Review Article

INTERNATIONAL JOURNAL OF SURGERY

OPEN

Extracorporeal membrane oxygenation as life-saving bridge for patients with airway obstruction caused by neck and chest tumors to salvage procedure: an in-depth review

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Abstract

Narrowed or stenotic airways are frequently encountered in emergency practice. Neck and chest tumors-caused airway obstruction usually follow a severe clinical course, necessitating urgent ventilation as a bridge to perform emergency operations. In certain cases, traditional ventilation methods may not safely address complicated airway conditions. In such instances, special cardiopulmonary support becomes necessary to manage both hemodynamics and ventilation for patients. Extracorporeal membrane oxygenation (ECMO) is considered a last resort treatment for respiratory failure. When dealing with emergency difficult airway situations, ECMO offers certain advantages over conventional ventilation. However, its effectiveness in managing airway obstruction due to solid tumors located in the neck or chest is not well-established due to limited clinical practice. Published articles about this topic are still limited and primarily rely on case series and reports. As a result, they offer insufficient data and illustrations to fully elucidate emergency issues. In the present article, the authors summarize the existing literature concerning ECMO utility in managing patients with airway obstruction due to solid tumor located in the neck or chest based on PubMed, Web of Science, and other medical databases, to conduct an in-depth review. The authors conducted an analysis of 27 studies, including a total of 54 patients with airway obstruction caused by tumors. All patients underwent surgical relief of airway obstruction with ECMO as ventilatory support. Postoperatively, 87% of the patients (47/54) survived. 7.4% of the patients (4/54) died due to postoperative disease progression, unrelated to ECMO complications. The prognosis of 5.6% of the patients (3/54) could not be obtained. Additionally, the authors present an interesting case series ($n = 5$) based on a real-world research to demonstrate the different outcomes among airway-obstructed patients due to neck and chest masses. In this series, four patients supported by ECMO were successfully discharged postoperatively, while one patient on conventional ventilation died due to respiratory collapse before surgery. Meanwhile, the authors share novel illustrations and clinical figures to supplement the understanding of this condition. The findings presented in this article provide a basis for further studies and can be used to improve management of the patients.

Keywords: airway obstruction, extracorporeal membrane oxygenation, neck and chest tumors

Introduction

Airway obstruction is a lethal emergency condition, that can cause hypoxic respiratory failure and immediate cardiopulmonary collapse[1–4]. Life-threatening airway obstruction can be encountered in patients with narrowed airways caused by neck or chest tumor masses[5,6]. On the one hand, endotracheal tumors, such as adenoid cystic carcinoma/mucoepidermoid carcinoma/squamous cell carcinoma (SCC) and comparatively rare schwannoma, potentially lead to stenosis of the tracheal lumen[7–11]. On the other hand, extrinsic airway compression, such as mediastinal mass, thyroid cancer, lung tumors, esophageal neoplasms, and some thoracic benign tumors, is capable of causing obstructed airways[6,7,12–17]. Providing emergency

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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International Journal of Surgery (2025) 111:1090–1100

Received 31 January 2024; Accepted 25 July 2024

Published online 5 August 2024

http://dx.doi.org/10.1097/JS9.0000000000002008

respiratory support serves as a crucial link between getting through critical moments and initiating following anticancer treatment for patients[18]. While surgeries and stent implantations are common interventions for obstructed airways, certain patient subsets cannot receive adequate treatment without effective respiratory support[15,17]. Traditional emergency ventilation, such as tracheal intubations and tracheotomies, are only suitable for relatively secure-airway patients[7]. Extracorporeal membrane oxygenation (ECMO) emerges as a salvage option for patients experiencing respiratory failure. Some published articles indicate that individuals with airway obstruction due to neck and chest tumors can benefit from ECMO support[7,15,17,18]. Early initiation of ECMO can provide these patients with sufficient cardiopulmonary support, a safe environment for airway surgery, and adequate preoperative preparation time[7,15,17]. This article consolidates existing researches on ECMO application in managing patients with tumor-caused airway obstruction with a tumor mass at the neck or chest. In addition, we provide interesting case series, sharing illustrations and significant figures to supplement the understanding of this life-threatening condition. This review article offers a strong rationale for considering ECMO as an alternative approach to ventilation treatment for patients with airway obstruction caused by tumors.

The constraints of conventional ventilation methods in addressing patients with airway obstructions induced by endoluminal or extrinsic tumors

Blockage in central airways, including trachea or mainstem bronchi, arises from different conditions associated with neck and chest tumors, leading to considerable morbidity and mortality. The predominant factor contributing to airway obstruction from tumors usually entails direct extension and compression, originating from endoluminal (Fig. 1A) and extrinsic tumors (Fig. 1B). The episodes of airway obstruction linked to neck and chest tumors are increasing in prevalence due to the growing population of cancer patients[7]. When the airway undergoes critical narrowing, it poses a severe threat to the patient's life due to the imminent risk of suffocation. Ensuring optimal respiratory support for effective oxygenation becomes a crucial consideration in the treatment of

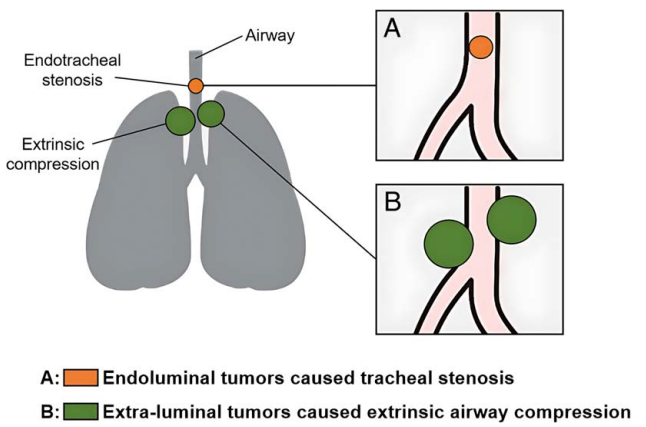


Figure 1. The predominant factor of tumor-caused airway obstruction. (A) Endoluminal tumors caused tracheal stenosis; (B) Extra-luminal tumors caused extrinsic airway compression.

HIGHLIGHTS

- We further demonstrate that ECMO can offer sufficient respiratory support, allowing for the planning and implementation of subsequent treatments while minimizing procedure-related complications.
- We provide an interesting case series to show the different outcomes among airway-obstructed patients due to neck masses, comparing those undergoing conventional ventilation to those supported by venovenous (VV) ECMO.
- Published articles about this topic are still limited, we share novel illustrations and clinical figures to supplement the understanding of this condition.

severe airway obstruction resulting from tumors[4,6,7,19–24]. Swift ventilation can be a life-saving intervention, providing immediate relief for patients experiencing symptomatic airway blockage. Additionally, it can facilitate other therapeutic techniques such as interventions, stent placements, surgeries, chemotherapy, or radiation[7,15,17,18]. To guarantee sufficient ventilation (CO_2 removal) and oxygenation in patients with an unstable respiratory condition, conventional approaches like endotracheal intubation and rigid bronchoscopy may be favored to perform in fluent airway status (Fig. 2A). Nevertheless, in cases of extreme severity, methods above may become impractical even risky, potentially posing the risk of complete airway blockage. Neither intermittent positive pressure ventilation nor spontaneous ventilation through ventilating the port is not viable option for critical endotracheal obstruction (Fig. 2B) or extrinsic airway compression (Fig. 2C) caused by tumors due to severe or complicated airway disorders[7]. Clinically, the choice of ventilation approach can be determined by the site of obstruction. Unfortunately, tracheal intubation may encounter difficulties passing through certain narrowed sites caused by tumors, such as masses in the tongue, larynx, pharynx, and thyroid. This procedure possibly leads to a completely obstructed airway (Fig. 2D). Tracheostomy has a high major bleeding risk and even asphyxia because of the adjacent tumor with highly intensive vascularity[7,25,26]. Meanwhile, standard tracheostomy has a limited role in addressing airway obstruction caused by mediastinal masses, lower esophageal issues, lower respiratory tract problems, and bronchial obstructions[27–31]. This limitation arises from the difficulty in reaching and ensuring sufficient oxygenation at these lower obstruction sites using a conventional tube (Fig. 2E). In recent times, stent placement has gained widespread recognition as a safe, straightforward, and effective method for relieving both malignant and benign airway obstructions[15,17,23,30–32]. Nevertheless, in cases involving critical airway obstruction, the placement of airway stents can pose significant risks without effective ventilation. The collapse of the airway can severely impede the capabilities of oxygenation and ventilation during these processes, even with conventional ventilation support[4,17]. Thus, effective respiratory support should be established before treatment procedures in these patients.

The benefits of employing ECMO for the management of patients experiencing tumor-caused airway obstruction

For individuals experiencing airway obstruction with an acute respiratory deterioration, stabilization of breathing becomes a

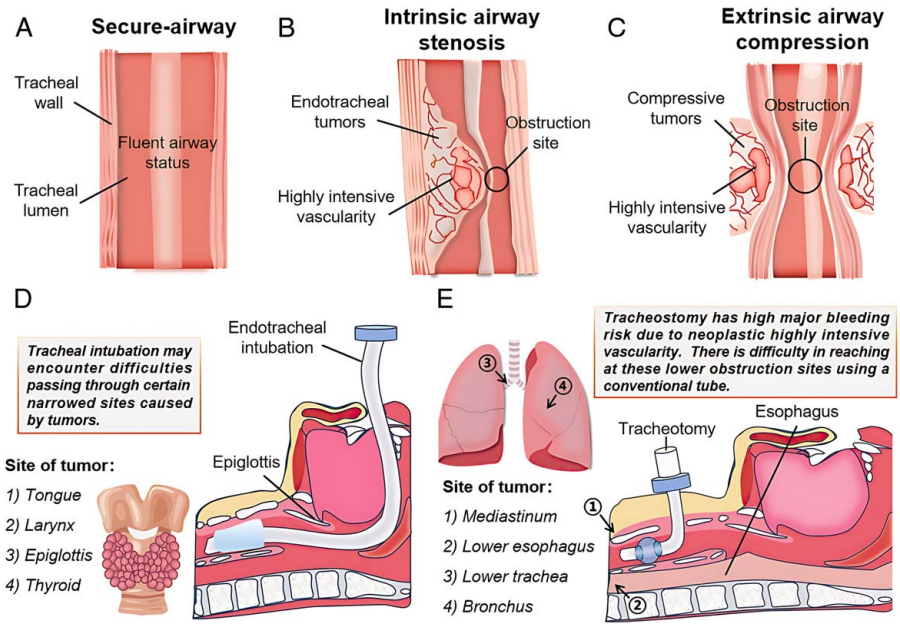


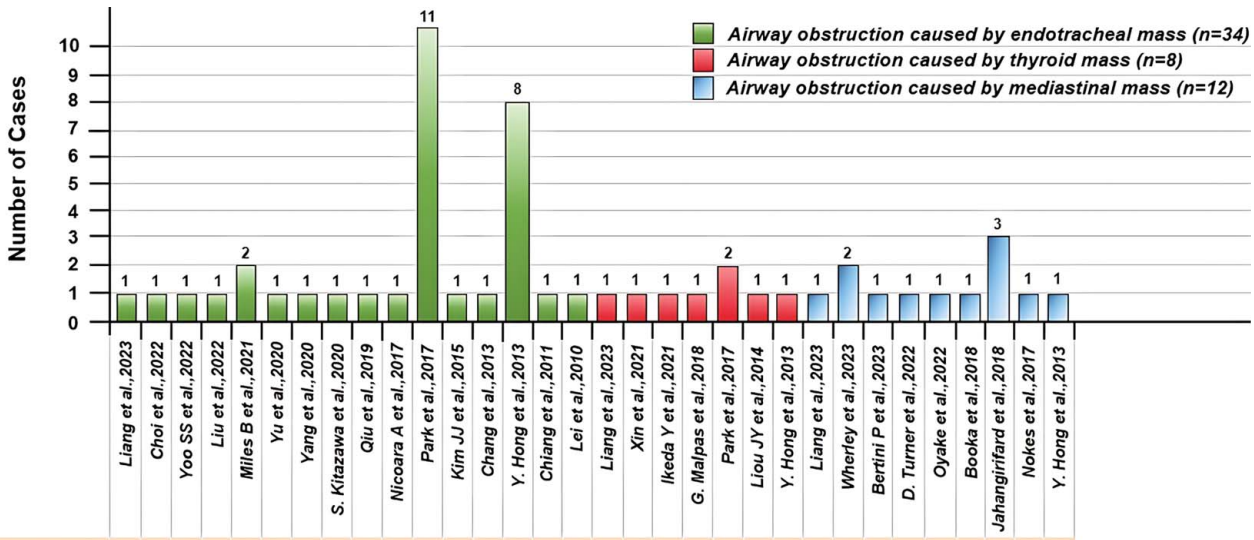
Figure 2. The limitations of conventional ventilation are evident in several aspects. (A) The conventional approach is more adept at managing fluent airway than addressing airway obstruction; (B, C) Neck and chest tumors can cause endotracheal stenosis and extrinsic airway compression, leading to a complex airway condition; (D) Tracheal intubation may encounter difficulties passing through certain narrowed sites caused by tumors and can result in a completely obstructed airway; (E) Tracheostomy has difficulty in reaching at these lower obstruction sites (black arrow) using a conventional tube, and carries a high-risk of major bleeding.

crucial prerequisite before initiating effective treatments. Ensuring the openness of the airway and reinstating proper ventilation are essential aspects of the treatment strategy. To guarantee efficient ventilation (CO_2 removal) and oxygenation in airway-tumorous-obstructed patients at unstable status, ECMO can offer sufficient respiratory support, allowing for the planning and implementation of subsequent treatments while minimizing procedure-related complications[33–38]. Hong *et al.*[17], focused on a single-center exploration of using VV ECMO to secure ventilatory function, such as CO_2 removal and oxygenating, in patients facing a heightened risk of central airway obstruction during life-saving interventions, like tracheal mass removal or placement of an endotracheal stent. In this study involving 18 patients with tumor-caused airway obstruction with a tumor mass at the neck or chest, 16 were successfully weaned off ECMO. In addition, Park *et al.*[15], reported in a single-center case series, including 16 individuals with airway obstruction due to solid tumors located in the neck or chest. In their study, the successful placement of stents under VV ECMO respiratory support was demonstrated on individuals facing severe airway obstruction, particularly respiratory distress situations, even with assistance in breathing and an incapacity to recline in a supine posture. Recently, Liang *et al.*[7], presented findings showcasing VV ECMO application as the bridge for emergency operation in three airway-obstructed patients with tumor mass in the neck or chest. Despite being a retrospective, small-sample, single-center study, all patients successfully underwent ECMO to restore airway security thus survived until their discharge from the hospital. This study advocates for the early initiation of ECMO as a bridge to provide ventilation and support surgical procedures in patients facing critical central airway stenosis due to neck and chest tumors. Generally, the VV technique suffice when the primary requirements revolve around ventilation and oxygenation. However, reported cases of ECMO application in cases of airway obstruction also involve veno-arterial (VA) ECMO[13,36]. This choice of the VA approach becomes justified when patients are encountering cardiovascular complications[39]. In situations of airway obstruction, especially those without cardiac events, VV ECMO may be deemed more suitable than VA ECMO to ensure sufficient ventilation. The emergency use of ECMO has limited indications as it can elevate complications risk related to ECMO, with its application restricted to centers equipped with established capabilities for emergency ECMO deployment. Reported ECMO-related complication rates range from 24 to 55%, encompassing potentially life-threatening issues: air leakage, thrombosis, hemolysis, and bleeding[40,41]. As the number of patients facing cancer-related complications continues to increase, there is an expected rise in the incidence and prevalence of airway obstruction caused by tumors, particularly among the elderly. It is crucial to carefully weigh the potential complications and the specific capabilities of ECMO application when considering its emergency use.

The reported data of ECMO application for the management of patients with tumor-caused airway obstruction

In the major studies conducted on this subject over the last decade, the published works are relatively limited and predominantly rely on case series and reports. This means that most of them are retrospective studies from single centers or single cases, which present biases in evidence-based medicine. Additionally, these studies are based on experiences from different centers, lacking a true consensus. We integrated and analyzed patient backgrounds, surgical methods, ECMO modes, and outcomes from existing studies, and proposed reasonable optimization suggestions to

address the gaps in the current research. Reported cases data and details of ECMO application for managing patients with tumor-caused airway obstruction with tumor mass in the neck or chest are presented in Figure 3. To our knowledge, 54 patients were reported by published papers above. Out of the 54 patients, 36 were males, 15 were females, with a maximum age as 88 years old, a minimum age as 13 years old. Forty-three patients experiencing airway obstruction received support from VV ECMO, while only 2 patients were supported by VA ECMO. ECMO comprises two primary types: VA mode offering hemodynamic and respiratory supports, and VV mode focusing solely on respiratory support by enabling respiratory gas exchange beyond the body's confines[42–44]. Extracorporeal life support organization specifies criteria for VV ECMO use, encompassing the intubation of patients requiring lung transplant, hypoxic respiratory failure, CO_2 retention on mechanical ventilation, severe air leak syndromes, and instances of immediate cardiac or respiratory collapse (e.g. unresponsiveness to optimal care, blocked airway, pulmonary embolism, etc.)[31]. Consequently, VV mode emerges as the valuable bridge for airway-obstructed patients with a tumor mass at the neck or chest in need of subsequent procedures. Interestingly, owing to persistent hypoxemia and unstable cardiovascular parameters, Ikeda *et al.*[13], and Chang *et al.*[36], respectively reported VA ECMO cases of tumor-caused airway obstruction, these patients exhibited favorable postoperative outcomes without any reported complications. The etiology of airway obstruction in 54 patients is outlined, with 28 cases attributed to primary neck and chest tumors and 26 cases to metastatic neck and chest tumors. A detailed presentation of the typical clinical symptoms and definitive diagnoses of the 54 patients is provided in Table 1. The diagnosis was confirmed through histopathology, bronchoscopic biopsy, and/or computed tomography (CT) of the neck and chest. The principal causes of airway obstruction involved endotracheal, thyroidal, and mediastinal masses. An endotracheal mass is the significant manifestation of primary or metastatic tumors leading to airway obstruction ($n = 34$). Lung cancer serves as the most prevalent metastatic malignancies in the trachea and bronchus. Because airway spread is a significant route for lung cancer to metastasis. Interestingly, Y. Hong *et al.*[17], reported a meaningful case where VV ECMO was employed as a bridge for tracheal stent insertion showed within a 58-year-old case with renal cell carcinoma, lung metastasis, and resultant airway obstruction. Eighty-seven percent of the patients (47/54) survived postoperatively without encountering any unexpected emergency during surgery. 7.4% of the patients (4/54) died due to postoperative disease progression.



	Liang et al.,2023	Choi et al.,2022	Yoo SS et al.,2022	Liu et al.,2022	Miles B et al.,2021	Yu et al.,2020	Yang et al.,2020	S. Kitazawa et al.,2020	Qiu et al.,2019	Nicoara A et al.,2017	Park et al.,2017	Kim JJ et al.,2015	Chang et al.,2013	Y. Hong et al.,2013	Chiang et al.,2011	Lei et al.,2010	Liang et al.,2023	Xin et al.,2021	Ikeda Y et al.,2021	G. Malpas et al.,2018	Park et al.,2017	Liou JY et al.,2014	Y. Hong et al.,2013	Liang et al.,2023	Wherley et al.,2023	Bertini P et al.,2023	D. Turner et al.,2022	Oyake et al.,2022	Booka et al.,2018	Jahangirifard et al.,2018	Nokes et al.,2017	Y. Hong et al.,2013
References (no.)	7	8	9	23	33	25	34	32	10	11	15	35	36	17	37	38	7	12	13	14	15	16	17	7	27	28	29	30	19	20	31	17
Patient (s) Sex	F	M	M	M	2M	NA	M	F	M	M	9M/ 2F	F	M	6M/ 2F	F	M	M	F	F	M	2M	M	M	F	NA/ NA	M	F	M	F	2M/ 1F	F	M
Patient (s) Age	46	50	53	41	52/ 66	58	50	39	53	37	30- 82	88	81	16- 70	71	55	52	76	73	77	68/ 67	76	67	46	NA/ NA	36	29	15	73	13- 59	49	19
Mode of ECMO	VV	VV	VV	VV	VV/ VV	VV	VV	VV	VV	VV	11 VV	NA	VA	8 VV	VV	NA	VV	NA	VA	VV	VV/ VV	VV	VV	VV	NA/ NA	NA	VV	VV	VV	3 NA	VV	VV
Causes of airway obstruction	PT	PT	PT	MT	MT/ PT	MT	PT	MT	PT	PT	10MT /1PT	MT	MT	5MT /3PT	PT	PT	PT	MT	MT	MT	2PT	MT	PT	PT	2PT	PT	PT	PT	PT	3PT	MT	PT
Treatment (s)	MR	TR	C	MR +S	MR/ MR	EK	PE	MR +S	MR	MR	11S	MR	MR by PDT	8 MR	MR	MR	MR	TE	TE	TE+ LE+ LND	2S	TE	S	MR	NA/ NA	NA	MR	S	EE	3MR	S+ C	DO
Outcome (s)	A	A	A	A	2A	A	A	A	A	A	10A /1D	A	A	8A	A	A	A	D	A	A	1A /1D	A	D	A	NA/ NA	NA	A	A	A	3A	A	A

Figure 3. Statistical summary on published works of ECMO application for managing patients with tumor-caused airway obstruction with mass at neck or chest. A, alive; C, chemotherapy; DO, debulking operation; D, death; EK, electric knife; EE, esophagectomy; ECMO, extracorporeal membrane oxygenation; F, female; LE, laryngectomy; LND, lymph node dissection; M, male; MT, metastatic tumor; MR, mass resection; PDT, photodynamic therapy; PT, primary tumor; PE, pneumonectomy; S, stent; TE, thyroidectomy; TR, trachea reconstruction; VV, venovenous; VA, venoarterial. The Arabic numerals standing for order number of references, years of age, and number of cases.

Table 1

Clinical symptoms and diagnosis corresponding with Figure 3.

References (no.)/Number of case(s)	Typical clinical symptoms	Definitive diagnosis
7 ($n=3$)	Three cases with dyspnea	Case 1 with thyroid follicular carcinoma/Case 2 with mediastinal teratoma/Case 3 with tracheal adenoid cystic carcinoma
8 ($n=1$)	Cough and throat discomfort	Tracheal adenoid cystic carcinoma
9 ($n=1$)	Worsening dyspnea	SCC of right main bronchus
10 ($n=1$)	Progressive dyspnea	Tracheal mucoepidermoid carcinoma
11 ($n=1$)	Dyspnea, foreign body sensation with breathing	Endobronchial schwannoma
12 ($n=1$)	Neck pain, cough with sputum	SCC of the thyroid
13 ($n=1$)	Neck discomfort	Thyroid carcinoma
14 ($n=1$)	Severe asthma, sitting upright breathing	PTC with high-grade transformation, predominantly to SCC
15 ($n=13$)	Thirteen cases with critical airway obstruction	Nine cases with lung cancer/1 case with tracheal cancer/1 case with thymus cancer/2 cases with thyroid cancer
16 ($n=1$)	Respiratory distress with stridor	Thyroid carcinoma
17 ($n=10$)	Ten cases with central airway obstruction	Five cases with tracheal NSCLC/1 case with tracheal adenoid cystic carcinoma/1 case with bronchial cancer/ 1 case with tracheal schwannoma/1 case with thyroid cancer/1 case with mediastinal lymphoma
19 ($n=1$)	Shortness of breath	Esophageal neurofibroma
20 ($n=3$)	Case 1 with exertional dyspnea/Case 2 with exertional dyspnea and dry cough/Case 3 with chronic cough and dyspnea	Case 1 with mediastinal neoplasm/Case 2 with mediastinal liposarcoma/Case 3 with mediastinal telangiectatic osteosarcoma
23 ($n=1$)	Progressive dyspnea	Carinal metastatic melanoma
25 ($n=1$)	Dyspnea	Tracheal metastatic SCC
27 ($n=2$)	One case with postural symptoms/1 case presenting acutely with a symptomatic middle mediastinal mass	One case with mediastinal lymphoma/1 case with middle mediastinal mass
28 ($n=1$)	Signs of bronchial and vascular compression	Non-Hodgkin's lymphoma adhered to the pleura and pericardium
29 ($n=1$)	Dyspnea at rest	Mediastinal cavernous hemangioma
30 ($n=1$)	Dyspnea in the supine position	Mediastinal T-Lymphoblastic Lymphoma
31 ($n=1$)	Respiratory distress	Mediastinal plasmacytoma
32 ($n=1$)	Severe respiratory distress	Lung adenocarcinoma
33 ($n=2$)	Case 1 with hemoptysis and respiratory failure/Case 2 with dyspnea and COPD	Case 1 with bronchial NSCLC/Case 2 with tracheal moderately differentiated SCC
34 ($n=1$)	Chest tightness and shortness of breath	Left main bronchial SCC and adenoid cystic carcinoma
35 ($n=1$)	Dyspnea at rest and a productive cough	Tracheal malignant teratoma
36 ($n=1$)	Blood tinged sputum	Bronchial NSCLC
37 ($n=1$)	Dyspnea, sleep deprivation, and weight loss	Tracheal SCC
38 ($n=1$)	Intermittent hemoptysis and short breath	Left main bronchial adenosquamous cell carcinoma

*Typical clinical symptoms and definitive diagnoses were obtained from published papers presented in Figure 3.
COPD, chronic obstructive pulmonary disease; NSCLC, nonsmall cell lung cancer; PTC, papillary thyroid carcinoma; SCC, squamous cell carcinoma.

The prognosis of 5.6% of the patients (3/54) could not be obtained. Among the 47 surviving patients, all were successfully discharged from hospital without experiencing any ECMO or surgery-caused adverse events. However, four patients, despite successfully being weaned off ECMO, were unable to be discharged from the hospital. Their death were related to complication of tracheostomy[15], wound infection progressed to sepsis[12], and respiratory problems associated with the underlying disease[17]. These patients died of surgery-related complications and underlying cardiopulmonary diseases. To improve patient survival rates, surgeons and specialized ECMO teams need to reach a consensus on the patient's general condition, underlying diseases, tolerance, surgical indications, postoperative complications, and perioperative management before initiating any interventions[7,17]. ECMO can serve as a valuable bridge, providing support for interventions addressing tumor-caused airway obstruction with tumor mass in neck or chest. This is particularly relevant for high-risk, yet life-saving interventions, including tracheal stent insertion, masses removal, or trachea reconstruction.

Comprehensive case series and literature review for explanatory purposes

The primary treatment goal for these patients is to establish an effective ventilation. According to incomplete statistics, the 1-year survival rate of patients undergoing thoracic surgery with ECMO support at our center exceeds 80%[45]. This figure is consistent with the overall survival rate of 87% (47/54) reported in published literature. Building on this, we share our experience with ECMO management of airway obstruction caused by tumors and summarize the quantitative data of our patients ($n=5$) in Table 2 for easy case comparison. Additionally, we discuss the pathophysiological mechanisms of tumor-induced airway obstruction in detail. In this context, we present three patients (Case 1–3, comprising 1 male and 2 females; mean age, 47 years; range, 18–66 years) who underwent surgical interventions with VV ECMO support for malignancy-caused airway obstruction ($n=2$) or benign ($n=1$) etiology. Additionally, we conducted a single-center, small-sample cases analysis ($n=2$) to demonstrate the outcomes of ventilation among patients

Table 2

Clinical data of case series based on real-world context ($n = 5$).

	Case 1	Case 2	Case 3	Case 4	Case 5
Age (y)	66	58	18	52	38
Sex	Male	Female	Female	Male	Male
Symptom	Dyspnea	Dyspnea	Dyspnea	Dyspnea	Dyspnea
Tumor site	Endotracheal mass	Pulmonary hilar mass	Mediastinal mass	Multiple neck masses	Multiple neck masses
Surgical pathology report	Squamous cell carcinoma	Squamous cell carcinoma	Mature cystic teratoma	Thyroid carcinoma	Thyroid carcinoma
Obstruction cause	Endotracheal stenosis	Extrinsic airway compression	Extrinsic airway compression	Extrinsic airway compression	Extrinsic airway compression
Ventilation mode	VV ECMO	VV ECMO	VV ECMO	VV ECMO	Tracheal intubation + MV
Intervention details	Endoluminal tumor resection via bronchoscopy	Palliative resection of pulmonary hilar mass	Complete mediastinal mass resection through thoracotomy	Thyroidectomy + Neck lymph node dissection + tracheal reconstruction	NA
Operative duration (h)	2.2	3.5	4.5	4	NA
Disconnection from ECMO	Immediate postoperative phase	Immediate postoperative phase	Immediate postoperative phase	Immediate postoperative phase	NA
PVA	Intubation	Intubation	Intubation	Intubation	NA
ICU (days)	1	1	2	1	NA
General ward (days)	1	3	4	2	NA
ECMO related complications	None report	None report	None report	None report	NA
Outcomes	Alive	Alive	Alive	Death	Death
Long-term follow-up	5 months postsurgery	7 months postsurgery	18 months postsurgery	3 months postsurgery	NA

*We showcased clinical data among patients undergoing either ECMO (Case 4) or non-ECMO (Case 5) for critical airway obstruction resulting from thyroid cancer only for illustrative purposes, Case 4 experienced significant symptomatic relief after the surgery, on the contrary, Case 5 succumbed to cardiopulmonary collapse before emergency surgery.
MV, mechanical ventilation; PVA, postoperative assisted ventilation; VV ECMO, venovenous extracorporeal membrane oxygenation.

undergoing either VV ECMO (Case 4) or tracheal intubation accompanied mechanical ventilation (MV) (Case 5) for critical airway obstruction resulting from thyroid cancer. However, it is essential to acknowledge the significant limitations of our case series. On the contrary, these three extra-case (Case 1–3) contribute minimally to this topic from the standpoint of evidence-based medicine. Comparing one ECMO case (Case 4) with one non-ECMO case (Case 5) lacks relevance to scientific evidence and serves only illustrative purposes. Therefore, we provide a detailed description and standardized report of these cases and

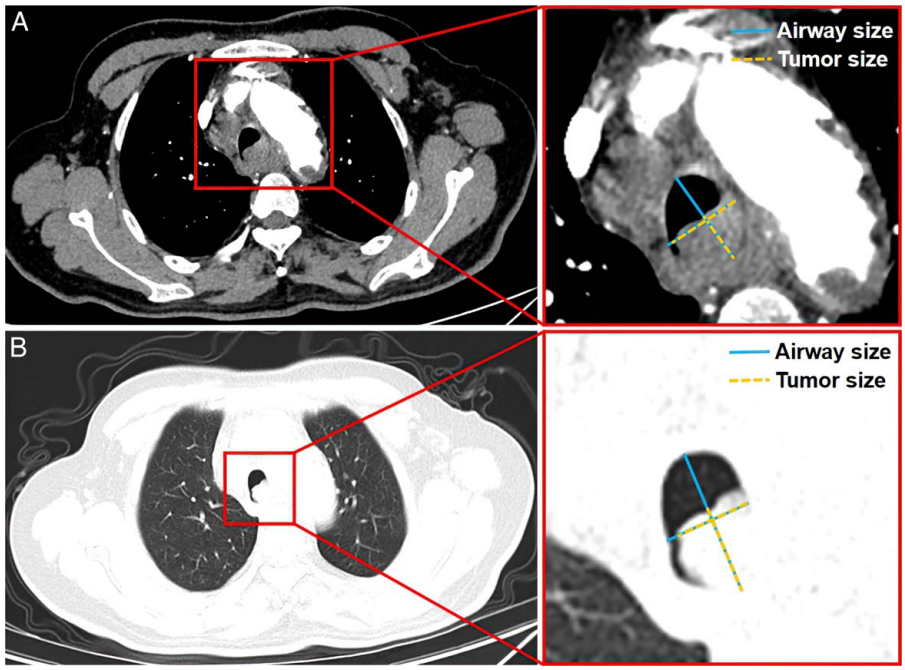


Figure 4. Endotracheal SCC caused central airway obstruction. (A) Typical airway stenosis caused by endotracheal mass; (B) The irregular neoplasm originated from the trachea leading to an incomplete airway obstruction. Blue and yellow lines expressed airway size and tumor size, respectively.

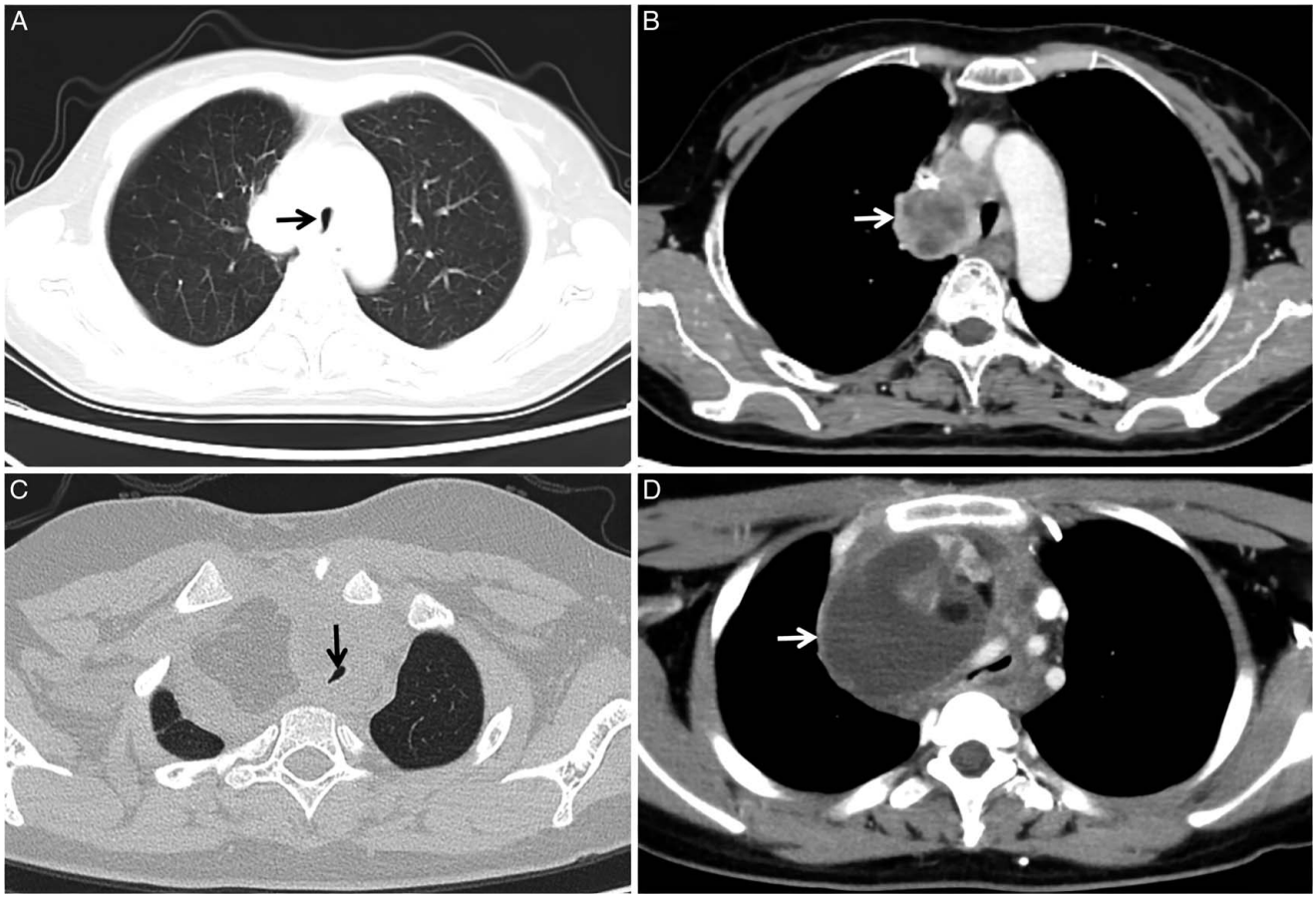


Figure 5. Extrinsic airway compression caused airway obstruction. (A, B) Pulmonary hilar mass compressed airway, causing partially obstructed airway; (C, D) A large compressive mediastinal mass caused airway migration and stenosis. Black and white arrows expressed the positions of airways and tumors, respectively.

include a review of the literature and captivating anatomical illustrations to enhance understanding of this issue.

Case 1. Patient background

A 66-year-old male presented with dyspnea was sent to our center for management of an obstructed airway caused by endotracheal SCC. Intervention details: A chest CT scan illustrated a large irregular mass generating from the trachea, partially obstructing the central airway (Fig. 4A). Meanwhile, CT scan revealed severe stenosis of tracheal lumen (Fig. 4B). Given the risk of complete airway obstruction with tracheal intubation, we opted for a planned approach using VV ECMO to facilitate the safe resection of the endoluminal tumor via bronchoscopy, with an operative duration of 2.2 h. Intubation ventilation was initiated following the elimination of endotracheal stenosis. The patient was transferred to the ICU for a 1-day stay, followed by one day in the general ward. Outcomes: The patient's recovery was successful, and he was discharged from the hospital without experiencing any adverse events. Until now, the patient remains alive (5 months postsurgery).

Case 2. Patient background

A 58-year-old woman with a history of lung cancer experiencing acute hypoxic respiratory failure was sent to our center for managing extrinsic airway compression caused by a pulmonary hilar SCC (Fig. 5A-B). Intervention details: She underwent palliative resection of pulmonary hilar mass under VV ECMO support. The operative duration were 3.5 h. Postoperatively, the patient was transferred to the ICU and received assisted ventilation via intubation. She remained in the ICU for 1 day before being transferred to the general ward for a three-day stay. Outcomes: Until now, the patient is still alive, undergoing systematic chemotherapy and thoracic radiotherapy (7 months postsurgery).

Case 3. Patient background

An 18-year-old woman presenting with a large mediastinal teratoma causing extrinsic airway compression (Fig. 5C-D) was sent to our center. Intervention details: The patient underwent complete mediastinal mass resection through thoracotomy under VV ECMO support. The operative duration were 4.5 h. Postoperatively, the patient was transferred to the ICU and received ventilation via intubation. She remained in the ICU for 2 days before being transferred to the general ward for a four-day stay. Outcomes: She experienced successful postoperative outcomes without complications. Until now, the patient is still alive (18 months postsurgery).

Case 4. Patient background

A 52-year-old man presented with thickening of thyroid isthmus and multiple neck masses (Fig. 6A), resulting in symptomatic

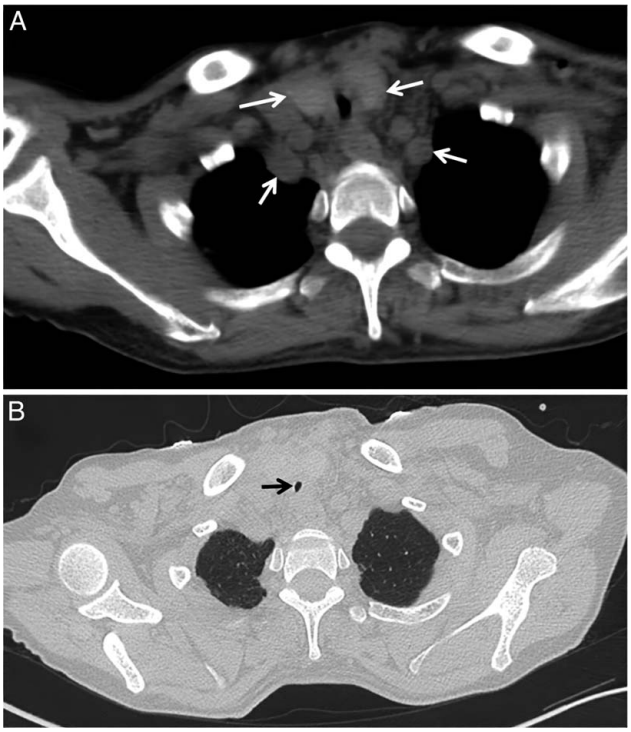


Figure 6. Airway obstruction caused by multiple metastatic neck masses. (A, B) Invasion and compression of airway caused by solid tumor that extended up to thoracic entrance, in a 52-year-old male case with thyroid cancer. Black and white arrows expressed the positions of airways and tumors, respectively.

narrowing of the airways (Fig. 6B). Intervention details: We applied VV ECMO application as a bridge to thyroidectomy, neck lymph node dissection, and tracheal reconstruction in this patient. The operative duration were 4 h. Following the resolution of tracheal stenosis, the patient received ventilation via intubation. Postoperatively, he was transferred to the ICU for a 1-day stay, followed by 2 days in the general ward. Outcomes: Although the patient experienced significant symptomatic relief after the surgery, he ultimately succumbed to malignancy progression about 3 months later.

Case 5. Patient background

A 38-year-old male presented acutely with a symptomatic airway stenosis (Fig. 7A) and irregularity (Fig. 7B) due to multiple neck masses. Intervention details: He was sent to our center and supported with tracheal intubation for ventilation and oxygenation (Fig. 7C). Outcomes: Unfortunately, the obstructing airway and pulmonary infection progressed to cardiopulmonary collapse, leading to his death before emergency surgery. Discussion on pathophysiological mechanisms: In this fatal case, tracheal intubation failed to provide adequate oxygenation and ventilation due to multiple neck masses causing lower site obstructions, resulting in a difficult airway (Fig. 7D). The limited length of tracheal intubation (Fig. 8A), with the lower obstructed trachea or bronchus acting as a stenotic bridge (Fig. 8B), hindered the oxygen flow to reach the pulmonary alveoli causing insufficient oxygenation and CO_2 removal (Fig. 8C).

When being used for our case series, patients typically undergo weaning and disconnection from ECMO either at the conclusion of the surgical procedure or during the immediate postoperative

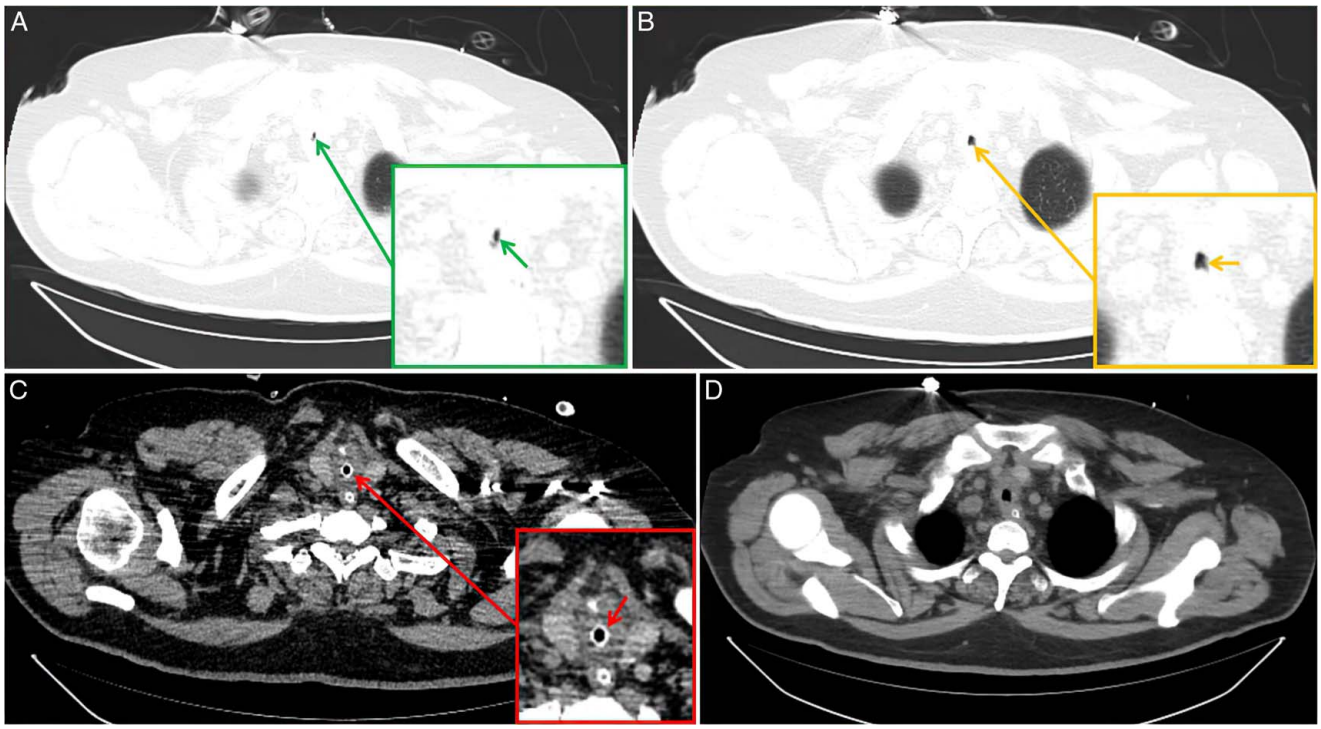


Figure 7. Failed attempt using tracheal intubation as a bridge to support ventilation therapy in a 38-year-old male patient. (A) Severe stenotic airway (green arrow); (B) Irregular and narrowed airway (yellow arrow); (C) Tracheal intubation as a bridge to ventilation (red arrow); (D) Multiple obstruction sites leading to a complicated airway condition.

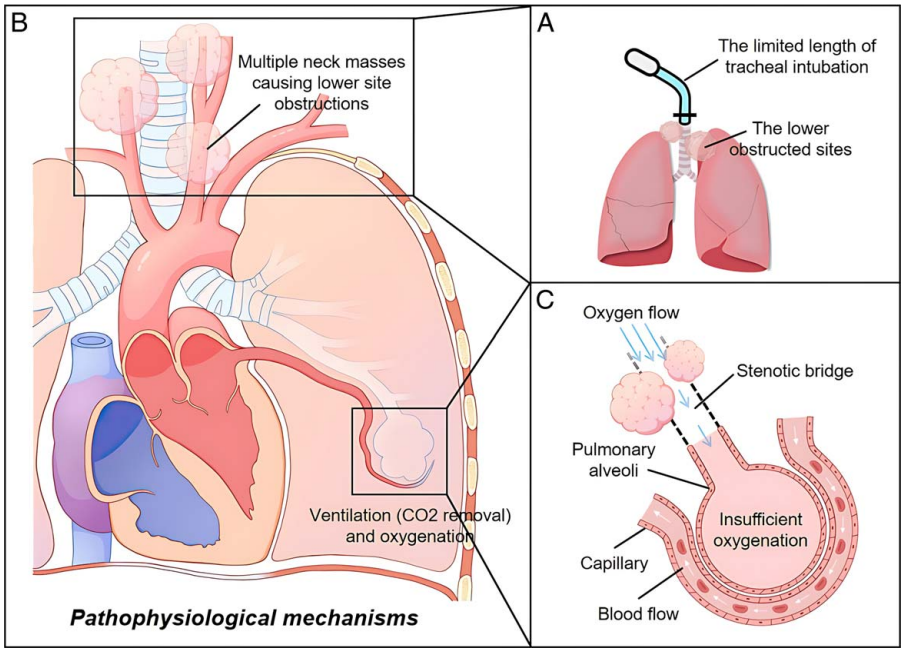


Figure 8. Pathophysiological mechanisms based on anatomical illustrations. (A) There is difficulty in reaching at these lower obstruction sites using a conventional tube with limited length; (B) Lower obstructed trachea or bronchus acting as a stenotic bridge; (C) Insufficient oxygenation and CO_2 removal of this fatal case.

phase, once secure airway access is established and native lung function is deemed sufficient. However, if pulmonary issues persist with ongoing respiratory insufficiency or significant hemodynamic instability, ECMO must be sustained and gradually tapered off in the postoperative period as the underlying condition improves.

The utilization of ECMO in our case series spared patients from the need for more invasive cardiopulmonary bypass (CPB) during the removal of neck and chest tumors. One significant drawback of employing CPB for airway surgery is the necessity for full anticoagulation. In contrast, ECMO utilizing heparin-coated cannulae and circuit tubing necessitates a markedly reduced level of heparinization, typically targeting an activated clotting time of 160–180 s. Consequently, this approach offers the advantage of mitigating bleeding complications[46]. A study reported that a patient undergoing tracheal surgery while on VV ECMO did not receive any anticoagulation, yet experienced no thrombotic events[47]. Typically, at the conclusion of the airway procedure, protamine is administered to reverse the anticoagulant effect of heparin and prevent postoperative bleeding. ECMO necessitates a smaller circuit priming volume compared to CPB, potentially reducing dilutional coagulopathy and associated complications such as pulmonary edema[48].

In critically ill patients requiring lung or heart support, the use of ECMO is often associated with numerous thromboembolic, infectious, mechanical, and hemorrhagic complications. These complications significantly impact patient outcomes, leading to increased morbidity and mortality[49]. Venous thrombosis following cannulation is the predominant complication associated with VV ECMO, occurring in as many as 62% of cases of extended ECMO usage[50]. Given the brief duration of ECMO in patients undergoing airway surgery, the likelihood of such complications is presumed to be minimal and has not been reported thus far, including in our case series. Initiating ECMO prior to airway interventions may reduce adverse events associated with respiratory failure and airway compromise. However, it may unnecessarily expose patients to ECMO-related risks and higher procedural costs[51,52]. In the absence of data identifying risk factors for respiratory emergencies during airway interventions, the decision to initiate ECMO relies on clinical judgement and may benefit from the diverse expertise of a multidisciplinary team[51]. The VV technique may be sufficient when only ventilation and oxygenation are required, but if airway obstruction leads to cardiac arrest or shock, a venoarterial approach is necessary[7,17]. Compared to VV ECMO, venoarterial ECMO diminishes pulmonary blood flow and is linked to an increased occurrence of neurological events (e.g. microemboli, hemorrhage, or cerebral infarction), cognitive impairment, and significant local complications such as arterial dissection, pseudoaneurysm formation, or limb ischemia[7,17,53,54].

Bleeding is also a common complication of VV ECMO, observed in 10–30% of patients[41]. The administration of anticoagulants required to sustain VV ECMO alongside airway interventions aimed at alleviating airway obstruction can potentially lead to significant bleeding, particularly owing to the abundant blood vessels associated with tumors. Recent guidelines suggest that in instances of substantial bleeding, such as following open chest surgery, it may be prudent for patients to refrain from anticoagulation for 4–6 h. In cases where bleeding proves challenging to manage, a period of anticoagulant-free status for 12 h is deemed suitable[55]. Maintaining a delicate balance between anticoagulation and surgical bleeding is imperative. All ECMO applications were emergent rather than preventive[56]. The emergent use of ECMO is indicated but carries an increased risk of ECMO-related complications, and its implementation requires access to specialized centers capable of providing emergent ECMO support. Physicians utilizing ECMO to support interventions for airway-obstructed patients must

possess comprehensive knowledge of ECMO-associated complications. An experienced ECMO team can effectively manage and reduce the frequency of these complications[57,58]. VV ECMO potentially plays a crucial role in ensuring adequate ventilation and effective oxygenation for individuals with tumor-caused airway obstruction, especially in cases involving multiple obstructed airway sites.

Conclusion

In conclusion, high-risk yet life-saving procedures, like tracheal stent placement or the surgical removal of mediastinal or endotracheal masses, can be successfully conducted with respiratory support using ECMO in patients experiencing airway obstruction due to neck and chest tumors. This is particularly applicable in cases where there is a risk of life-threatening conditions such as complete airway obstruction, significant bleeding, or even asphyxia. This article elaborates on the lethality of airway obstruction caused by tumors and the limitations of traditional treatments, providing a strong rationale and foundation for exploring ECMO as an alternative approach. However, further studies are necessary to validate standardized methods and establish specific indications for these patients.

Ethical approval

All procedures adhered to relevant guidelines and regulations and received approval from the Ethics Committee on Biomedical Research at West China Hospital of Sichuan University (Approval Number: 2021-233).

Consent

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 Editor-in-Chief of this journal on request. The patients in this manuscript have given written informed consent to publish this information. In addition, institutional approval was obtained to publish the cases details.

Source of funding

There was no funding.

Author contribution

S.S., L.L., and Z.L.: as co-first authors who contributed equally to creation and presentation of the published work, specifically writing the initial draft; L.W. and T.Z.: contributed to provision of study materials, patients, and instrumentation; Z.L. and N.C.: contributed to critical review, commentary, and revision. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

Conflicts of interest disclosure

There is no any conflict of interest statement.

Research registration unique identifying number (UIN)

This is a review article. There is no any Clinical Trial in our research. We did not recruit any human participants.

Guarantor

Shitong Su, Lianjing Liang, Zijian Liu, and Nianyong Chen.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Provenance and peer review

Not commissioned, externally peer-reviewed.

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