CASE REPORT

Intraoperative Use of Veno-Arterial ECMO in Tracheal Surgery: Two Case Reports

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ABSTRACT

Background: Tracheal tumors and stenosis are rare but potentially life-threatening conditions due to severe airway obstruction. Anesthetic management during tracheal surgery is particularly challenging because of the high risk of hypoxia and ventilation failure during airway manipulation. Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) has been used as a supportive strategy to maintain oxygenation and circulation during high-risk procedures, although clinical experience remains limited.

Case: We report two cases of tracheal surgery performed with perioperative VA-ECMO support. The first case involved a 55-year-old man presenting with progressive dyspnea and cough for three months. Bronchoscopic examination revealed a tumor in the distal third of the trachea, and the patient underwent tumor resection with tracheal reconstruction. The second case was a 15-year-old male with hoarseness and respiratory symptoms following prolonged intubation. Bronchoscopy demonstrated cicatricial tracheal stenosis in the proximal third of the trachea, and the patient underwent endobronchial laser therapy followed by tracheal bougienage. In both patients, VA-ECMO with femorofemoral cannulation was established preemptively before anesthetic induction, with a single bolus of systemic heparinization (400 IU/kg). During airway manipulation, mechanical ventilation was suspended, and oxygenation was maintained through ECMO. An episode of Harlequin syndrome was managed by increasing the ECMO blood flow. Both procedures were completed without major perioperative complications.

Discussion: These cases illustrate the complexity of anesthetic management in high-risk tracheal surgery. VA-ECMO facilitated airway manipulation by maintaining adequate oxygenation and hemodynamic stability during critical intraoperative periods, while requiring close monitoring for ECMO-related complications.

Conclusion: VA-ECMO may be considered as an intraoperative support strategy in tracheal surgery with a high risk of airway obstruction. This case report highlights the potential role of VA-ECMO in increasing the safety margin of anesthetic management, although further evaluation is needed to define optimal indications and protocols.

Keywords: airway management; differential hypoxemia; ECMO; high-risk tracheal surgery; perioperative care

INTRODUCTION

Tracheal tumors are rare, with an incidence of approximately 0.1 per 100,000 population per year, and are malignant in about 90% of adult cases.[1] Surgical resection is required because it is associated with improved 5-year survival rates.[2] Furthermore, airway stenosis is a life-threatening condition that requires prompt intervention and may result from various causes, including tracheal intubation, tuberculosis, and autoimmune diseases.[3] Airway surgery involving the trachea and bronchi presents unique challenges in achieving effective airway management.[4] Airway manipulation during surgical procedures may lead to hypoxia and even cardiac arrest. Therefore, maintaining adequate oxygenation and ventilation during tracheal surgery represents a significant challenge for anesthesiologists, as airway patency and respiratory function are top priorities.[3,5]

Extracorporeal membrane oxygenation (ECMO) has been increasingly used as a supportive modality during high-risk airway interventions. The application of ECMO in tracheal repair procedures is relatively recent and has shown growing evidence in facilitating complex airway interventions. This approach may improve patient outcomes.[6,7] Several ECMO strategies are available, including veno-venous extracorporeal membrane oxygenation (VV-ECMO), with cannulation via the femoral vein–internal jugular vein or femoral vein–femoral vein, and veno-arterial extracorporeal membrane oxygenation (VA-ECMO), cardiopulmonary bypass (CPB), or modified CPB, which involve cannulation of the femoral artery and vein for patients requiring circulatory support, particularly in cases of circulatory collapse or significant surgical bleeding.[8]

CASE

First Case

A 55-year-old man weighing 50 kg presented with progressive dyspnea accompanied by intermittent cough and hoarseness for the past three months admitted to the outpatient department in October 2025. The cough was productive with a small amount of yellow sputum. Hemoptysis was denied. The patient had previously received treatment from a pulmonologist without significant clinical improvement. He had a history of heavy smoking for approximately 20 years, while a history of hypertension, cerebrovascular disease, and diabetes mellitus was denied.

Physical examination revealed a conscious patient with a blood pressure of 140/92 mmHg, a heart rate of 66 beats/min, a respiratory rate of 24 breaths/min, an oxygen saturation of 95% on room air, and a body temperature of 36.4°C. The patient was underweight. Pulmonary auscultation demonstrated vesicular breath sounds with coarse bilateral crackles.

Chest radiography showed left lung hyperaeration, traction bronchiectasis in the left upper lung zone, bilateral pneumonia, and minimal left pleural effusion suspicious for subpleural pulmonary metastasis. A thoracic CT scan performed in June 2025 revealed an endobronchial mass extending from the carina to the left main bronchus, with mediastinal invasion causing compression and narrowing of the carina and left main bronchus. The mass was adherent to the left pulmonary artery and pulmonary trunk, resulting in collapse of the left lower lobe, narrowing of the left hemithorax, leftward displacement of the trachea, mediastinal organs, and heart, elevation of the left hemidiaphragm, deformity of the left thoracic cavity, and multiple lymphadenopathies.

In July 2025, cryobiopsy and bronchoscopic recanalization were attempted by a pulmonologist but were unsuccessful. Bronchoscopy demonstrated a mass in the distal third of the trachea with smooth mucosa, mobility, firm consistency, hypervascularization, and a tendency to bleed easily; the carina could not be evaluated. In September 2025, rigid bronchoscopy performed by an otorhinolaryngologist confirmed the presence of a mass occupying the distal third of the tracheal lumen with secretions. The patient was diagnosed with a distal-third tracheal tumor extending to the left main bronchus and was referred to a thoracic surgeon for tracheal repair via sternotomy.

With the patient in the supine position, standard monitoring, including non-invasive blood pressure, electrocardiography, and pulse oximetry, was applied. Premedication consisted of ondansetron 4 mg and dexamethasone 5 mg. Low-dose spinal anesthesia was performed using 40 mg hyperbaric prilocaine, combined with a continuous morphine infusion at 10 mcg/kg/h. Preemptive femoral venous and arterial cannulation for VA-ECMO was performed by the thoracic surgery team while the patient received supplemental oxygen via nasal cannula at 3 L/min. Immediately before cannulation, a single bolus of systemic heparinization (400 IU/kg; total 20,000 IU) was administered to achieve an activated clotting time (ACT) greater than 480 seconds.

Before induction of general anesthesia, a right radial arterial catheter and a right internal jugular central venous catheter were placed. General anesthesia was induced with midazolam 3 mg, sufentanil 20 mcg, and desflurane at 6% concentration. Fiberoptic-guided intubation was performed using a 6.0-mm endotracheal tube advanced into the right main bronchus. After confirmation of tube position, atracurium 30 mg was administered.

Anesthetic depth was maintained with inhaled desflurane at 4–6% concentration, continuous atracurium infusion at 10 mcg/kg/min, and morphine infusion at 10–20 mcg/kg/h. VA-ECMO was applied using a modified CPB configuration. ECMO parameters were maintained as follows: blood flow 50–70 mL/kg/min, gas-to-blood ratio 0.5–1.0, and fraction of sweep gas oxygen (FGO_2) 50–70%. Blood flow and sweep gas flow were adjusted based on pulse oximetry and arterial blood gas analysis to maintain arterial oxygen tension (PaO_2) between 60–80 mmHg and arterial carbon dioxide tension ($PaCO_2$) between 35–45 mmHg. Normothermia was maintained at approximately 36.5°C.

Arterial blood gas analysis and oxygen saturation were routinely monitored via the radial arterial line to detect differential hypoxemia, while near-infrared spectroscopy (NIRS) was used for cerebral oxygenation monitoring. ACT was measured every 30 minutes, targeting 160–200 seconds during ECMO support.

During airway manipulation, ventilatory function was fully supported by ECMO. After approximately 20 minutes, an episode of Harlequin syndrome (differential hypoxemia) occurred, secondary to cessation of mechanical ventilation during VA-ECMO support, resulting in acute desaturation. Oxygenation improved following an increase in ECMO blood flow.

After tumor resection and tracheal anastomosis, intraoperative bronchoscopy through the endotracheal tube was performed to confirm the absence of active airway bleeding. ECMO support was gradually weaned from partial to complete discontinuation as ventilatory support was fully resumed by the mechanical ventilator. The endotracheal tube was then exchanged for a larger size using a bougie.

Following surgery, the patient was transferred to the intensive care unit (ICU) for close monitoring. The endotracheal tube was maintained for three days to ensure airway patency and to prevent postoperative complications such as laryngeal edema, anastomotic bleeding, vocal cord injury, and subcutaneous emphysema. Upon ICU admission, the patient was hemodynamically stable with a blood pressure of 157/102 mmHg, heart rate of 124 beats/min, respiratory rate of 14 breaths/min, and oxygen saturation of 100% on mechanical ventilation with an inspired oxygen fraction of 50%.

Analgesia was provided with continuous morphine infusion at 10–20 mcg/kg/h during ICU care. After three days, the patient remained hemodynamically stable, allowing gradual ventilator weaning and subsequent extubation. Twenty-four hours after extubation, the patient remained stable and was able to communicate effectively, after which he was transferred to the general ward.

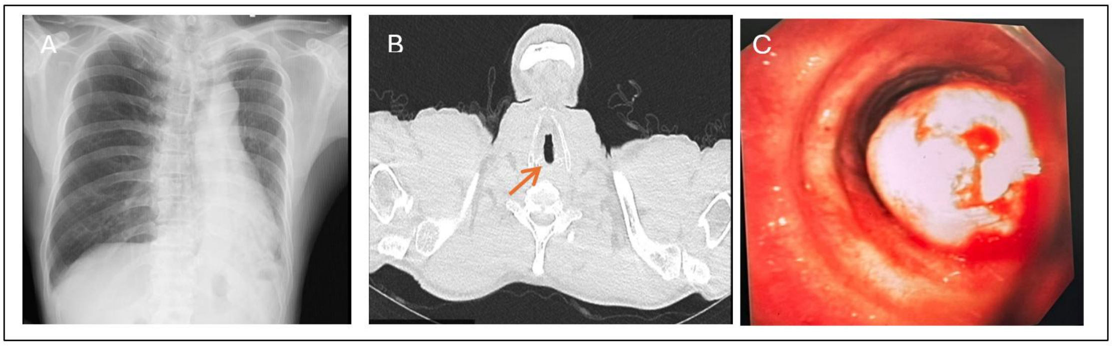

Figure 1. Preoperative diagnostic evaluation of Patient 1. (A) Chest radiograph; (B) Thoracic CT scan showing narrowing of the tracheal lumen (red arrow); (C) Bronchoscopic findings demonstrating a mass in the distal third of the trachea

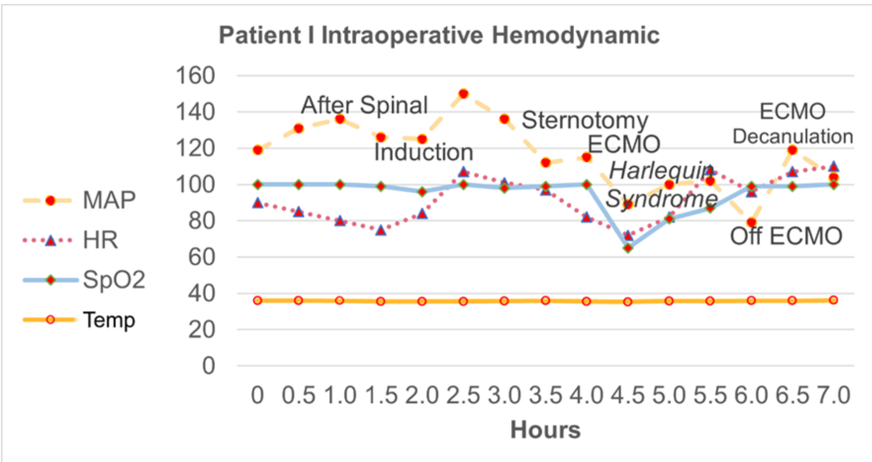

Figure 2. Patient I intraoperative hemodynamics

Table 1. Changes in intraoperative hemodynamic variables during tracheal surgery (Patient 1)

Hrs	RE	SE	SPI	Right NIRS (%)	Left NIRS (%)	SVR (dynes/cm²)	CO (L/min)	CI (L/min/m^2)	CVP (mmHg)	Description
1.0	89	86	29	71						After spinal
1.5	58	48	26	71	67	1156	8.1	7.7	20	Before induction
2.0	51	49	56	75	73	1067	6.6	6.3	25	Intubation
2.5	33	33	47	81	79	1262	7.8	7,3	25	Post-intubation
3.0	41	41	47	80	84	1193	5.5	5,2	22	Sternotomy
3.5	45	45	40	70	79	867	4.8	4,5	20	
4.0	43	42	36	58	69	700	5.6	5,5	19	on ECMO
4.5	46	43	19	41	57	1648	5.0	4,7	21	
4.6	37	37	18	41	38	874	7.6	7,2	25	Desaturation
5.0	50	47	20	41	42	811	7.1	6,7	29	
5.5	53	52	21	60	42	950	6.4	6.0	27	
5.6	36	35	55	70	62	1052	7.0	6.7	25	ECMO weaning
6.0	38	37	71	74	68	891	4.4	4.2	23	Off ECMO
6.5	35	35	44	75	70	791	9.2	8.7	22	ECMO Decannulation
7.0	37	38	45	75	72	920	9.1	8.8	21	

RE: response entropy; SE: state entropy; SPI: surgical pleth index; NIRS: near infrared spectroscopy; SVR: systemic vascular resistance; CO: cardiac output; CI: cardiac index; CVP: central venous pressure

Second Case

A 15-year-old male weighing 83 kg (predicted body weight 68 kg) presented with progressive hoarseness following extubation after a 5-day stay in the pediatric intensive care unit (PICU) four months earlier, where he had been treated for decompressive craniectomy due to subarachnoid hemorrhage (SAH) and subdural hematoma (SDH). His symptoms had worsened since August 2025. Hoarseness was accompanied by audible breathing, which was exacerbated by physical activity.

Preoperative examination revealed a conscious patient (compos mentis) with a blood pressure of 136/83 mmHg, heart rate of 95 beats/min, respiratory rate of 24 breaths/min, oxygen saturation of 98% on room air, and body temperature of 36.5°C. The patient was overweight. Pulmonary examination demonstrated biphasic stridor and wheezing during both inspiration and expiration, most prominent in the suprasternal region and the right second to third intercostal spaces.

A CT scan performed in August 2025 showed bilateral thickening of the longus colli muscles and the bilateral visceral space, resulting in airway narrowing at the level of the C7 vertebral body, suggestive of laryngitis. Bronchoscopic evaluation performed during the same period revealed proximal tracheal stenosis due to cicatricial tissue involving the proximal third of the trachea, with tracheal nodules located at the 6 and 12 o'clock positions. The patient was diagnosed with chronic airway obstruction secondary to tracheal stenosis.

Despite treatment with nebulized therapy and oral methylprednisolone prescribed by the pediatric team, no clinical improvement was observed. The patient was subsequently referred to a thoracic surgeon. Balloon dilatation of the tracheal stenosis was attempted in September 2025 but was unsuccessful, leading to a planned endobronchial laser tracheal repair with ECMO support.

With the patient in the supine position, standard monitoring, including non-invasive blood pressure, electrocardiography, and pulse oximetry, was applied. Premedication consisted of ondansetron 4 mg and dexamethasone 5 mg. Low-dose spinal anesthesia was performed using 40 mg hyperbaric prilocaine, combined with continuous morphine infusion at 10 mcg/kg/h. Preemptive femoral venous and arterial cannulation for VA-ECMO was performed by the thoracic surgery team while supplemental oxygen was administered via nasal cannula at 3 L/min. Immediately before cannulation, a single bolus of systemic heparinization (400 IU/kg; total 27,000 IU) was administered to achieve an ACT greater than 480 seconds.

Before induction of general anesthesia, a right radial arterial catheter and a right internal jugular central venous catheter were placed. General anesthesia was induced with midazolam 3 mg, sufentanil 20 mcg, and desflurane at 6% concentration. Fiberoptic-guided intubation was performed using a 7.0-mm endotracheal tube positioned proximal to the stenotic lesion. After confirmation of tube position, atracurium 50 mg was administered. Anesthetic depth was maintained with inhaled desflurane at 4–6% concentration, continuous atracurium infusion at 10 mcg/kg/min, and morphine infusion at 10–20 mcg/kg/h.

Immediately before airway intervention, mechanical ventilation was replaced by VA-ECMO support. ECMO parameters were maintained as follows: blood flow

50–70 mL/kg/min, gas-to-blood ratio 0.5–1.0, and FGO_2 50–70%. Blood flow and sweep gas were adjusted based on pulse oximetry and arterial blood gas analysis, as described for Patient 1.

Endobronchial laser therapy was performed through the endotracheal tube using laser settings of 10–20 W and high-frequency electrocautery at 40 W. Multiple applications were required to reduce the stenosis; however, the procedure was technically challenging due to septated tracheal stenosis. Consequently, tracheoplasty with balloon dilatation was performed from the distal aspect of the lesion. Intraoperatively, an episode of differential hypoxemia (Harlequin syndrome) occurred, similar to that observed in Patient 1.

Tracheal stent placement was not performed because of financial constraints. After completion of the airway intervention, a temporary tracheostomy was created to protect the airway until postoperative stabilization and restoration of tracheal lumen patency. ECMO support was gradually weaned and discontinued as ventilatory support was fully resumed by the mechanical ventilator.

Following surgery, the patient was transferred to the ICU for close monitoring with the tracheostomy maintained to ensure airway patency. Upon ICU admission, the patient's blood pressure was 96/42 mmHg, heart rate 120 beats/min, respiratory rate 20 breaths/min, and oxygen saturation 99% on mechanical ventilation with an inspired oxygen fraction of 60%.

Analgesia was provided with continuous morphine infusion at 10–20 mcg/kg/h. After 24 hours of ICU care, the patient remained hemodynamically stable, allowing transition from mechanical ventilation to tracheostomy mask oxygen at 8 L/min. On the following day, the patient was transferred to the general ward in stable condition.

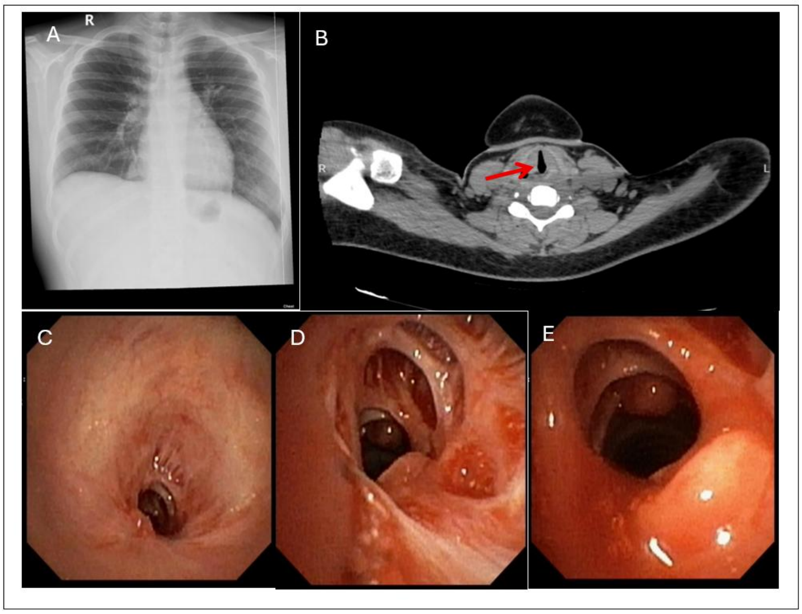

Figure 3. Preoperative diagnostic evaluation of Patient 2. (A) Chest radiograph; (B) Thoracic CT scan demonstrating tracheal lumen stenosis (red arrow); (C) Bronchoscopic findings showing stenosis in the proximal third of the trachea; (D) Multiple septated cicatricial tissue; (E) Tracheal nodules at the 6 and 12 o'clock positions.

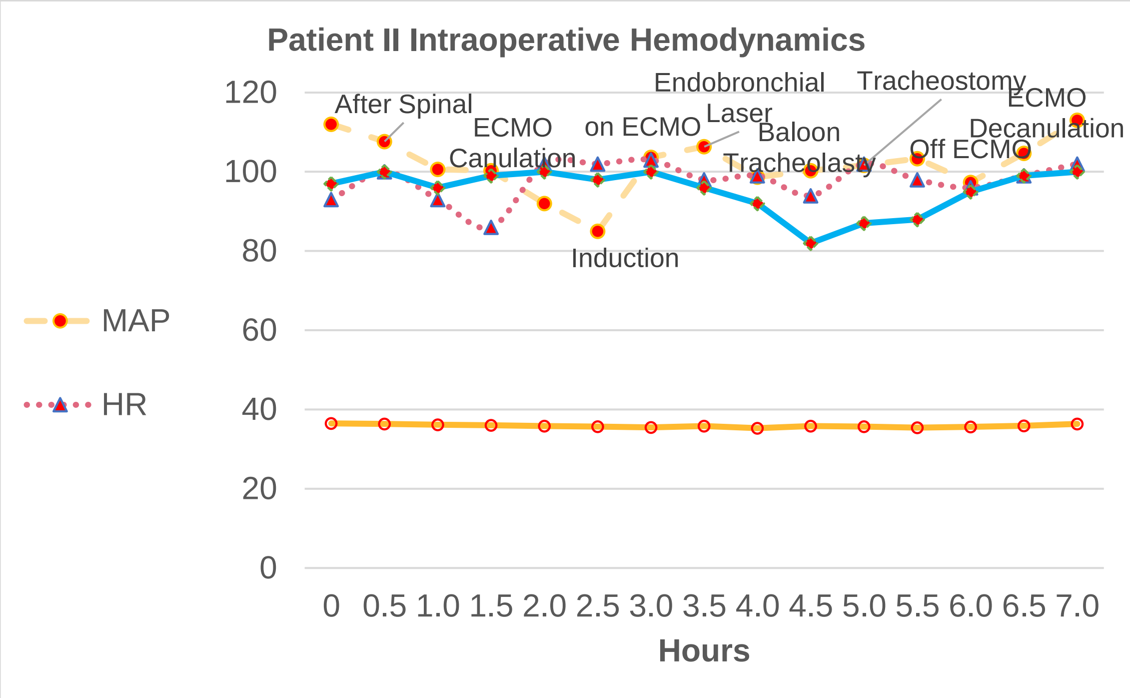

Figure 4. Patient II intraoperative hemodynamics

Table 2. Changes in intraoperative hemodynamic variables during tracheal surgery (Patient 2)

Hrs	RE	SE	SPI	Right NIRS (%)	Left NIRS (%)	SVR (dynes/cm²)	CO (L/min)	CI (L/min/m^2)	CVP (mmHg)	Keterangan
0.5	99	89	85	91	72	640	11.0	5.6	7	After Spinal Anesthesia
1.0	98	88	85	80	85	1135	6.2	3.2	10	Incision for Canulation
1.5	98	89	46	81	88	1099	6.7	3.4	9	ECMO Canulation
2.0	94	86	35	81	89	1600	4.5	2.3	7	
2.5	90	83	34	81	90	1083	6.5	3.3	7	Intubation
3.0	42	39	35	79	78	1065	5.6	5.5	8	ECMO start
3.5	40	39	36	78	72	1076	5.0	4.7	7	Endobronchial Laser
4.0	35	33	19	72	71	1089	5.2	5.9	8	Balloon Tracheoplasty
4.5	33	35	25	61	65	987	6.2	6.1	6	
5.0	45	47	20	58	55	950	5.5	5.3	7	Tracheotomy
5.5	44	42	19	60	62	1052	6.2	6.6	8	ECMO weaning
6.0	36	35	20	70	68	976	5.1	5.6	7	ECMO Off
6.5	38	37	43	74	70	975	6.5	6.7	8	ECMO Decannulation
7.0	34	35	40	75	72	920	6.4	6.8	8	End of surgery

RE: response entropy; SE: state entropy; SPI: surgical pleth index; NIRS: near infrared spectroscopy; SVR: systemic vascular resistance; CO: cardiac output; CI: cardiac index; CVP: central venous pressure

DISCUSSION

The diagnosis and management of both cases illustrate the complexity of perioperative care, particularly in maintaining adequate oxygenation and circulatory stability during high-risk airway manipulation using ECMO.[3] ECMO is an established rescue therapy for patients with severe respiratory compromise and has been recognized as an effective strategy for maintaining oxygenation during surgical procedures involving critical airway pathology.[9]

Although both patients were hemodynamically stable preoperatively and could physiologically have been supported with VV-ECMO for isolated respiratory assistance, VA-ECMO was selected based on procedural context and immediate feasibility at the time of surgery. Both operations were performed on the same day, and the available ECMO configuration supported femorofemoral VA-ECMO deployment. Accordingly, VA-ECMO was employed as the extracorporeal support strategy during airway intervention. Recognizing the modality-specific risk of differential hypoxemia (Harlequin syndrome) associated with peripheral VA-ECMO in patients with preserved native cardiac output, a predefined monitoring and mitigation strategy was implemented.[10,11] Continuous cerebral NIRS, radial arterial blood gas analysis, and close surveillance of systemic oxygenation were used to facilitate early detection of upper-body hypoxemia. When differential hypoxemia was observed, ECMO blood flow and sweep gas settings were promptly adjusted to augment systemic oxygen delivery. Although maximal flow optimization was limited by cannula size, early recognition and timely intervention were sufficient to restore adequate oxygenation.[12] These cases emphasize that ECMO modality selection in complex airway surgery may be influenced by procedural context and that proactive monitoring and mitigation are essential to minimize modality-specific complications.

Theoretically, definitive treatment for tracheal stenosis or tracheal tumors is tracheal resection with end-to-end anastomosis (TREE), which offers favorable long-term outcomes.[13] However, this approach is not always selected as the first-line strategy because of its technical complexity and the substantial risks associated with perioperative airway management.[14] In the present report, the first case involved a distal third tracheal tumor with extension into the left main bronchus. Tumor resection and tracheal repair were performed with VA-ECMO support to facilitate extensive resection without prolonged hypoxic episodes. In the second case, a proximally located, septated tracheal stenosis was managed with endobronchial laser therapy followed by bougienation tracheoplasty, demonstrating the role of ECMO in maintaining oxygenation throughout the procedure.

In both cases, femorofemoral VA-ECMO cannulation was performed preemptively while the patients were awake, before anesthetic induction, to preserve respiratory function and anticipate the risks associated with airway manipulation.[15] Anticoagulation was achieved with a single bolus of heparin administered immediately before ECMO insertion, without additional heparin dosing during the procedure, while maintaining the ACT between 160 and 200 seconds. Before initiation of tracheal repair, mechanical ventilation was discontinued, and respiratory support was fully maintained by ECMO through adjustment of blood flow and sweep gas parameters. This strategy eliminated the need for distal endotracheal tube placement beyond the lesion, allowing airway surgery to proceed without mechanical ventilation.[13] In this report, VA-ECMO was applied using a modified CPB configuration with a roller pump. Conventional CPB used in cardiac surgery is associated with extensive blood–air interface exposure, resulting in increased anticoagulation requirements. In contrast, modified CPB systems have been shown to reduce inflammatory responses, limit hemodilution, decrease anticoagulation requirements, and reduce transfusion needs.[16]

Differential hypoxemia (Harlequin syndrome) is a recognized complication of peripheral VA-ECMO, resulting from preferential perfusion of the upper body with poorly oxygenated native cardiac output while oxygenated ECMO flow predominantly supplies the lower body. In both cases, early detection was facilitated by continuous cerebral NIRS and arterial blood gas analysis obtained from the right radial artery. Management consisted primarily of increasing ECMO blood flow to augment systemic oxygen delivery, which resulted in prompt improvement in oxygen saturation.[17] However, maximal flow optimization was constrained by cannula size, highlighting an important technical limitation of peripheral VA-ECMO. These cases underscore the importance of vigilant neuromonitoring, timely recognition, and proactive adjustment of ECMO parameters to mitigate differential hypoxemia during high-risk airway surgery.

Following completion of the airway procedures, ECMO support was gradually weaned while mechanical ventilation was reintroduced. Endotracheal tube placement after distal tracheal resection and tracheostomy following proximal tracheal repair was employed to maintain airway patency and minimize tension at the anastomotic site. Both patients demonstrated stable hemodynamics and adequate oxygenation during postoperative intensive care without major complications.[18]

CONCLUSION

Anesthetic management of tracheal surgery presents significant challenges due to the risk of airway obstruction, hypoxia, and ventilation failure during tracheal manipulation. The use of VA-ECMO as intraoperative respiratory and circulatory support provided a stable physiologic environment during critical phases of airway intervention, reducing reliance on conventional ventilation. This approach may be considered as a supportive anesthetic strategy for selected patients undergoing complex airway procedures.

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