Extra-corporeal membrane oxygenation for thyroid surgery in patients with severe tracheal stenosis

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Abstract
Venovenous extra-cor-poreal membrane oxygenation is effective for maintaining gas exchange in patients with respiratory failure or severe tracheal stenosis. Perioperative anesthetic management of severe airway obstruction can be associated with ventilation or intubation difficulties. Consequently, venovenous extra-corporeal membrane oxygenation could be an option for treating such patients to avoid potential risks. However, only a limited number of similar cases have been reported. Therefore, we have summarized two cases to provide theoretical and practical references for treating patients with respiratory failure or severe tracheal stenosis using extra-corporeal membrane oxygenation.

Keywords
Extra-corporeal membrane oxygenation, tracheal compression, severe tracheal stenosis, anesthesia, difficult airway

Introduction
A giant thyroid gland can compress the trachea, leading to anatomical changes. In this instance, perioperative anesthe-sis management is complex in patients with predictable difficult airways. Currently, in managing patients with difficult airways, a sequence of interventions is recommended from laryngoscopy and endotracheal tube placement to a supraglottic airway device, face mask ventilation, and cricothyrotomy.¹,² However, in very severe cases, these procedures may be impossible and even dangerous, and failure to establish an advanced airway may further lead to complete airway obstruction. Thus, venovenous extra-cor-poreal membrane oxygenation (vv-ECMO) is being increasingly accepted perioperatively, as it can be used not only to support ventilation in patients with respiratory failure, but also to manage hypoxic patients with critical airway obstruction during various procedures, such as stent placement and removal, rigid bronchoscopy, or pediatric surgery.³–⁷ Here, we report two patients with giant thyroid tumors who had progressive dyspnea due to airway stenosis, who underwent successful tumor removal where extra-corporeal membrane oxygenation (ECMO) was prophylactically implanted to prevent airway-related problems.

Case
Patients 1 (age/weight/height: 68 years/55.4 kg/1.63 m, respectively) and 2 (age/weight/height: 78 years/50 kg/1.45 m, respectively), with dyspnea for 14 h and 14 days, respectively, were shown by computed tomography (CT) to have compression of the enlarged thyroid gland, with the narrowest points of the trachea being 2 mm and 1.7 mm, respectively (Figures 1 and 2).

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After being monitored, when each patient entered the operating room, ECMO was prepared with the Sorin ECMO tubing system (Oxygenator D905 EOS with REVOLUTION™ pump and Sorin PTS) primed by isotonic electrolyte solution. Both patients remained awake and were administered oxygen therapy via a non-rebreather mask. Local infiltration anesthesia was performed under sterile conditions with 1% lidocaine, and activated clotting time (ACT) was maintained for 160–200 s with 5000 IU heparin sodium. Color-Doppler ultrasound was utilized for evaluation of the vascular bed and to guide percutaneous cannulation of ECMO with transesophageal echocardiography (TEE) for tube position in superior vena cava (SVC). In each patient, one catheter was inserted into the inferior vena cava via the femoral vein for drainage (Medos 20F, Xenios AG, Heilbronn, Germany), and the other into the right internal jugular vein for perfusion (Medos 18F, Xenios AG, Heilbronn, Germany).

Patient 1 had dyspnea due to pain during incision dilatation and cannula over the guidewire, and oxygen saturation decreased to 88% (Figure 3). After implementation of supplemental oxygen via a face mask at 8 L/min, mitigating anxiety, and increasing the dosage of local anesthetics, the patient was calmed and saturation returned to baseline level (100%). The initial ECMO settings included a flow of 3.5 L/min, speed of 3200 revolutions/min, and inspiratory oxygen fraction (FiO2) of 100%.

With ECMO support, induction of general anesthesia was achieved using intravenous midazolam (3 mg), sufentanil (20 μg), propofol (60 mg), and rocuronium (30 mg). When loss of consciousness and muscle relaxation was achieved, an enhanced endotracheal tube (internal diameter, ID: 6.0 for patient 1; ID 5.0, patient 2) was directed into the glottis with visual laryngoscopy. Visual laryngoscopy was then changed to fiberoptic bronchoscopy (outer diameter, ODs: 3.8) to continue intubation (Figure 4). After the narrowest airway was dilated to show the tracheal carina and the depth of the tube was confirmed as connected to the anesthetic machine for mechanical ventilation, the flow rate of ECMO was decreased to 1L/min when pulse oxygen saturation reached 100%. The peripheral capillary oxygen saturation (SpO2) of patient 1 had decreased to 88% 3 min after initiation of ECMO and returned to 100% after the anesthetic machine provided adequate pulmonary gas exchange (Table 1). In contrast, the SpO2 of patient 2 showed an uneventful curve during the entire process.

With tracheal stenosis relief postoperatively, arterial blood gas analysis was performed after the sweep gas of the ECMO was turned off for 20 min. The results confirmed that the patients could support oxygenation and ventilation without ECMO (Table 1). Consequently, the patients were weaned off ECMO and transferred to the intensive care unit (ICU) for further monitoring. Both

Figure 1. Imaging results of patient 1. Trachea was displacing and severely narrowing by mass (red arrow). (a) CT of airway stenosis in pulmonary window; (b) CT of airway stenosis in pulmonary window; and (c) 3D reconstruction of cervical airway and vessels.
patients recovered spontaneous respiration confirmed by blood gas analysis every 2 h in the ICU and were successfully extubated and sent to the general ward safely 19 and 26 h postoperatively. Eventually, they underwent uneventful recovery and were discharged on the 5th and 7th days after operation without dyspnea or other complications of anesthesia or ECMO. The final pathological diagnosis confirmed thyroid nodular goiter for patient 1 and Hashimoto thyroiditis and thyroid nodular goiter for patient 2.

**Discussion**

Severe tracheal stenosis is relatively rare, and the most common cause is thyroid gland enlargement. It is inadvisable for an anesthetist to insert an endotracheal tube, as careless
induction of anesthesia may result in failure in intubation, further hypoxemia, and even respiratory or cardiac arrest due to airway obstruction. Under these circumstances, ECMO emerges as a reliable alternative for treatment. Given cardiac function was normal, vv-ECMO was adopted in these two patients to reduce the risk of developing respiratory compromise, with fewer complications. In our case series, the trachea of each patient was narrow. As a result, we relied on adequate local anesthesia before general anesthesia rather than sedative drugs or opioids, given the concern that, although the inhibitory effect of these medicines on respiration is minor, they may still impact the fragile balance between ventilation and central airway obstruction, leading to major respiration problems. This treatment modality has been utilized, while many studies still report sedation during cannulation. Considering the small number of similar studies published, the optimal treatment during cannulation needs further research.

Notably, compared with the stability of patient 2, patient 1 demonstrated a gradual decrease in SpO2 to 88% after ECMO. A possible explanation for this effect is that the drainage and perfusion cannula are closed in venovenous procedures, allowing oxygenated blood into the ECMO circuit again and ECMO deoxygenated blood into circulation, acknowledged as recirculation, thereby reducing the overall efficiency of gas exchange. Considering that recirculation could not be fully eliminated, the Extracorporeal Life Support Organization (ELSO) guideline explicitly states

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**Figure 3.** Curves of SpO2 of patients at each critical time point.

**Figure 4.** The patient was performed endotracheal intubation guided by fiberoptic bronchoscopy after implementation of ECMO.
that oxygen delivery from the circuit should be adequate for full support (systemic saturation greater than 80\% with PaO₂ 40 mmHg (VV) at low ventilator settings and FiO₂), which was a criterion fulfilled in our two cases. 9 Given our concern to avoid excessive recirculation during ECMO support, we preferred fem-jug rather than fem-fem, as the return blood is directed toward the SVC rather than the tricuspid valve, potentially creating abnormal flows away from the valve and more recirculation. This might produce a lower capacity for gas change in replacement of lungs without the establishment of an advanced airway. If failure to establish an advanced airway occurs, poor oxygenation capacity can put the patient at risk. This ECMO pattern and therapeutic use have been presented in other similar studies.10 After intubation, although SpO₂ in both patients was normal, and gas exchange was controlled by mechanical ventilation, ECMO was still run to prevent the risk of thrombosis in the ECMO circuit.

However, as it is invasive, ECMO may cause side effects, including potentially life-threatening complications, such as bleeding, hemolysis, air leakage, and thrombosis.3,11 Nevertheless, safe and calm management is always preferable over hurried decisions in the event of acute cardiopulmonary compromise. In this report, although ECMO played a role in supporting gas exchange entirely only for a short while, it provided time and calmness to deal with the airway, allowing the vital signs to remain stable in the event of failure to manage endotracheal intubation. More studies are needed to evaluate complications in shorter periods of time compared with those of patients with traditional indications, to provide a reference for clinical applications and follow-up studies.

**Conclusion**

Our findings suggest that vv-ECMO could play a role in managing severe central airway obstruction, as it provides doctors with adequate time to plan and implement management of patients. Although the risks and benefits should be weighed before making a decision, the use of ECMO for gas exchange before the induction of general anesthesia may be a rational and effective strategy to guarantee safety in patients with severe central airway obstruction. The indications for ECMO should be further expanded.

**Author contributions**

Y.Z. and X.Y. managed ECMO of the patients; L.Z. and Y.W. managed anesthesia of the patients; J.D. and C.X. managed patients in the ICU; C.L. managed surgery of the patients; Z.L. and Y.G. drafted the article. All authors read and approved the final manuscript.

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**Ethical approval**

Our institution does not require ethical approval for reporting individual cases or case series.

**Informed consent**

Written informed consent was obtained from patients for their anonymized information to be published in this article.

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