Review Article

Extracorporeal membrane oxygenation for general thoracic surgery: case series and narrative review

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Background and Objective: Extracorporeal membrane oxygenation (ECMO) has historically been utilized as a temporary life support option for patients with severe cardiac and pulmonary dysfunction. Recent advancements have enabled the safe application of ECMO in a wider variety of patients; we present a review of its use in patients undergoing general thoracic procedures supported by a case series at our institution.

Methods: We review current literature focusing on ECMO applications in thoracic surgery outside of the traditional use. Additionally, we offer three cases of ECMO utilization to illustrate success stories and key lessons learned regarding the use of ECMO in general thoracic surgery.

Key Content and Findings: Technologic advancements and enhanced safety profiles have enabled the safe application of ECMO in a wide array of patients far beyond the historic indications of cardiogenic shock and acute respiratory distress syndrome (ARDS). It is now feasible to consider ECMO for management of acute thoracic emergencies, as well as to better facilitate operative safety in complex general thoracic surgical procedures. Both venovenous and venoarterial ECMO can be utilized in carefully selected patients to provide cardiopulmonary support while enabling improved visualization and increased mobilization without concern for respiratory and/or cardiac compromise.

Conclusions: Enthusiasm for the use of ECMO has increased in recent years. What was once considered a salvage therapy in cases of life-threatening cardiopulmonary decompensation now plays an increasingly important role in the safe conduct of complex thoracic surgery procedures, provides much needed time for organ recovery, and offers acute resuscitation options. This shift broadens our ability to deliver life-saving care to patients that previously would have otherwise had limited treatment options.

Keywords: Extracorporeal membrane oxygenation (ECMO); thoracic surgery; non-traditional applications

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Introduction

The utilization of extracorporeal membrane oxygenation (ECMO) in cases of cardiogenic shock dates to the mid-1970s (1). During the early phases of ECMO use, mortality and complication rates were high; improvements in perfusion circuit technology, cannulation techniques, and management strategies have drastically increased the safe utilization of ECMO. The use of ECMO in the management of acute respiratory distress syndrome (ARDS) during the recent coronavirus disease 2019 (COVID-19) pandemic and previously during the influenza A (H1N1) and Middle Eastern Respiratory Syndrome (MERS) outbreaks further demonstrates this advancement (2-5). While long-term data are still being collected, the growing understanding of ECMO has led to an expansion of its use far beyond historic indications (6,7). In this review we focus on further developments that have enabled the safe use of ECMO in complex general thoracic surgery patients. Such advancements necessitate that the modern thoracic surgical practice possess a breadth of knowledge regarding ECMO utilization as it could serve as an invaluable tool in critical situations for which conventional options may not be adequate. We aim to provide a concise review of current ECMO applications in thoracic surgery while highlighting a case series of successful ECMO utilization in complex thoracic surgery patients at our institution. We present this article in accordance with the Narrative Review reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-961/rc).

Methods

A thorough search of the literature was completed to compile a summary of that knowledge which currently exists surrounding the utilization of ECMO in the larger practice of general thoracic surgery. The search strategy is further illustrated in *Table 1*. In managing our three cases, all procedures were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patients for publication of this review.

Discussion

ECMO in general thoracic surgery

The utilization of ECMO has increased exponentially in recent years (8). What was once reserved for severe ARDS and cardiogenic shock is now a viable modality in technically complex airway resections, for functionally borderline operative candidates, and to manage a variety of complications in the field of thoracic surgery (9,10). As ECMO utilization continues to expand, it is imperative that it remains in the thoracic surgeon's armamentarium when addressing complex general thoracic surgical issues.

ECMO for potential airway compromise

ECMO has proven effective in the management of acute thoracic emergencies, including acute tracheal obstruction, thoracic hemorrhage, and trauma (11). In the setting of severe hypoxemia secondary to obstruction with rapid progression to shock and cardiac arrest, intubation, emergent surgical airway, and pharmacologic interventions can provide temporary ventilatory support, but the underlying obstructive physiology remains. This notion has been detailed by Willms *et al.* in their review of emergent ECMO in cases of acute trachael obstruction and their case of tracheal mass obstruction (12). Additionally, Kim *et al.* discuss the use of ECMO to manage airway obstructions with a focus on acute pulmonary hemorrhage in five of their patients, four of whom were successfully weaned from ECMO postoperatively (13). Our case of airway obstruction (Case 1) is an example of how venovenous (V-V) ECMO can be used safely to manage a challenging airway with the potential for acute obstruction.

Case 1

A 64-year-old female presented for evaluation of dyspnea with exertional stridor in the setting of a large thyroid goiter. Computed tomography (CT) imaging revealed a 4-mm airway. Due to her critical airway status, she was admitted to the intensive care unit (ICU). In multidisciplinary team discussions, the main concern was safe airway access for intubation as these patients often experience airway obstruction during induction of anesthesia. The decision to utilize mechanical support prior to induction was made in order to facilitate a safer and more controlled environment for high-risk intubation. The patient was brought to the operating room where local anesthetic and heparin was administered prior to placement of a 23-Fr right internal jugular return cannula and a 25-Fr multistage right common femoral venous drainage cannula. She was placed on V-V ECMO and achieved adequate flows. The patient was then successfully anesthetized and

Table 1 Search strategy summary

Items	Specification
Date of search	05/12/2023
Databases and other sources searched	PubMed
Search terms used	((Thoracic surgery[MeSH Terms]) OR (video assisted thoracic surgery[MeSH Terms]) OR (general thoracic surgery)) AND ((ecmo[MeSH Terms]) OR (veno arterial ecmo) OR (veno venous ecmo))
Timeframe	01 Jan 2010 – 01 May 2023
Inclusion and exclusion criteria	Inclusion criteria: observational and retrospective studies, as well as case series and case reports
	Exclusion criteria: non-English language, full-text not available, ECMO for non-thoracic surgery indications
Selection process	Authors M.E.C. and B.B.D. independently performed the initial search and selected articles for inclusion, first based on titles and abstracts and then based on full text manuscripts. Selected articles were conferred with authors P.R.D.S. and J.D'C., and discrepancies were solved by consensus among these four authors

ECMO, extracorporeal membrane oxygenation.

intubated with a 5.0-mm endotracheal tube. The goiter, which had a significant substernal component, was resected without the need for sternotomy. At the end of the case, heparinization was reversed with protamine in the standard fashion and the patient was weaned and decannulated from V-V ECMO. She was extubated without complication and recovered well after the procedure.

The critically ill patient with lung failure

When considering the applicability of non-emergent ECMO, it is relevant to consider the utilization of ECMO both for diagnostic procedures and as a bridge to recovery or lung transplantation (14). This patient population, often with varying degrees of concomitant cardiac dysfunction, has demonstrated reduced complication rates and shorter duration of post-operative mechanical ventilation (15-17). Of note, venoarterial (V-A) ECMO is often preferred to V-V ECMO in these cases due to the added cardiac support, particularly in patients with right ventricular dysfunction. Intraoperative V-A ECMO can often be maintained post-operatively or converted to V-V ECMO in patients with adequate cardiac function (18). In those needing isolated support, V-V ECMO is a reasonable approach throughout the perioperative period. When this approach of planned perioperative ECMO is extrapolated to other thoracic surgery settings, the patient population that may benefit from ECMO utilization drastically broadens. This includes patients undergoing thoracic resection that are unable to tolerate single-lung ventilation as represented in the case report provided by Redwan *et al.* or those requiring contralateral resection following pneumonectomy (19,20). It may also be important to consider the utility of low-flow ECMO for extracorporeal carbon dioxide removal (ECCO2R) in the setting of anticipated hypercapnia during lung volume reduction surgery as demonstrated by Akil and colleagues (21-23).

We utilize Case 2 below to demonstrate the utility of ECMO as perioperative support in a patient with declining lung function requiring a lung biopsy for further decision-making.

Case 2

A 61-year-old male with history of idiopathic pulmonary fibrosis (IPF), coronary artery disease (CAD), aortic stenosis status post coronary artery bypass grafting (CABG), aortic valve replacement (AVR) and septal myomectomy presented to our emergency department with a several month history of worsening shortness of breath. Initial imaging revealed diffuse bilateral ground glass opacities. In the setting of hypoxic respiratory failure, the patient was admitted to the ICU for further management. He was placed on continuous flow BiPAP and the thoracic surgery team was consulted for a surgical lung biopsy. Following anesthesia induction and intubation; he had persistent hypoxia, signs of early right ventricular failure and hemodynamic compromise that did not improve with administration of nitric oxide. The decision was made to place the patient on V-V ECMO in order to safely obtain the lung biopsy. A 17-Fr return cannula was placed in the right IJ and a 25-Fr multistage drainage cannula in the common femoral vein. The patient was transitioned to ECMO without complication and the biopsy was completed via a mini right anterior thoracotomy. Wedge resections of the middle and lower lobes were obtained and sent for microbiology and frozen and permanent pathologic analysis. The patient returned to the ICU in critical but stable condition on V-V ECMO.

The patient underwent early tracheostomy placement on post-operative day (POD) 2 and was ambulating off sedation on POD 4. In the setting of his irreversible and progressive pulmonary disease he was transferred for lung transplantation and shortly thereafter underwent a bilateral sequential lung transplantation (24). He did well and was discharged one month following transplant without tracheostomy or supplemental oxygen. He is doing well as an outpatient now over 24 months post-transplant.

ECMO in complex resections and airway reconstruction

Tracheobronchial resections and reconstructions present a unique challenge in achieving adequate surgical exposure while maintaining ventilation control. As is seen in lung transplant, intraoperative ECMO use over mechanical ventilation significantly improves site visualization and mobilization. The concept can be applied to major airway resections in which V-V or V-A ECMO is employed to enable progression of complex cases without concern of ventilatory and/or hemodynamic compromise. The literature offers several case reports of intraoperative V-V and V-A ECMO during complex thoracic surgery cases (13,25-30). The same is true when considering complex thoracic malignancy resection such as those invading the thoracic aorta. Utilization of an aortic cross-clamp with V-A ECMO perfusion of the lower body allows for *en-bloc* resection in such instances (31). Similarly, the use of V-A ECMO in resection of centrally located tumors requiring excessive cardiac manipulation offers obvious advantage (32).

It is critical for the team managing such patients to remain aware of available resources in both emergency and planned scenarios (16,33). As part of our practice, it is not uncommon to prep patients for ECMO when there is anticipated technical complexity to a procedure, such as a patient with a central tumor or other pathology whereby the preoperative imaging suggests a technical challenge to resection or reconstruction. This is especially beneficial in cases necessitating left or right lateral decubitus positions, as establishing expedient vascular access after positioning can be quite difficult. This is usually accomplished by placing 5-Fr micropuncture catheters in the femoral artery and vein under ultrasound guidance. These catheters have a very low risk of complication and can be easily removed at the end of the case if not utilized. In cases with a high anticipated risk during induction of anesthesia or intubation, we have not only gained vascular access, but cannulated and established ECMO flow prior to beginning the case. Stokes *et al.* provide a similar approach utilizing V-V ECMO in their review (34). To better illustrate this practice, we offer the following example.

Case 3

A 32-year-old male with history of complex esophageal stricture and tracheoesophageal fistula (TEF) presented with hematemesis following endoscopic stent replacement. The patient deteriorated rapidly and was urgently intubated due to acute hypoxia in the setting of aspiration pneumonia. Over the ensuing days, he had several decompensation episodes with high peak airway pressures. Bedside bronchoscopy revealed significant mucopurulent secretions bilaterally. Following complete removal of the secretions, significant bilious output was visualized coming from the known TEF in the proximal left mainstem at the level of the carina. Of note, the previously placed esophageal stent was visible. The patient was subsequently taken to the operating room for repair. Due to the complex nature of the intended repair, anticipated challenge in maintaining single lung ventilation, and expectation for further pulmonary decline he was placed on V-V ECMO with a 25-Fr multistage drainage cannula in the right common femoral and a 17-Fr single stage return cannula in the right IJ. He tolerated ECMO cannulation without complication. An esophagogastroduodenoscopy (EGD) was performed and the previously placed esophageal stent was removed. A right posterolateral thoracotomy was performed, the esophagus was dissected free from the airway and placed in discontinuity, and the airway was repaired with aortic homograft buttressed with an intercostal muscle flap. As anticipated his pulmonary function continued to decline during the abdominal portion of the operation. Four days later he returned to the operating room for cervical esophagostomy and tracheostomy placement. His respiratory function significantly improved, and he was decannulated on POD 10. Four months later, he underwent a substernal gastric pull-through to reestablish gastrointestinal (GI) continuity and is doing well at last contact, over 2 years following his index operation.

When to avoid ECMO in general thoracic surgery patients

While the utility of ECMO is rapidly advancing in the field of thoracic surgery, it is also worth noting that some patients remain poor or prohibitive candidates for ECMO. As is true of all life-sustaining extraordinary measures, the ultimate goal of bridge therapy must be identified prior to initiation. While absolute contraindications to ECMO remain few (including intracranial processes with likelihood of bleed, irreversible pulmonary destruction without option for transplant, advanced metastatic disease, etc.), the relative contraindications remain widely debated and circumstantial (35,36). In certain practices, it may be helpful for the thoracic surgeon become comfortable implementing ECMO into their practice alongside other cardiothoracic surgeons with ECMO expertise.

Conclusions

Since its first applications in the 1970s, ECMO has served as a rescue therapy for patients with ARDS and cardiogenic shock. In recent years, advancements in cannulation strategies and ECMO standards have enabled the widespread utilization of ECMO in a broadened patient population with direct utility in acute airway obstruction, post-operative airway complication management, and planned support during complex mediastinal operations. The applicability of ECMO outside of its historic applications is drastically expanding, one thoracic surgery patient at a time. The concept, indications, techniques, and management of ECMO should be kept in the "toolbox" of approaches for complex general thoracic procedures that my otherwise not have been able to be safely accomplished in the past.

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Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-961/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. In managing our three cases, all procedures were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patients for publication of this review.

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