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Case Report

Application of extracorporeal membrane oxygenation (ECMO) in tracheal tumor resection

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Abstract: Objective: Normal gas exchange and sufficient oxygenation are key preconditions for tracheal tumor resection. Due to the complex of diseases, conventional airway management during anesthesia, in some special cases, may meet some difficulties or risks. Then, some other options should be considered. We presented three cases where extracorporeal membrane oxygenation (ECMO) was used for cardiopulmonary support during complex airway reconstruction. Case Report: Case 1 is a patient with left bronchial squamous cell carcinoma, who previously underwent left pneumectomy and now presented for carinal resection. Case 2 is a patient with a space-occupying lesion in the trachea, just above the carina and extending into the left main bronchus, with severe respiratory insufficiency and high airway resistance on mechanical ventilation. Case 3 is a patient with a near-occlusive, hemorrhagic upper tracheal mass. In all three cases, veno-arterial or veno-venous ECMO was applied during surgical resection. Results: All three patients underwent successful tracheal resection. When veno-arterial ECMO was applied, discontinuous mechanical ventilation was still required to maintain oxygenation. This was not the case for veno-venous ECMO. Conclusion: ECMO may be applied as an option of cardiopulmonary support during tracheal resection. Gas exchange is preserved while good surgical access for tracheal operations is maintained. The use of ECMO during tracheal resection is recommended for tumors invading, obstructing, or proximal to the carina, main or left bronchial lesions in which left pneumectomy was previously performed, and in patients with tracheal tumors who have difficult access for tracheotomy.

Keywords: Extracorporeal membrane oxygenation, tracheal neoplasms, thoracic surgery

Introduction

Airway management for tracheal tumor resection can be a significant challenge. Conventional measures include oropharyngeal or nasopharyngeal intubation, apnea with intermittent bag mask ventilation, fiberoptic intubation, the use of a ventilating bronchoscope, tracheostomy, and jet ventilation [1, 2]. However, in complicated tumor location and obstructing lesions, these conventional methods are not always suitable. For example, patients with only one lung, or those with upper tracheal tumors, obstructing tracheal lesions, or hemorrhage, inappropriate attempts to intubate may not result in successful oxygenation and ventilation, and may result in cardiopulmonary arrest. Occasionally, surgery was abandoned in such patients, eliminating the opportunity for survival.

We present three patients with complicated tracheal tumors who underwent resection between April 2014 to April 2015, in which extracorporeal membrane oxygenation (ECMO) was applied for cardiopulmonary support. This study was approved by the institutional review board of the Fourth Military Medical University in China. Informed consent was obtained from each patient prior to documentation of findings and results.

Case reports

Case 1

A 55 year old male (weight 74 kg, BSA 1.86 m^2) presented with two months of dry cough. 14 months earlier, he was diagnosed with a central-type squamous carcinoma of the left upper lobe and underwent left pneumectomy. He

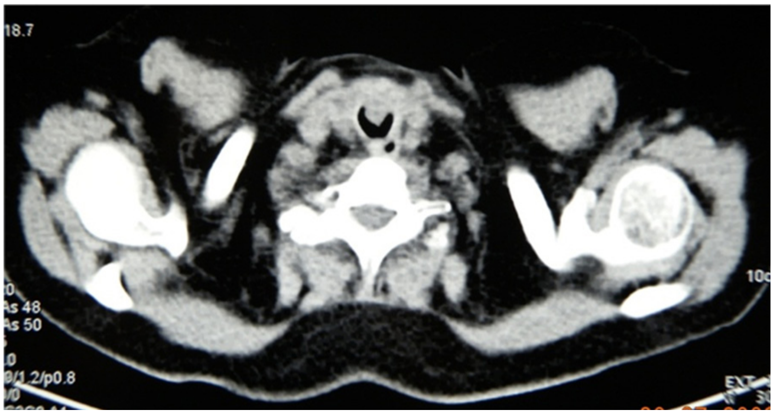

Figure 1. Preoperative CT scan, Case 3.

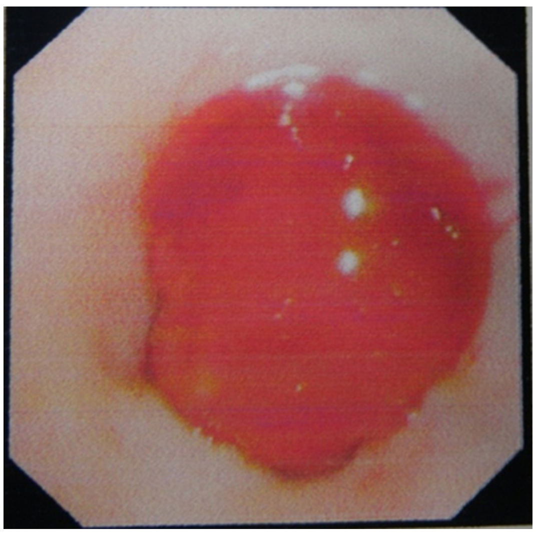

Figure 2. Preoperative bronchoscopy, Case 3.

received adjuvant four cycles of chemotherapy and one cycle of radiotherapy. Computed tomography (CT) demonstrated a left pleural effusion, without right sided or mediastinal lesions, and no lymphatic or distant metastases. Bronchoscopy demonstrated an abnormal left bronchial mucosa. The biopsy confirmed squamous cell carcinoma. He was scheduled for carinal resection. A median sternotomy was considered, which would have allowed ventilation of the right lung by endotracheal or cross-table intubation. But for carinal resection, right thoracotomy was used more commonly and would be more convenient for operation, without hindering by heart and great vessels. So a right thoracotomy approach (which requiring right lung collapse) with ECMO for cardiopulmonary support was decided.

Case 2

A 65 year old male (weight 58 kg, BSA 1.68 m^2) presented with one month of chest pain, dyspnea, and intermittent hemoptysis. He had a 20 year history of hypertension and 5 year history of coronary arterial disease. He was initially admitted to a district hospital and treated with inhaled oxygen and hemostatics. CT scan demonstrated a space-occupying lesion in the trachea, just above the carina and obstructing the left inferior lobar bronchus. Bilateral main stem bronchus stenosis, left inferior lobar atelectasis, and a left pleural effusion were present. Due to deterioration of his clinical status, he was transferred to our institution for further evaluation and treatment.

Upon evaluation in our institution, his SpO_2 was 90-93% on oxygen. The quantity of hemoptysis was 10-20 mL per day. He was transferred to ICU immediately. A bronchoscopic examination was not performed at once because of the possibility of asphyxia and bleeding. A repeat CT scan showed left pulmonary atelectasis and complete obstruction of the left main stem bronchus. On hospital day 3, he became severely dyspneic and cyanotic, and bradycardic (53 bpm) with loss of consciousness. Emergency endotracheal intubation and mechanical ventilation and resuscitation was performed. Airway resistance was very high and the patient continued to struggle on the ventilator with a SpO_2 of 81-86%, PaO_2 of 46 mmHg and $PaCO_2$ of 73 mmHg. Emergency surgical treatment with ECMO was therefore undertaken.

Case 3

A 60 year old female (weight 76 kg, BSA 1.81 m^2) presented with a 6 month history of cough, expectoration, and blood-stained sputum. Two years previously, she underwent resection of a thyroid cancer, followed by discontinuous radiotherapy. 20 days prior to admission, an outside hospital CT scan revealed right carotid artery, left supraclavicular, and suprasternal fossae lymphadenopathy. Several nodules were seen in the left upper and right inferior lobes of the

Table 1. Initiation of ECMO

		Case 1	Case 2	Case 3
Time of initiation		After general anesthesia	Prior to general anesthesia	Prior to general anesthesia
Location		operating room	ICU	operating room
Mode		VA-ECMO	VV-ECMO	VV-ECMO
Cannula	Drainage	Femoral vein		
	Return	Femoral artery	Internal jugular vein	
Flow rate		2.4 L/min/m^2		
Gas flow		4 L/min		
Oxygen concentration		80%	100%	

lungs. A soft tissue mass was visualized in the upper trachea (**Figure 1**). Differential diagnosis included 1) metastatic lung cancer; 2) secondary malignant neoplasm of the neck; and 3) supraclavicular nodal metastasis. She received chemotherapy 2 days prior to admission to our institution; however, her cough and bloody sputum worsened (100 mL/day), and was accompanied by severe dyspnea.

Emergent ultrathin bronchoscopy demonstrated a near-obstructing intratracheal mass, 1 cm in size and 1 cm below the vocal cords, with stigmata of recent hemorrhage (**Figure 2**). Due to the bleeding and location within the lumen, the patient was almost asphyxic and was scheduled for emergency surgery. Considering the risk of drop of the mass and asphyxia caused by bleeding or airway obstruct, endoscopic tumor resection was not attempted.

The patient had severe cervical cicatricial contracture as a complication of her prior thyroid cancer surgery. Due to the difficulty in performing tracheotomy and the risk of asphyxia from chronic excessive cervical rear extension, ECMO was instituted prior to general anesthesia.

Initiation and operation of ECMO

In Case 1, veno-arterial ECMO (VA-ECMO) was initiated after general anesthesia and endotracheal intubation. The patient was positioned supine and a Bio-Medicus (Medtronic) heparin-bonded venous cannula was placed in the right femoral vein as the drainage cannula; a heparin-bonded arterial cannula was placed in the right femoral artery as the return cannula. The patient was carefully placed in the left lateral decubitus position after ECMO initiation. In Case 2 and 3, veno-venous ECMO (VV-ECMO) was initiated prior to general anesthesia and the patients were placed supine throughout the entire procedure. A heparin-bonded venous cannula was placed in the right femoral vein as the drainage cannula, and a heparin-bonded arterial cannula was placed in the right internal jugular vein as the return cannula (**Table 1**).

The blood tubing package (Medtronic) consisted of a polypropylene hollow fiber membrane oxygenator, a centrifugal pump, and tubing. All components, which were all heparin-bonded, constituted the ECMO circuit. The circuit was primed with 500 ml compound electrolyte solution and driven by Bio-Console 560 extracorporeal blood pumping system (Medtronic). No heparin was given to the patient before institution of ECMO.

ECMO circulation commenced at 2.4 L/min/m^2 with 4 L/min sweep oxygen flow at 80% (Case 1) or 100% (Cases 2 and 3). ECMO circuit monitoring consisted of inlet pressure, oxygen saturation of blood in the drainage cannula, gas sweep flow, circuit flow, pump speed, and hematocrit. Invasive pressures were measured from a right radial arterial catheter and a right (Case 1) or left (Case 2 and 3) internal jugular vein central venous catheter. A pulse oximeter sensor was placed on the right fingertip.

Surgical treatment

In Case 1, right thoracotomy and carinal resection and tracheal-right bronchus anastomosis were performed. The extent of resection was 2.5 cm above the carina. In Case 2, thoracosternotomy was performed. The mass was located directly at the carina, with approximately 80% tracheal luminal obstruction. The left main bronchus was completely obstructed by hematoma and viscous sputum; thus, the carina was resected to 3 cm above the lesion. Because of severe edema and fragility of the left main

Table 2. Patients' monitor data during ECMO

	Patient 1		Patient 2	Patient 3
MAP (mmHg)	73-89		70-88	68-84
Pulse oxygen saturation (SpO_2)	Right hand	Left hand	91-94%	92-94%
	80-100%	100%		
Oxygen saturation of blood in the drainage cannula	68-82%		69-78%	72-84%
Requirement for mechanical ventilation	When mechanical ventilation was stopped, right hand SpO_2 began to decrease. Thus, discontinuous mechanical ventilation was instituted.		no	no
Hematocrit	0.31-0.36		0.27-0.33	0.29-0.33
Duration of ECMO	107 minutes		133 minutes	97 minutes

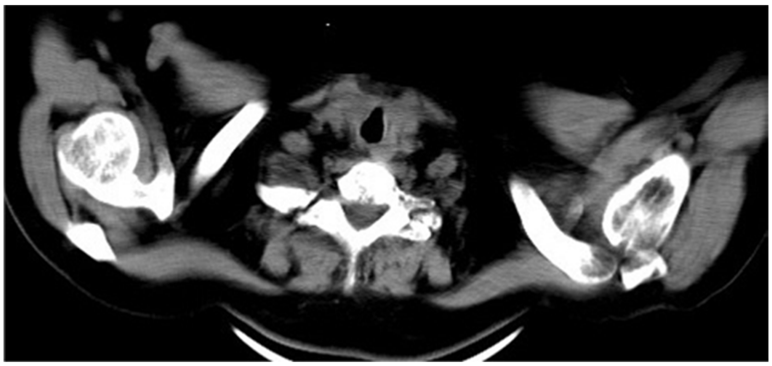

Figure 3. CT scan 1 month postoperatively, Case 3.

bronchus, it was not anastomosed to the trachea. Instead, left pneumonectomy and tracheal-right main bronchus anastomosis was performed. As in Case 3, the trachea and mass were exposed through a transverse cervical incision, through which 2 cm of trachea was resected.

Results

In Case 1 (**Table 2**), intraoperative mean arterial pressure (MAP) was 73-89 mmHg, oxygen saturation of the blood in the drainage cannula was 68-82%, and the hematocrit was 0.31-0.36. However, when mechanical ventilation was stopped, pulse oxygen saturation (SpO_2) began to decrease. When the sensor was moved to the left hand, pulse oxygen saturation was 100%. Thus, discontinuous mechanical ventilation was given to maintain a SpO_2 of 85%-100% in the right hand. The carinal resection and trachea-right bronchus anastomosis was performed in 22 minutes. During this period, the right lung was collapsed and the lowest right hand SpO_2 was 80%.

In Case 2 (**Table 2**), intraoperative MAP was 70-88 mmHg, oxygen saturation of blood in the drainage cannula was 69-78%, and the hematocrit was 0.27-0.33. During the apneic period, SpO_2 was 91-94%, and PaO_2 was 61-66 mmHg.

In Case 3 (**Table 2**), hemodynamics was stable intraoperatively, the oxygen saturation of blood in the drainage cannula was 72-84%, and the hematocrit was 0.29-0.33. During the apneic period, SpO_2 was 92-94%, and PaO_2 was 62-68 mmHg.

When tracheorrhaphy was performed, continuous mechanical ventilation was given. The flow in the ECMO circuit was gradually reduced until it was terminated. Operative times were 2 hours and 40 minutes in Case 1, 6 hours and 10 minutes in Case 2, and 2 hours and 20 minutes in Case 3. The duration of ECMO was 107 minutes, 284 minutes, and 97 minutes, respectively.

Postoperatively, all three patients were initially admitted to the intensive care unit, sedated and on mechanical ventilation. 24 hours later, fiberoptic bronchoscopy was performed to rule out swelling, bleeding, and residual disease, after which the patients were extubated. All three patients were transferred to the general ward on postoperative day 2, and discharged within 14 days. One month postoperative CT scan demonstrated complete resolution of tracheal stenosis in all three cases (**Figure 3**). Postoperative histopathology confirmed the lesions to be squamous cell carcinoma (Case 1), small cell carcinoma (Case 2), and adenocarcinoma (Case 3).

Discussion

Normal gas exchange and oxygenation are key preconditions for tracheal tumor resection. In the cases presented in this report, traditional assisted ventilation was not suitable. In Case 1, carinal resection would have often been performed with cross-table intubation in the distal trachea. However, as the patient had undergone prior left pneumectomy, right thoracotomy and right lung collapse were required; thus, traditional endotracheal ventilation and oxygenation were impossible. In Case 2, the patient's significant respiratory insufficiency confirmed the fact that the tracheal stenosis had reached a critical level of 75% or greater. Mechanical ventilation would not have been able to supply enough oxygenation and would lead to high airway resistance. In Case 3, the patient had a near-obstructing, actively hemorrhagic upper tracheal mass. In this situation, blind induction of anesthesia and intubation may have caused complete airway obstruction, with the risk of distal dislodgment of portions of the mass and an increased airway obstruction due to the movement of the mass itself. Any of these would lead to cardiopulmonary arrest. Under these circumstances, ECMO was considered to be the most appropriate solution.

Conventional cardiopulmonary bypass (CPB) or percutaneous cardiopulmonary support (PCPS) has been used during surgical treatment of airway stenosis in some institutions [3-7]. However, there are potential disadvantages in using CPB. First, systemic anticoagulation increases the risk of postoperative bleeding [7]. For those who require extensive dissection or a staged operation, postoperative bleeding can be fatal. Second, the CPB circuit contains a venous reservoir with an air-blood interface, which is associated with a high risk of coagulopathy and systemic inflammatory response [2, 8]. Third, CPB may adversely affect pulmonary and renal function due to leukocyte sequestration and activation [2, 9].

ECMO can overcome the problems associated with CPB. With heparin bonded cannula and the blood tubing package, the ECMO circuit has better histocompatibility than CPB, and intravenous heparin is not required for such a relatively short operative time. In our patients, the range of time of ECMO was between 97-284 minutes. There was no evidence of clotting in the ECMO circuit; moreover, it is hermetic with no air-blood interface. All these features result in fewer postoperative complications than with CPB.

In Case 1, VA-ECMO was instituted; however, SpO_2 of the right hand was unsatisfactory, meaning that oxygenation to the right upper body was insufficient. This is likely due to the fact that the heart was pumping deoxygenated blood through the right lung, resisting the oxygenated femoral arterial blood. To avoid fatal coronary and cerebral ischemia, discontinuous mechanical ventilation was given, which interrupted the operation. These experiences illustrate that VA-ECMO may not be the ideal choice in this situation. In the Cases 2 and 3, VV-ECMO was applied, resulting in the least change in hemodynamics. Although arterial blood is a mixture of oxygenated and deoxygenated blood, sufficient ECMO flow and pure oxygen results in adequate blood oxygen content (SpO_2 91-94% in these cases).

Previous reports have described bronchoscopic removal of tracheal stents and endoscopic laser resection of obstructing tracheal tumor under ECMO [2, 10, 11]. In these cases, the tumors were largely near or across the carina, so conventional tracheal intubation would be inappropriate. ECMO has also been used in tracheal surgery of infants with desirable results [10, 12]. In our cases, 2 patients required carinal resection. In the patient with ongoing hemorrhage, endoscopic treatment may have caused distal dislodgment of fragments of the mass. Thus, thoracotomy or cervical incision was performed. All three operations were successful with the institution of ECMO.

Conclusion

In summary, we deem that patients who are unsuitable for conventional tracheal intubation and mechanical ventilation, as in tumors invading the carina, in nearly obstructive lesions, in main stem bronchus or carinal lesions after left pneumectomy, or patients with difficult anatomy for tracheotomy, ECMO is a safe and effective alternative during tracheal resection. It allows for normal gas exchange and provides good surgical access for tracheal operations, avoiding aggravating hypoxia and carbon dioxide accumulation caused by inappropriate intubation and ventilation. Because of its minimal disturbance to circulatory function and satisfactory global oxygenating function, VV-ECMO is preferable to VA-ECMO.

Disclosure of conflict of interest

None.

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