CASE REPORT

Extracorporeal Membrane Oxygenator Rotational Cannula Catastrophe: A Role of Echocardiography in Rescue

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VENO-VENOUS EXTRACORPOREAL membrane oxygenation (VV-ECMO) has evolved as a salvage therapy for adults with refractory hypoxemia and hypercapnia that is resistant to maximal conventional mechanical ventilation. By providing a direct mechanism for oxygenation and elimination of carbon dioxide, VV-ECMO can provide a period of "lung rest," in which a protective lung ventilation strategy—in the form of low tidal volumes, low inspired oxygen fraction, and low inspiratory pressures—can be instituted and may further improve outcomes by mitigating ventilator-induced lung injury.[1,2] In most approaches to VV-ECMO, a cannula is placed in a central vein. Blood is withdrawn from the central vein into an extracorporeal circuit with use of a mechanical pump before the blood enters a membrane-type oxygenator. Within the oxygenator, blood passes along one side of the membrane, which provides a blood-gas interface for gas exchange. The oxygenated extracorporeal blood then may be warmed or cooled as needed and is returned to the central vein. This specific technique is termed "veno-venous" ECMO because blood is both withdrawn from and returned to the central venous system.

Cannulation for VV-ECMO may involve a 2-site or a single-site approach. In the 2-site approach, blood typically is withdrawn from the inferior vena cava through a drainage cannula in the femoral vein, and oxygenated blood is returned into the right atrium through an additional cannula in the internal jugular vein. This 2-site approach results in recirculation of blood in which the returned oxygenated blood is drawn back (or "sucked in") into the circuit in a closed loop without contributing to systemic oxygenation.[3]

The recent introduction of a bicaval dual-lumen cannula (Avalon Elite Bi-Caval Dual Lumen Catheter; Maquet Cardiopulmonary, Rastatt, Germany) allows single-site cannulation of the internal jugular vein. Venous blood is withdrawn through 1 lumen with ports in both the superior and inferior vena cavae. Extracorporeal oxygenated blood is returned through the second lumen and is directed across the tricuspid valve. The advantages of the single-site approach include improved patient mobility because of avoidance of femoral site cannulation and reduced recirculation when the cannula is properly positioned.[4]

In the authors' institution, bicaval dual-lumen central venous cannulation is performed using fluoroscopic guidance, and adequate cannula positioning is confirmed by daily chest x-ray. Echocardiography is used when there is a question about cannula position despite radiographic confirmation. The majority of reports on bicaval cannula malposition describe a longitudinal displacement of the cannula, in which the cannula migrates superiorly or inferiorly in the vena cavae, resulting in recirculation, hypoxemia, and pump flow reductions.[5,6]

In this case report, the authors describe an unusual "rotational" malposition of the bicaval dual-lumen cannula, in which oxygenated blood was directed in a suboptimal position away from the tricuspid valve, resulting in recirculation and life-threatening hypoxemia. This malposition occurred despite adequate vertical cannula position and was discovered only by echocardiography.

CASE PRESENTATION

A 41-year-old, 175-cm, 115.6-kg white male presented to the authors' institution as a transfer to the ECMO service. The patient was involved in a motor vehicle accident 7 days before being transferred and had developed acute respiratory distress syndrome secondary to pulmonary contusions and pneumonia. He was transferred to the authors' facility to undergo VV-ECMO to alleviate severe refractory hypoxemia, hypercapnia, and reduced lung compliance. The patient's trachea was intubated with an endotracheal tube (size #7.5), and he was sedated and placed under general anesthesia with the use of propofol, fentanyl, and cisatracurium (Table 1). Even though the inspired oxygen fraction (F_IO_2) and positive end-expiratory pressure (PEEP) levels were increased, general anesthesia was administered, and nitric oxide was initiated, the patient's condition remained hypoxemic and hypercapnic (Table 1). Subsequently, the patient developed sinus tachycardia and hypertension that most likely resulted from the patient's worsening respiratory status (see Table 1).

As a result of progressive deterioration in the patient's respiratory status, a decision was made to initiate VV-ECMO using the dual-lumen bicaval cannula (Avalon Elite Bi-Caval Dual Lumen Catheter). Using Seldinger's technique under fluoroscopic guidance, the right internal jugular vein was

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Table 1. Patient's Admission Information

ABG	PH	$PaCO_2$ (mmHg)	PaO_2 (mmHg)	HCO_3	SpO_2 %	
	7.32	72	54	36	83	
Ventilator settings	Mode	PEEP (cmH_2O)	F_IO_2	PIP (cmH_2O)	F bpm	VT mL/PBW
	AC/VC	16	1	42	25	6
Medications	Proprofol (μg/kg/min)	Fentanyl (μg/h)	Cisatracurium (μg/kg/min)	NO PPM		
	50	200	3	20		
Vital signs	37.5°C	136 bpm	180/89 (108)			

Abbreviations: ABG, arterial blood gases; AC/VC, assist control/volume control; bpm, breaths per minute; F, frequency; F_IO_2, inspired oxygen fraction; HCO_3, bicarbonate "calculated"; NO, nitric oxide; $PaCO_2$, arterial partial pressure of carbon dioxide; PaO_2, arterial partial pressure of oxygen; PBW, predicted body weight; PEEP, positive end-expiratory pressure; PPM, parts per million; SpO_2, arterial oxygen saturation; μg/kg/min, microgram per kilogram per minute; VT, tidal volume.

cannulated uneventfully. Subsequently, the ECMO circuit was connected to the cannula, and ECMO flow was initiated at a flow rate of 4 L/min, delivered oxygen fraction of 1.0, and a sweep rate of 5 L/min. A heparin infusion was administered for anticoagulation to maintain an activated clotting time of 160 to 240 msec. An immediate post-procedure chest x-ray was obtained to confirm correct positing of the cannula. Shortly after confirmation of cannula position, the patient's clinical condition began to deteriorate. A progressive decline in arterial oxygen saturation occurred, coupled with tachycardia and hypertension (Fig 1). This coincided with a reduction in ECMO flows and a rise in ECMO venous saturation (ECMO SvO_2, 96%), indicative of recirculation. A chest x-ray was obtained immediately and showed adequate cannula position. As a result of the progressive clinical deterioration, transesophageal echocardiography (TEE) was performed to further confirm cannula position. Midesophageal bicaval TEE showed that the cannula had rotated in such a way that the port for oxygenated blood was directed toward the interatrial septum rather than toward the tricuspid valve (Video 1). Despite the inadequate rotational position, the longitudinal position of the cannula in both vena cavae appeared adequate. The ECMO surgical team was notified immediately, and the cannula was repositioned using TEE guidance (Video 2). The repositioning of the cannula was accompanied by dramatic improvement in the patient's hemodynamics, as evidenced by an increase in arterial oxygen saturation and the gradual resolution of tachycardia and hypertension. In addition, ECMO flows increased to 4 L/min with no chattering events, phenomena that result from excessive negative pressure created by the pump, causing intermittent collapse of the venous circulation. A confirmatory transthoracic echocardiogram (TTE) was obtained and showed

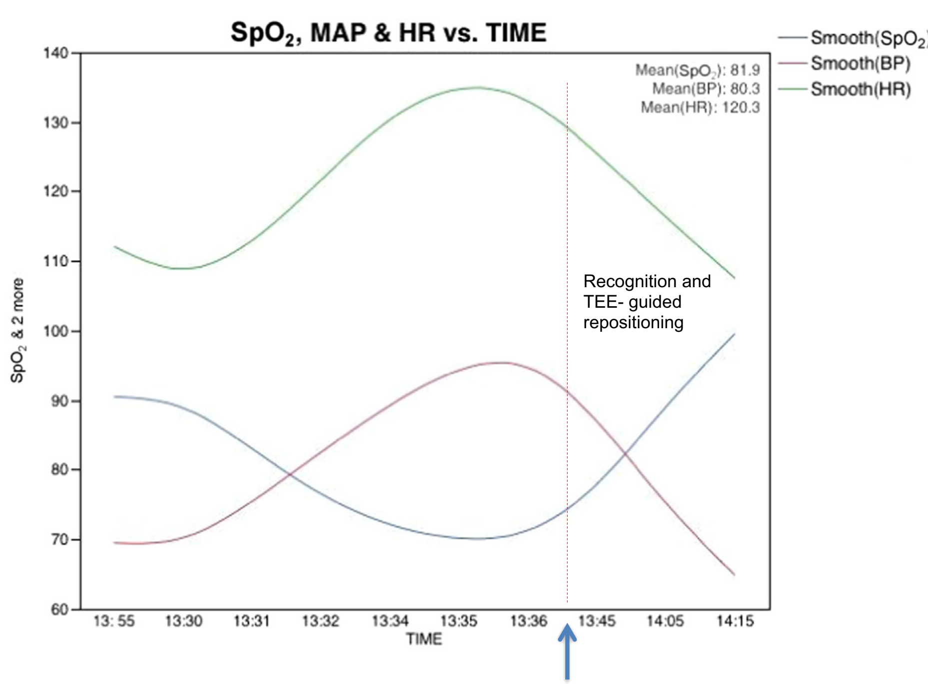

Fig 1. **Patient's hemodynamic profile over time during VV-ECMO cannulation. Heart rate *(HR, green)* and mean arterial pressure *(MAP, red)* increased from baseline because of VV-ECMO cannula malposition. Meanwhile, arterial oxygen saturation *(SpO_2, blue)* declined from baseline values. With optimal cannula repositioning *(arrow)*, HR, MAP, and SpO_2 returned to normal values.**