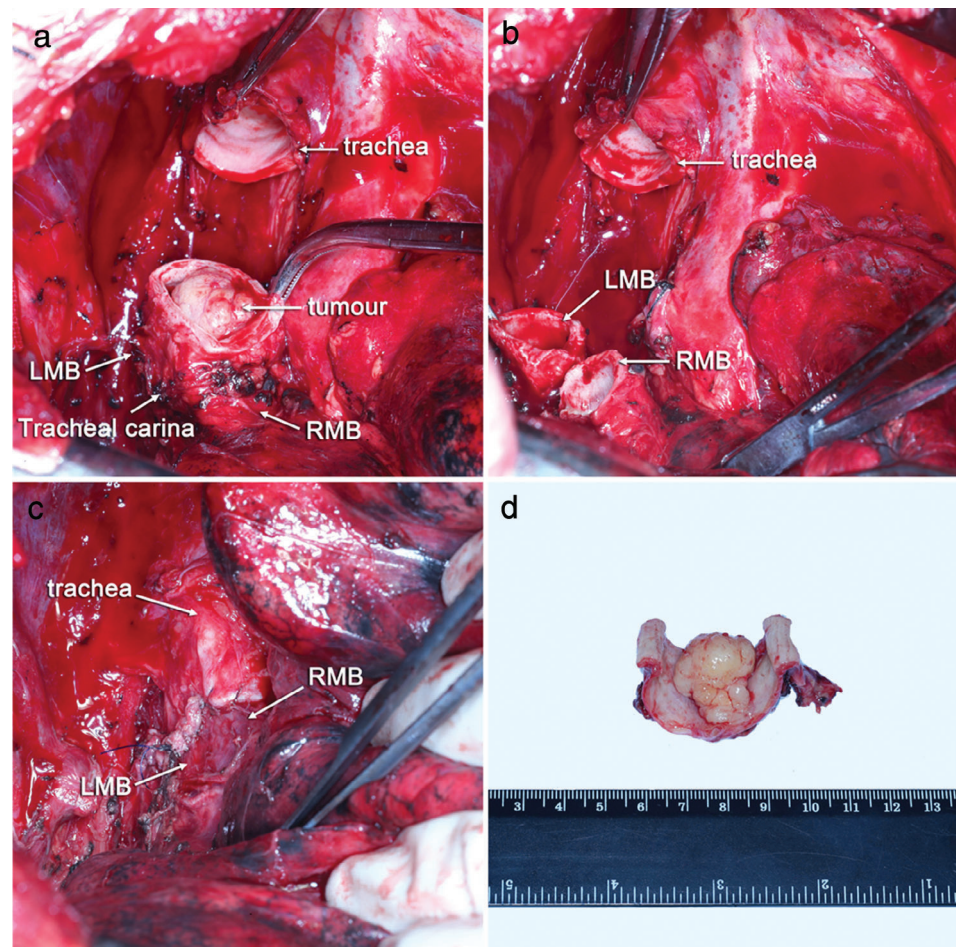


Figure 1 Preoperative examination revealed the intratracheal tumor by (a) fiberoptic bronchoscopy and (b–d) computed tomography.

Figure 2 (a) Tracheal transection revealed the tumor obstructed most of the lumen; (b) tracheal carina and tumor resection; (c) reconstructed carina; and (d) resected tumor. LMB, left main bronchus; RMB, right main bronchus.



return tube to introduce extracorporeal oxygenated blood into the body. The distal end of the venous cannula was then adjusted to the junction of the inferior vena cava-right atrium and the distal end of the arterial cannula was adjusted to the right atrium facing the tricuspid valve to minimize ECMO circulation. Once the ECMO pipes were pre-filled they were connected to the patient's arteriovenous cannulas. When the centrifugal pump reached 1000 r/minutes, the venous tube clamp was released, followed by the arterial tube clamp. The ECMO flow rate was maintained at 3 L/minutes, FiO_2 at 60%, and the airflow at 1.5 L/minutes. We then adjusted the ventilator parameters: FiO_2 was set at 30%, positive end expiratory pressure (PEEP) was set at 5 cm H_2O , the respiratory rate was set at 8 times/minute and the tidal volume was set at 6 mL/kg. Oxygen saturation was between 98% and 100%. The patient was then moved to the left lateral position. Following conventional disinfection and draping, a 15 cm incision was made at the fourth intercostal of the posterolateral right chest, observing total thoracic adhesions and pleural atresia. To free the pleural adhesion, we stopped the ventilator to collapse the lungs and gradually increased

the ECMO flow to 4.5 L/minute. The FiO_2 was unchanged and the airflow was adjusted to 2.5 L/minute. The oxygen saturation of the patient was between 95% and 98%. After the lungs collapsed the adhesion and the lower lung ligament were quickly released exposing the trachea, carina, and left and right main bronchi. In palpation, the tumor was located in the region of the carina and with poor mobility. The trachea was then circularly cut off at a distance of 1.0 cm above the tumor, and the left and right main bronchi were also circularly cut off at a distance of 0.5 cm below the tumor. A tracheal tumor specimen was removed and sent for pathological examination. The resected trachea and carina were approximately 4.0 cm. After three hours of ECMO, the ACT was 189 seconds. Because it was within the target range (160–220 seconds), no heparin was applied. To reconstruct the carina, the left and right main bronchial sidewalls were anastomosed and then moved upwards to coincide with the end of the upper trachea. After anastomosis, the ECMO was deactivated and the ECMO cannulas were immediately removed. The ACT was 140 seconds. A dose of 25 mg protamine was used to neutralize the heparin and the ventilator was used again for oxygen supply (Fig 2).

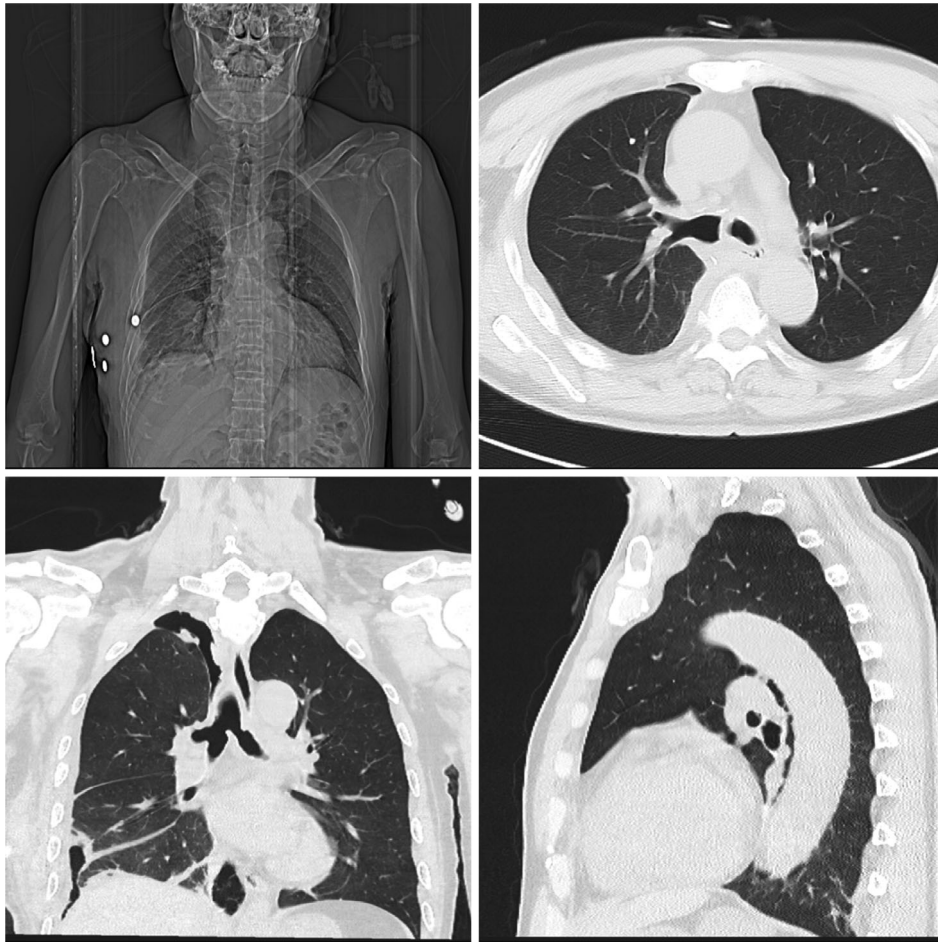


Figure 3 Postoperative three-dimensional computed tomography showed the reconstructed trachea/bronchus.

During surgery, the VV-ECMO oxygen supply was satisfactorily maintained and the surgical field was clearly revealed, as tracheal intubation did not cause any blocking. The precision of anastomosis was confirmed by repeated tests and the morphology of the reconstructed carina was verified by fiberoptic bronchoscope. Because of the administration of intraoperative systemic heparinization, the free surface of the thoracic adhesion was extensively oozing (total amount approximately 2000 mL); therefore, 1800 mL of red blood cells were transfused. After suspending the ECMO and neutralizing the heparin with protamine, the oozing immediately stopped.

Results

After the surgery, the patient returned to the thoracic surgery intensive care unit and recovered smoothly. He was discharged from the hospital eight days after the operation, and his head was kept low for two weeks by using a neck brace. Postoperative pathological results revealed low-grade mucoepidermoid carcinoma of the trachea; no tumor tissue

was found in the three margin sites of the trachea and bronchi, and no tumor metastasis was observed in the lymph nodes of each group. Postoperative three-

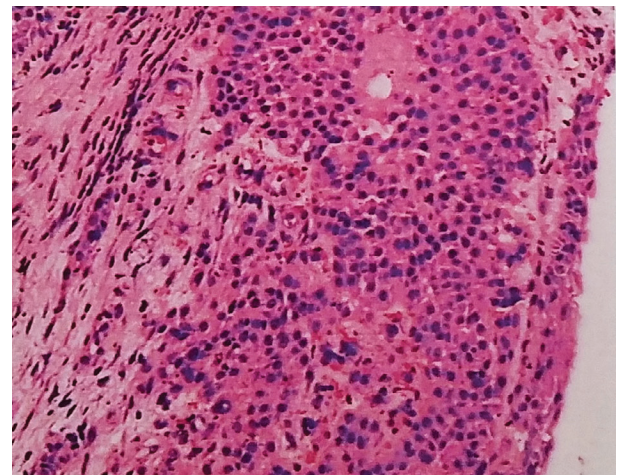


Figure 4 Postoperative pathological results revealed a low-grade mucoepidermoid carcinoma.

dimensional dynamic CT imaging of the respiratory tract showed that the trachea was in the middle, and the antero-posterior diameter of the main bronchus was approximately 10 cm (right) and 6.7 cm (left). There was no significant change in the dynamic expiratory and inspiratory phases or airway diameters (Figs 3–4).

Discussion

There are few clinical indications for carina resection and reconstruction, except for certain non-small cell lung cancer and other benign or low-grade malignant tracheal tumors that invade the carina.⁵ However, because of the particular anatomical structure of the tracheal carina, larger surgical wound, smaller surgical space, and the higher incidence of serious complications, carina resection and reconstruction is one of the most complicated and difficult thoracic operations to perform. Another challenge involved with carina resection and reconstruction is to continue oxygenation during open airway surgery. Distal airway management usually involves cross-field ventilation using endotracheal intubation or jet ventilation with an endotracheal tube, both of which may obstruct the surgical area and lead to lung barotrauma and ventilation problems.^{6,7} It is necessary to maintain the patient's oxygen supply, but also to minimize the interference of intubation to the surgery. Hypoxia during surgery can cause multiple organ malfunctions, leading to serious complications and surgical failure. Therefore, it is difficult to obtain satisfactory results using conventional ventilation.

Extracorporeal lung support (ECLS) is a mature alternative to traditional ventilation. The initial experience of intraoperative ECLS in thoracic surgery can be traced back to cardiopulmonary bypass (CPB). Several case series reported the use of CPB in extended resection of thoracic tumors involving the heart or blood vessels.^{8–10} CPB not only provides respiratory support, but also ensures hemodynamic stability, which allows safe execution of complex processes. However, some CPB-related complications have been reported, including heparinization resulting in increased demand for blood products, systemic inflammation caused by large amounts of artificial gases and pipeline surfaces, and the potential risk of systemic spread of cancer cells through inhalation and storage systems.¹¹

ECMO uses a smaller bypass circuit compared to CPB, which is a perfect alternative during lung transplantation and other cardiothoracic surgeries as there is no need for full heparinization and suction; it also has better biocompatibility.¹² ECMO can partially or completely replace heart and lung function over a short period of time.¹³ According to the circuit reflux mode it can be divided into venous-arterial (VA)-ECMO and VV-ECMO.¹⁴ VA-ECMO can

support part of or all circulatory and respiratory function, while VV-ECMO can assist respiratory function.^{14–16} In this case, we used VV-ECMO to maintain contented oxygen supply without tracheal intubation. The surgical field was clearly visible, which was very conducive to perform such a fine procedure in the small surgical space. It not only reduced the risks introduced by anesthesia and surgery, but also improved the accuracy of the anastomosis. We used right femoral vein drainage and right internal jugular vein return for intraoperative management and extubation. No additional heparin was administered as the ACT was controlled within the target range during surgery. However, this patient had severe pleural adhesions and suffered substantial wound area oozing during the procedure after heparinization. Therefore, precise adjustment of the ECMO running time and systemic heparinization, as well as accelerating the speed of anastomosis during surgery should reduce the amount of oozing in such patients.

In conclusion, ECMO-assisted endotracheal tumor resection and carina reconstruction is a simple and safe technique compared to traditional methods.

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Disclosure

No authors report any conflict of interest.

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