

Case Reports

Pre-Intubation Veno-Venous Extracorporeal Membrane Oxygenation in Patients at Risk for Respiratory Decompensation

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Abstract: Veno-venous extracorporeal membrane oxygenation (VV-ECMO) has emerged as a potential life-saving treatment for patients with acute respiratory failure. Given the accumulating literature supporting the use of VV-ECMO without therapeutic levels of anticoagulation, it might be feasible to use it for planned intubation before surgical procedures. Here, we report consecutive series of patients who underwent planned initiation of VV-ECMO, without anticoagulation, before induction of general anesthesia for anticipated difficult airways or respiratory decompensation. We describe the approach to safely initiate VV-ECMO in an awake patient. We retrospectively identified patients in a prospectively maintained database who underwent planned initiation of VV-ECMO before intubation. Standard statistical methods were used to determine post-procedure outcomes. Patients included were

three men and one woman, with a mean age of 34.3 ± 10.4 years. Indications included mediastinal lymphoma, foreign body obstruction, hemoptysis, and tracheo-esophageal fistula. VV-ECMO was initiated electively for all patients, and no anticoagulation was used. The median duration of VV-ECMO support was 2.5 days (1–11 days), the median length of ventilator dependence and intensive care unit stay was 1 day (1–23 days) and 5 days (4–31 days), respectively. The median length of stay was 18.5 days (8–39 days). There were no thrombotic complications and no mortality at 30 days. Initiation of awake VV-ECMO is feasible and is safe before intubation and induction of anesthesia in patients at high risk for respiratory decompensation. **Keywords:** extracorporeal membrane oxygenation, artificial lung, anesthesia induction, airway. *J Extra Corpor Technol. 2020;52:52–7*

OVERVIEW

Veno-venous extracorporeal membrane oxygenation (VV-ECMO) is rapidly emerging as a mainstay therapy for patients with refractory respiratory failure, despite best medical therapy (1). Rapid technological improvements and device miniaturization have allowed for expansion of indications for VV-ECMO. For example, the use of VV-ECMO for intraoperative support for patients undergoing surgical procedures such as lung resection, airway reconstruction, and lung transplantation is increasing (2,3). Some

centers have even proposed pre-emptive initiation of VV-ECMO for patients with impending respiratory failure. As a natural extension, VV-ECMO can provide respiratory support in patients with a tenuous respiratory status and can be initiated in either planned or emergent scenarios (4–6). Here, we report the feasibility of planned initiation of VV-ECMO before intubation in awake patients at high risk for respiratory decompensation with induction of general anesthesia.

Patients and Methods

We reviewed consecutive adult patients placed on VV-ECMO at our medical center between March 2017 and August 2019. Patient data were collected retrospectively from the electronic medical record and from a prospectively maintained institutional ECMO database. A waiver of consent for data collection was obtained from the Northwestern University Institutional Review Board (STU00207250). Four patients were identified who received

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awake, pre-induction VV-ECMO. All four patients had femoral–jugular VV-ECMO configuration. To reduce bleeding complications, patients were not given therapeutic levels of anticoagulants. The patients were administered standard deep vein thrombo-prophylaxis (5,000 U unfractionated heparin given subcutaneously every 8 hours) during their medical course, consistent with recent reports demonstrating the feasibility of using VV-ECMO without anticoagulation (7,8).

Initiation of VV-ECMO

The components of the VV-ECMO circuit included 1) an oxygenator (Quadrox iD Adult (7.0), MAQUET Holding B.V. & Co. KG, Rastatt, Germany), 2) a pump (Rotaflow, MAQUET Holding B.V. & Co. KG, Rastatt, Germany), 3) a standard heat exchanger and no reservoir, and 4) heparin-bonded tubing from the manufacturer of the pump. All the components in the ECMO circuit were heparin-bonded except for the cannulas. Circuits were primed with 2,000 mL of normal saline. Of the prime volume, ~700mL stayed in the circuit, while the rest was collected in the reservoir, which was discarded upon initiation of VV-ECMO. Initiation of VV-ECMO was performed in the operating room in the presence of a cardiothoracic anesthesiologist. Patients received a mild anxiolytic (benzodiazepine) and opioid-based analgesic (fentanyl). An intravenous line (18G or more) and an arterial line were placed, and continuous monitoring of vital signs, including pulse oximetry, was instituted before initiation of VV-ECMO. The groins and neck were prepared and draped, and 1% lidocaine was used for local anesthesia. Under ultrasound guidance, the veins were accessed and wired. Fem-Flex cannulas (Fem-Flex II, Edwards Lifescience, LLC, Irvine, CA) were placed in the jugular vein for outflow, and Bio-Medicus (Biomedicus, Medtronic, Minneapolis, MN) cannulas were placed in the femoral vein for inflow. Venous cannulas were advanced into the superior vena cava–atrial junction and inferior vena cava (IVC)–atrial junction. Fluoroscopy was used to monitor the placement when necessary. Typically, the cannula in the neck was advanced maximally, and the distance of the IVC cannula was determined using the venous access point to the xiphoid-sternal junction, as a guide. To de-air the neck cannula, patients were pre-hydrated by giving a 250-mL fluid bolus and transiently placed in the Trendelenburg position to allow for back bleeding immediately before connecting to the ECMO circuit. Both cannulas were de-aired, and ECMO was initiated, following which general anesthesia was induced. The ECMO flows were maintained at a speed to allow for normal blood oxygenation and carbon dioxide levels while minimizing hemolysis. The typical flow rates were 3.5–4.5 L/min.

DESCRIPTION

Patient 1

A 33-year-old woman, 15 weeks pregnant and with no significant medical history, presented with progressive dyspnea for 8 weeks. Chest imaging showed a large, $14.1 \times 13.8 \times 11.2$ -cm, locally invasive left upper lung mass with significant tracheal deviation and compression (Figures 1A and B). Despite oxygen saturations greater than 95% on room air, she had absent breath sounds over the upper left hemithorax and was unable to lie supine because of airway compression. A tracheal stent and biopsy of the mass were necessary, given the concerns for lymphoma. Because of the high risk for induction and intubation, the patient was placed on preoperative, awake VV-ECMO via the right internal jugular and right femoral veins using a 16-French Fem-Flex and 21-French long Bio-Medicus venous cannulas, respectively. She was then induced with general anesthesia. The intubation was made difficult by the inability of the endotracheal tube to be advanced beyond the proximal tracheal stenosis. However, VV-ECMO prevented desaturation and respiratory decompensation. A rigid bronchoscopy was necessary to maintain sufficient airway lumen and allow for flexible bronchoscope to be advanced. Bronchoscopy confirmed the severely narrowed trachea due to extrinsic compression. Cryotherapy for tissue excision was performed in the left upper lobe, which was occluded by tumor, and sent for histopathology examination. In addition, transbronchial needle aspiration was performed followed by placement of a Y-silicone stent to prevent airway collapse. The post-stent lumen size was 70% of normal. Biopsies were suggestive of lymphoma on the frozen section, but because of the necessity for more tissue, cervical mediastinoscopy was performed in the same setting that confirmed the diagnosis. The patient was weaned off VV-ECMO and extubated on postoperative day (POD) 1. Following decannulation and stent placement, she was able to lay flat and her dyspnea improved. She was started on a chemotherapy regime and achieved complete tumor response. At the time of stent removal, the bronchial lumen was within normal limits (Figure 1C). She remained in tumor remission at 13 months following treatment.

Patient 2

A 37-year-old man with an indwelling T-tube due to tracheal restenosis following laryngotracheal resection presented with severe stridor due to migration of the T-tube into the distal trachea. Flexible laryngoscopy was performed through the tracheal stoma, which was severely stenotic and could not accommodate the scope (Figure 2). Tracheostoma and trachea demonstrated severe granulation and scarring, moderate tracheomalacia, and partial obliteration of the tracheal rings with chronic erythema and

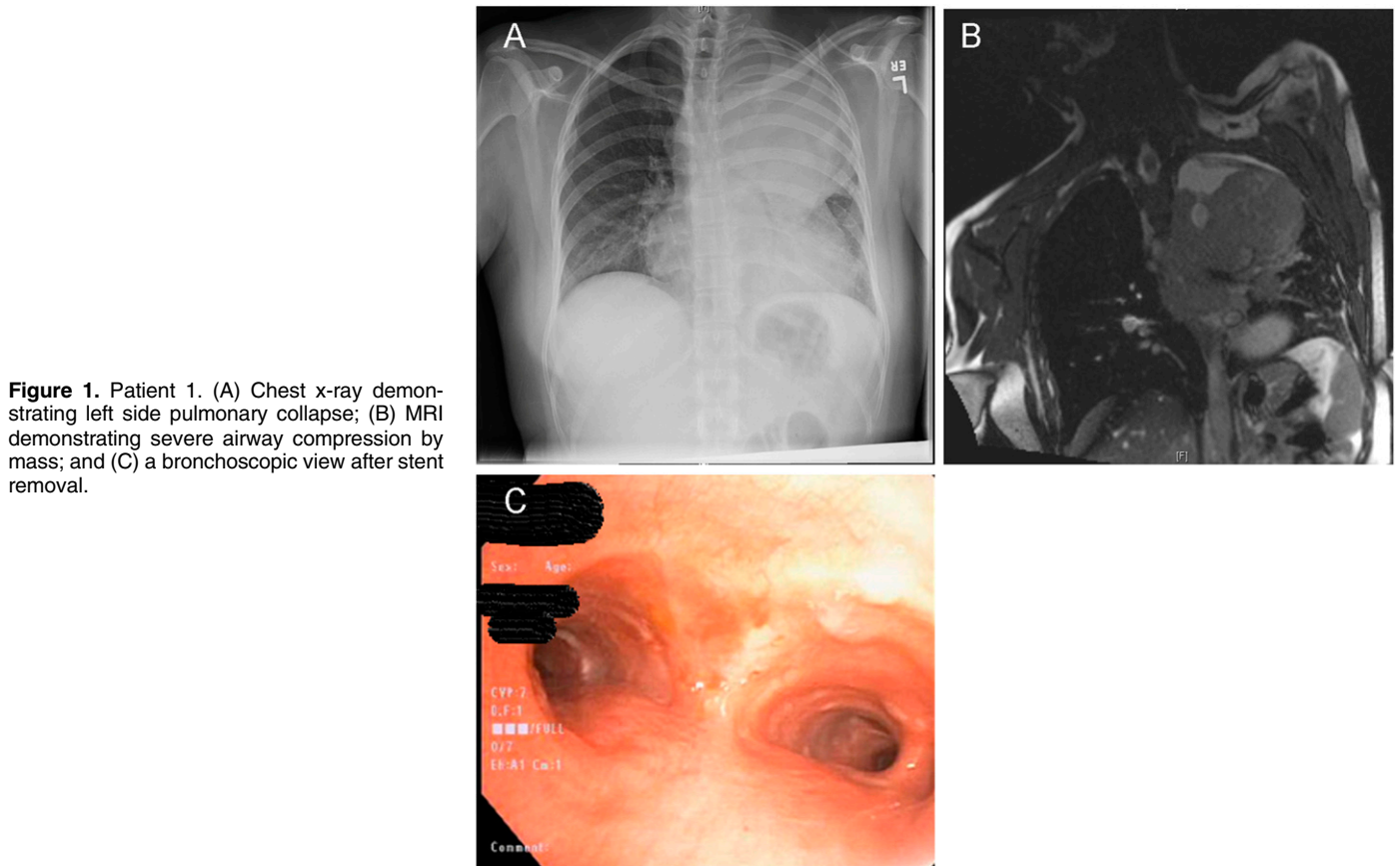


Figure 1. Patient 1. (A) Chest x-ray demonstrating left side pulmonary collapse; (B) MRI demonstrating severe airway compression by mass; and (C) a bronchoscopic view after stent removal.

edema. Distally in the main trachea, the large (size 11) T-tube was folded on itself with near-complete occlusion of the airway. Flexible laryngoscopy was attempted through the patient's nares to assess the upper airway and larynx but was poorly tolerated because of coughing and airway obstruction. The patient had a history of failed intubation due to the known severe subglottic stenosis. The patient was able to maintain saturations although he had severe tachypnea and stridor.

The patient was taken to the operating room for an urgent intervention and, given his high risk of airway compromise, placed on awake pre-induction VV-ECMO with a 16-French Fem-Flex cannula inserted into the right internal jugular vein and 19-French long venous Bio-Medicus cannula inserted into the right femoral vein using fluoroscopy. After initiating VV-ECMO, the patient was sedated and underwent rigid bronchoscopy with the removal of foreign body, tracheal dilation, and placement of a 6.0 Bivona TTS tracheal tube (Smith Medical, St. Paul, MN). He was weaned off VV-ECMO and extubated on POD 1 without any complications.

Patient 3

A 46-year-old man with a history of hypertrophic obstructive cardiomyopathy, histoplasmosis, and atrial fibrillation status

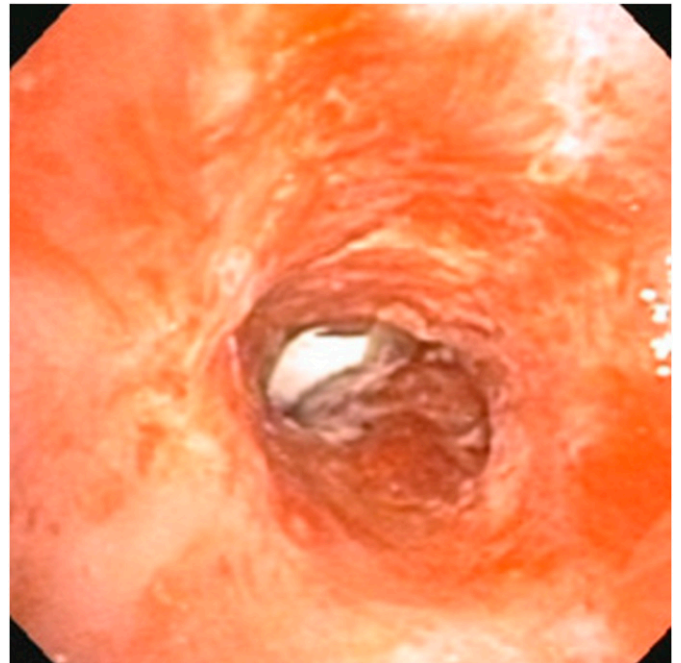


Figure 2. Patient 2. Subglottic stenosis.

after multiple catheter ablations and vein stenting presented with recurrent hemoptysis from the left upper lobe, despite multiple bronchial artery embolizations. Angiography revealed bilateral superior pulmonary vein stenosis, most prominent on the left superior vein (Figure 3A). Quantitative ventilation–perfusion lung scan demonstrated severely decreased perfusion in both upper lobes but more strikingly decreased ventilation in bilateral upper lobes. Ventilation was shown to be 28.4% on the left lung, 9.5% of which was ventilation in the left upper lobe (Figure 3B). On induction of general anesthesia, the patient developed severe refractory hypoxemic respiratory failure requiring emergent VV-ECMO. This was possibly caused because of ventilation–perfusion mismatch, resulting from preferential ventilation of upper lobes on mechanical ventilation, and dependent lower lobe atelectasis, without matching perfusion due to venous stenosis, as evident by the pre-operative perfusion scan. Alternatively, this could have resulted from hemoptysis, although bronchoscopy revealed no active bleeding, but there were stigmata of recent bleed from the left upper lobe. On separation from mechanical ventilation, he was decannulated from VV-ECMO and was subsequently discharged with plans for elective lobectomy. Given his previous respiratory collapse requiring emergent VV-ECMO after induction of general anesthesia, the patient was deemed high risk and was placed on VV-ECMO before intubation using a left internal jugular 16-French venous cannula and a 25-French Biomedical cannula in the right femoral vein. The patient was then induced and intubated, and video-assisted thoracoscopic surgery left upper lobectomy was performed safely. He was extubated on POD 1 and weaned off VV-ECMO on POD 4 without any complications. The patient remains free of hemoptysis at 12 months of follow-up.

Patient 4

A 21-year-old man with primary mediastinal B-cell lymphoma underwent chemotherapy with etoposide, doxorubicin, vincristine, cyclophosphamide-rituximab therapy with complete tumor response. However, he developed a 6-cm tracheo-esophageal fistula (TEF) treated with an esophageal stent at an outside hospital (Figures 4A and B). The esophageal stent migrated into the trachea through the tracheal defect, leading to severe tracheal occlusion and respiratory distress. Given the high risk for complete airway obstruction and inability to accomplish intubation, the patient was placed on VV-ECMO using a 15-French Fem-Flex cannula in the right internal jugular vein and a 19-French Bio-Medicus cannula in the right femoral vein. The patient then underwent general anesthesia and airway managed with a laryngeal mask airway. Flexible bronchoscopy demonstrated that the proximal half of the esophageal stent had migrated into the trachea, causing complete occlusion (Figure 4C). Using a combination of bronchoscopy and esophagoscopy, the stent was extracted. The main carina was found to be destroyed by the stent with disarticulation of the left main bronchus (Figure 4D). The patient was then intubated with a double-lumen endotracheal tube with bronchoscopic guidance. The patient then underwent right thoracotomy for division of distal esophagus, and a left lateral neck exploration for division of proximal esophagus and creation of esophagostomy. A 10 × 40-mm Bonastent into the left main bronchus with subsequent dilation with a 3-cm Merit Elation balloon to a maximal diameter of 10 mm was placed. He was extubated at the end of the procedure, required tracheal stent revision on POD 9, and decannulated from VV-ECMO on POD 11.

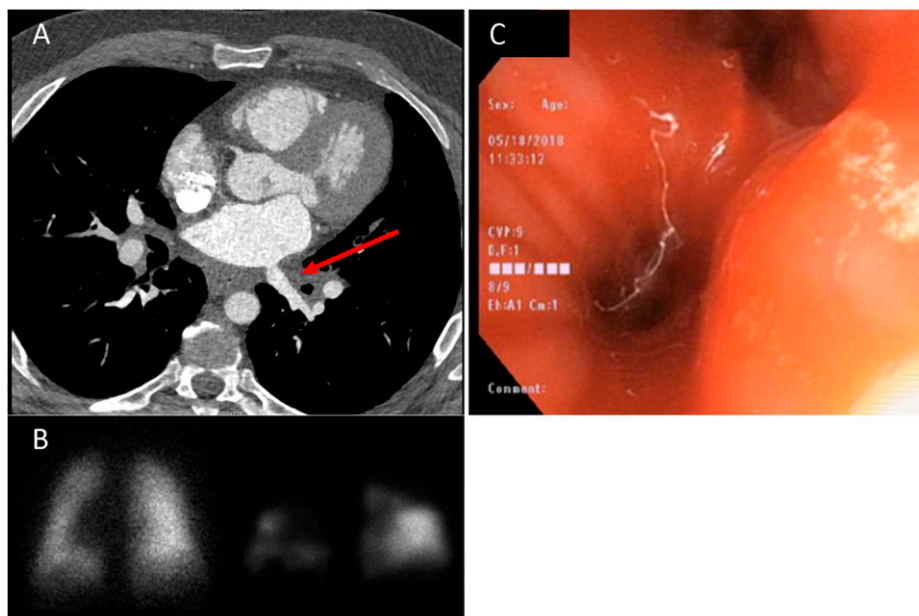


Figure 3. Patient 3. (A) Chest computed tomography (CT) demonstrating pulmonary vein stenosis; (B) ventilation–perfusion scan; and (C) bronchoscopic image of hemorrhagic airway.

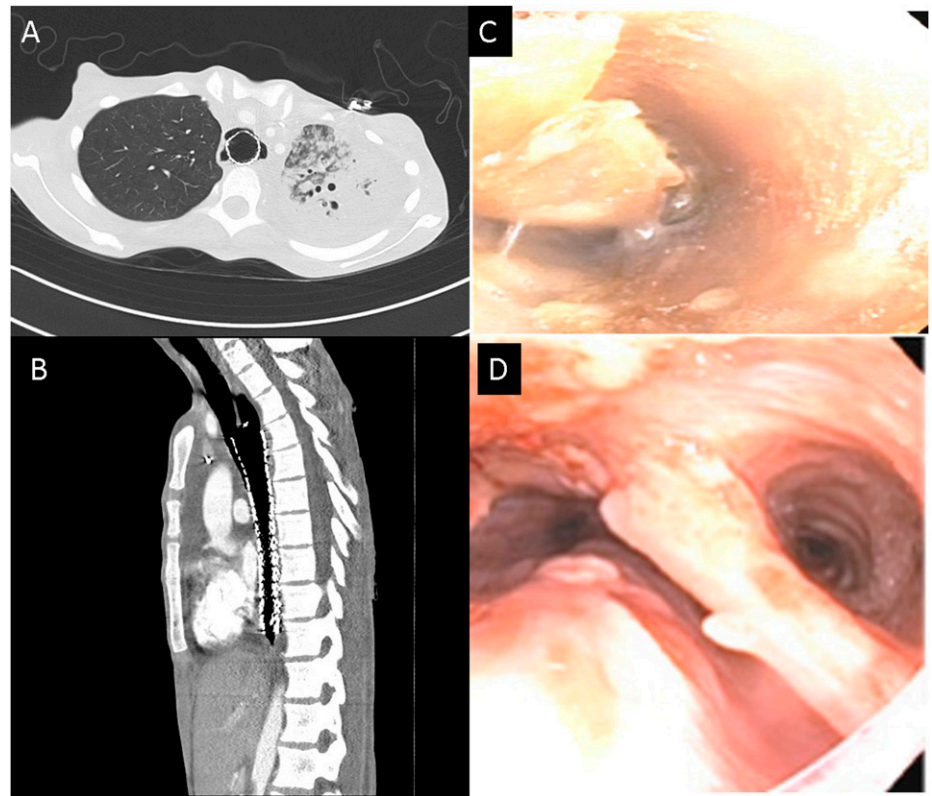


Figure 4. Patient 4. (A) Chest CT demonstrating TEF in the axial view; (B) chest CT demonstrating TEF in the sagittal view; (C) unpassable tracheal obstruction due to an esophageal stent; and (D) disarticulated left main stem bronchus.

COMMENT

Although the use of ECMO for respiratory failure has been widely described, the use of VV-ECMO for compromised airway is emerging (9). All patients were cannulated in a controlled setting without complications. On

induction of anesthesia, there was no respiratory compromise, allowing for a safe and controlled airway management strategy. There were no operative mortalities, no ECMO-related complications, and no 30-day mortality. In addition, there was no venous thrombosis on the outpatient follow-up at 3–4 weeks, determined using a venous duplex.

Table 1. Patient characteristics.

	Patient 1	Patient 2	Patient 3	Patient 4
Gender	Female	Male	Male	Male
Age (years)	33	37	46	21
BMI (kg/m)	23.4	24.5	34.2	14.1
Problem	Mediastinal lymphoma	Foreign body obstruction	Hemoptysis	TEF
Procedure	Mediastinal biopsy and tracheal stent	Removal of foreign body and tracheal dilation	Thoracoscopic left upper lobectomy	Thoracotomy, partial esophagectomy with esophagostomy, and flexible EGD, esophageal stent removal
VV-ECMO strategy	Right IJV and right FV	Right IJV and right FV	Left IJV and right FV	Right IJV and right FV
VV-ECMO duration (days)	1	1	4	11
Anticoagulation	No	No	No	No
Ventilator dependence (days)	1	1	1	29
Intensive care unit stay (days)	5	5	4	31
Length of hospital stay (days)	29	8	8	39
Status at 30 days	Alive	Alive	Alive	Alive
ECMO complication(s)	None	None	None	None

EGD, esophagogastroduodenoscopy; IJV, internal jugular vein; FV, femoral vein.

Induction of general anesthesia entails multiple risks to patients with an already compromised airway. If an endotracheal airway is not promptly secured following induction, particularly in high-risk patients with airway compromise, bag-masking may be insufficient. In such circumstances, an emergent surgical airway might also pose significant challenges and risks because of tracheal deviation or structural abnormalities. In these cases, a surgical airway may not have been possible or able to prevent life-threatening hypoxemia. Hence, we believe that without VV-ECMO, these patients would have not been able to be treated. A potential alternative is awake fiberoptic bronchoscopy-guided intubation, although this was not feasible in any of our patients. Nonetheless, for difficult airways, it may be considered before initiation of VV-ECMO. Our report is consistent with the anecdotal experience of other investigators who have used VA-ECMO or cardiopulmonary bypass for compromised airways (9,10), among others. The key difference in our approach is a planned approach without systemic anticoagulation, a complete percutaneous approach, and initiation of all cases in awake patients. We also used a two-cannula approach and not a dual lumen cannula in the atrio-caval or atrio-pulmonary artery configuration because dual lumen cannulas require a more complex positioning, which could be potentially unsafe in awake patients with respiratory compromise. For example, positioning of an Avalon cannula in the atrio-caval configuration is best accomplished using transesophageal echocardiography to determine the outflow jet across the tricuspid valve. Hence, our approach of using two cannulas was guided by the goal to offer the most simplistic initiation of VV-ECMO in these compromised patients. Last, a dual lumen cannula is much larger in diameter and can possibly be associated with more discomfort during the dilation of the subcutaneous track necessary for the positioning of the cannula.

VV-ECMO can be associated with complications such as bleeding, technical complications with vascular injury, hemolysis, and thrombocytopenia, among others. We also propose that VV-ECMO performed using a percutaneous approach is the safest and most comfortable approach for these awake patients. In addition, avoiding arterial access allows us to use ECMO without anticoagulation, minimizing blood loss during the surgical intervention. There is

accumulating evidence supporting the observation that the absence of systemic anticoagulation is safe during ECMO support (8). Our report is a case series, but a randomized study to investigate VV-ECMO for such patients with compromised airway might not be practical or feasible. We, therefore, propose that VV-ECMO may be considered for patients at high risk for respiratory decompensation on induction of general anesthesia.

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