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CASE REPORT

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Novel method for left ventricular unloading utilizing percutaneous pulmonary artery drainage in cardiorespiratory failure due to COVID-19 infection

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Abstract

Left ventricular (LV) unloading is an important concept in patients undergoing peripheral venoarterial extracorporeal membrane oxygenation (VA-ECMO). We present a case of a 32-year-old male in acute cardiorespiratory collapse due to coronavirus disease (COVID-19) who underwent VA-ECMO cannulation in the setting of cardiogenic shock and acute respiratory distress syndrome. Due to inability to utilize percutaneous LV assist device (pLVAD) for LV unloading due to small end diastolic dimension, alternative strategies were explored. A traditionally utilized right ventricular support device, the ProTek Duo (TandemLife, Pittsburgh, PA), was utilized to drain the pulmonary artery, leading to improvement in parameters for cardiogenic shock. To our knowledge, this is the first case in which a ProTek Duo has been utilized in conjunction with VA-ECMO to provide LV unloading in support of a patient in cardiogenic shock. This method can be employed in future challenging situations where pLVAD is not feasible.

KEYWORDS
cardiogenic shock, COVID-19, heart failure, mechanical circulatory support

1 | INTRODUCTION

Venoarterial extracorporeal membrane oxygenation (VA-ECMO) is a form of mechanical circulatory support (MCS) utilized to provide full cardiopulmonary support in patients with cardiorespiratory collapse as a potential bridge to recovery, durable device or transplant.[1] Novel coronavirus disease (COVID-19) due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is responsible for a global pandemic that has increased the consideration and use of ECMO in patients with isolated pulmonary manifestations of the disease as well as in patients with cardiogenic shock, requiring arterial cannulation.[2–5]

Utilization of VA-ECMO can intrinsically alter the left ventricular (LV) hemodynamics through a consequent increase in afterload secondary to retrograde arterial flow via the arterial cannula. Patients with reduced ventricular contractility will experience increased ventricular pressure, volume, and distention due to an inability to generate sufficient pressure to open the aortic valve against the resistance due to retrograde flow generated by the ECMO circuit.[6] Thus, following unloading, the patient's hemodynamic profile moves downward and to the left on the pressure volume relationship.

Strategies employed to provide LV unloading with the use of VA-ECMO include medical therapy via inotropes and vasodilators, intra-aortic balloon pump, surgical venting, atrial septostomy, and

Abbreviations: ARDS, acute respiratory distress syndrome; COVID-19, coronavirus disease; LV, left ventricle; MAP, mean arterial pressure; MCS, mechanical circulatory support; PA, pulmonary artery; pLVAD, percutaneous left ventricular assist device; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; TTE, transthoracic echocardiogram; VA-ECMO, venoarterial extracorporeal membrane oxygenation; VV-ECMO, venovenous.

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TABLE 1 Strategies for venoarterial extracorporeal membrane oxygenation left ventricular unloading

Modality of LV unloading	Strategy
Medical unloading	Inotropes
	Vasodilators
Passive unloading	Atrial septostomy
Active percutaneous unloading	IABP
	pLVAD
	pRVAD[a]
	Left atrial cannula to ECMO circuit
	Transaortic pigtail catheter in LV
Surgical unloading	Direct LV venting
	Central VA-ECMO

Abbreviations: IABP, intra-aortic balloon pump; LV, left ventricular; pLVAD, percutaneous left ventricular assist device; pRVAD, percutaneous right ventricular assist device; VA-ECMO, venoarterial extracorporeal membrane oxygenation.

[a]As described in this manuscript

currently the most commonly employed strategy, percutaneous LV assist device (pLVAD) (Table 1). However, each venting strategy has its own benefits and limitations with regard to the hemodynamic profile achieved and risks associated with placement and use. We present a novel case of LV unloading utilizing a ProTek Duo (TandemLife) MCS device to drain the pulmonary artery (PA) to improve ventricular hemodynamics in a patient with COVID-19 and cardiorespiratory collapse requiring VA-ECMO.

2 | CASE

A 32-year-old male with a past medical history of obesity presented with a chief complaint of ageusia, nausea, and diarrhea and was found to be COVID-19 positive. The patient was started on high flow nasal cannula in the setting of hypoxemia as well as remdesivir, dexamethasone, and toculizumab. Due to worsening acute respiratory distress syndrome (ARDS), the patient was subsequently intubated and started on mechanical ventilation. Following shock team and ECMO team discussion, the decision was made to proceed with venovenous (VV) ECMO cannulation, with right femoral vein drainage and right internal jugular vein return. After VV-ECMO cannulation, the patient developed profound hypoperfusion and shock with a pH of 7.1 and a lactic acid of 25 mmol/L (reference range <2 mmol/L).

Transthoracic echocardiogram (TTE) revealed LV ejection fraction of 20% with global hypokinesis and severely reduced right ventricular function with a small LV measuring <3.5 cm. Electrocardiogram did not show any acute ST segement changes or signs of ischemia. Patient remained severely hypotensive, with mean arterial pressures (MAP) < 55 mmHg despite titration of multiple vasoreactive medications including epinephrine, norepinephrine, phenylepinephrine, and vasopressin. As a result, the shock team made the decision to convert MCS support from VV-ECMO configuration to VA-ECMO, with a right femoral artery return cannula.

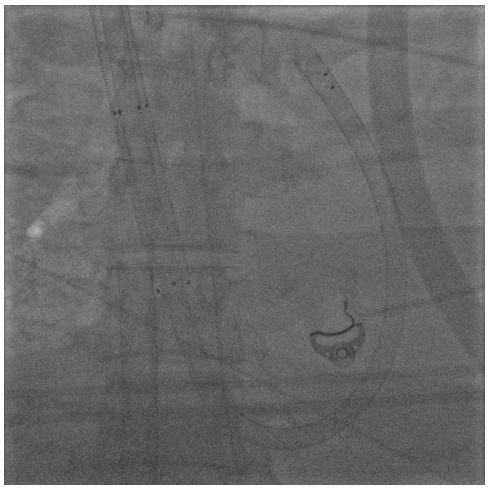

FIGURE 1 Placement of a ProTek Duo mechanical support device in the pulmonary artery to provide left ventricular unloading following venoarterial extracorporeal membrane oxygenation cannulation

Despite conversion to VA-ECMO while on multiple vasoreactive medications, the patient had ongoing shock and persistent systemic hypoperfusion with a rising lactic acid to 28 mmol/L. MAP was elevated to 89 mmHg following VA-ECMO cannulation, and LV dimensions increased to 4.5 cm. Due to lack of pulsatility and need for more flow with evidence of increased LV distention, an urgent need for LV unloading/venting strategy was required. In the setting of a small LV dimensions before ECMO cannulation, it was determined that a pLVAD would not be effective. Thus, the decision was made to proceed with placement of a ProTek Duo device as a collective right atrial and PA drainage device in a reverse configuration to drain the right heart and subsequently unload the LV.

The patient was brought to the cardiac catheterization laboratory urgently and the right internal jugular venous return cannula was cross clamped. An 18-G needle then introduced into the cannula to allow for an 0.035 in. wire to advance into the right ventricle. The cannula was then removed, and an 18-Fr sheath then advanced over a wire into the right internal jugular vein. A 7-Fr balloon wedge catheter was then advanced into the distal right branch PA, with a 0.035 in. extra stiff wire advanced into the catheter to allow for extra support. The catheter was then withdrawn over the wire, and the right internal jugular vein was dilated progressively to a 24-Fr size before advancement of the ProTek Duo into the right PA (Figure 1). The right ventricular support device was then connected to the ECMO circuit and configured to withdraw blood from the PA and return oxygenated blood into the arterial cannula.

Within 24 h following PA MCS device placement for LV unloading, markers of hypoperfusion improved with lactic acid decreasing to 2.5 mmol/L. MAP improved to 70 mmHg from 89 mmHg with

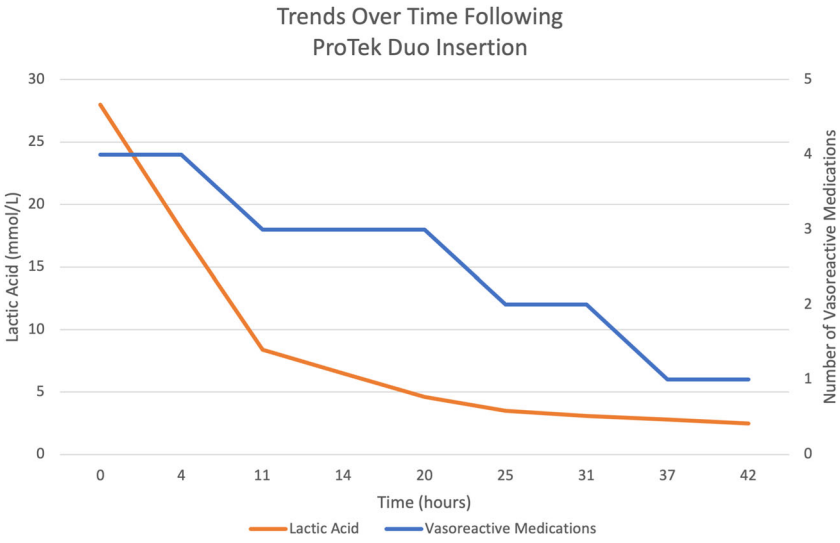

FIGURE 2 Trend of lactic acid (mmol/L) and number of vasoreactive medications over time following insertion of ProTek Duo mechanical support device in the pulmonary artery to provide left ventricular unloading [Color figure can be viewed at wileyonlinelibrary.com]

improved arterial pulsatility from 8 to 19 mmHg. Vasoreactive medication requirements began to decrease, with patient able to wean off norepinephrine, phenylepinephrine and vasopressin, remaining on low dose epinephrine for contractility and to allow the aortic valve to fully open as assessed on bedside TTE. LV dimensions improved from 4.5 cm before unloading to 4.2 cm following insertion of ProTek Duo. In addition, FiO_2 requirements and positive end expiratory pressure requirements decreased following unloading due to decreased pulmonary congestion. Trends of lactic acid and vasoreactive medications over time are shown in Figure 2.

Despite significant improvements in LV recovery and hypoperfusion, the patient unfortunately developed candidemia and was placed on comfort care following 3 weeks of intensive care hospitalization.

3 | DISCUSSION

LV unloading/venting is an important concept in the use of VA-ECMO due to increases in LV afterload seen as a result of peripheral arterial return. Improving LV hemodynamics to allow for reduced LV distension and elimination of pulmonary edema are important considerations in patients who require MCS support in the setting of cardiorespiratory collapse. We describe how a patient with COVID-19 underwent a novel LV unloading strategy via ProTek Duo cannulation in a reverse configuration to unload the LV.

The ProTek Duo pRVAD has been used for right ventricular support in the setting of a failing right ventricle or following LVAD placement.[7] However, this to our knowledge is the first reported case of LV unloading strategy with a ProTek Duo device. Due to inability to place pLVAD for LV unloading in the setting of small initial LV dimensions, and absence of immediately available transeptal systems, we elected to proceed with PA drainage which functionally reduces LA volume and LV volume and results in adequate LV venting. This configuration of right ventricular support device allowed for withdrawal of blood from the PA drainage and return oxygenated blood into the arterial cannula. This decreased O_2 requirements and pulmonary congestion with decreased positive end expiratory pressure as well as FiO_2, improved LV dimensions, improved pulsatility, reduced MAP and vasoactive/vasoconstrictive medications requirements. Drainage of the PA into the ECMO oxygenator with subsequent arterial return cannula allowed for a decrease in venous return to the LV resulting in physiologic and effective LV unloading as measured based on hemodynamic and TTE parameters.

Previously, PA drainage has been explored in porcine models for VA-ECMO LV unloading with promising results, allowing for maintenance of end-organ function as well as reduction in overall stroke work and pressure/volume area reductions.[8] Direct PA venting has been attempted through cannulas in the PA in both adult and pediatric patients as described in previous case series.[9–11] The use of ProTek Duo configuration however can allow for flows up to 4.5 L/min to provide maximal LV unloading and reduction in LV distention and risk for pulmonary edema. This was especially true in our patient due to concurrent COVID-19 infection and severe ARDS.

Other strategies for unloading in this patient where pLVAD is not suitable due to LV size include surgical venting as well as direct left atrial septostomy to allow for LV unloading.[12] However, due to acute critical illness surgical venting was not pursued.

4 | CONCLUSION

Cardiorespiratory collapse requiring VA-ECMO can necessitate a LV unloading strategy to decrease LV distention and subsequent pulmonary edema caused by increases in LV afterload from arterial return. We present a novel use of a RVAD, the ProTek Duo MCS device in a reverse configuration as a strategy to help unload the left ventricle with improvements in tissue perfusion and LV function. Understanding the various options for MCS configurations available to the multidisciplinary shock and ECMO teams is an important aspect of providing care in complex and challenging patients.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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