The ProtekDuo as Double Lumen Return Cannula in V-VP ECMO Configuration: A First-In-Man Method Description

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ABSTRACT
We present a case of acute respiratory distress syndrome (ARDS) secondary to COVID-19 who required venovenous extracorporeal membrane oxygenation (V-V ECMO). Initially, a right ventricular assist device (RVAD), the ProtekDuo with an oxygenator, was placed in an outside heart center and the patient was transferred to us for ECMO management. Due to severe hypoxia, the configuration was later modified, and a 25 Fr femoral drainage cannula was inserted for venous drainage only. The arterial return tubing was spliced and using a Y-connector, arterialized blood was returned through both limbs of the ProtekDuo resulting in a significantly increased oxygenation and flow.

Keywords: ARDS, COVID-19, ECLS, new method, right ventricular assist device

INTRODUCTION
The role of venovenous extracorporeal membrane oxygenation (V-V ECMO) in acute respiratory failure (ARF) with acute respiratory distress syndrome (ARDS) has been established over the last decade. Different mechanical circulatory support (MCS) techniques and devices have evolved parallelly, such as the ProtekDuo (CardiacAssist Inc., Pittsburgh, PA), a percutaneously, via right internal jugular vein inserted right ventricular assist device (RVAD), which can also be used in the V-V ECMO configuration, similar to a dual lumen ECMO cannula, when an oxygenator is added to the circuit. The inflow cannula is situated in the right atrium (RA), thereby receiving venous drainage from both the upper and lower body, and the outflow cannula is positioned in the main pulmonary artery, bypassing the right ventricle (RV).[1]

CASE REPORT
A 20-year-old Hispanic male was admitted to an outside hospital with ARF secondary to COVID-19 infection and developed ARDS requiring tracheal intubation and subsequently V-V ECMO. Before he was transferred to our Specialty Center for advanced ECMO management, an RVAD using a ProtekDuo plus oxygenator was used to provide a double lumen cannula approach similar to the Avalon Elite Bi-Caval Dual Lumen Catheter (Getinge) or Crescent Jugular Dual Lumen Catheter (Medtronic) for V-V ECMO support.
Due to severe hypoxia after arrival at our institution, we decided under the pressure of the clinical deterioration to modify the configuration and inserted a venous 25 Fr right femoral drainage cannula, which was used for venous drainage only and connected to the pump (CENTRIMAG, Abbott). The arterial return tubing was separated and by using a 3/8” Y-connector, oxygenated blood was returned through both ports of the ProtekDuo [Figure 1] with an immediate significant increase in oxygenation (SpO\textsubscript{2} from 78 to 100%) and flow (4.2 to 7.0 L/min) followed by the ability to adjust the ventilator to rest settings. With improving lung function, the patient was successfully weaned from the ECMO support and separated from ProtekDuo after 44 days, of which 29 days were on the modified configuration, without any device-related complications. He left the ICU 2 days later and after 2 additional days on the ward was transferred to an inpatient rehabilitation unit and subsequently home.

DISCUSSION

The ProtekDuo decreases RV preload and decompresses the RV, therefore, it is ideal in conjunction with many established pumps to provide temporary RV support if the isolated RV failure is present. It also may serve together with a left ventricular assist device in the setting of biventricular failure.\textsuperscript{[3]} Similar to the Avalon or Crescent cannulae, it can be used in the V-V ECMO configuration, draining venous blood from the right atrium (RA) and returning arterialized blood into the main pulmonary artery (P). Budd \textit{et al}.\textsuperscript{[1]} have recently described a novel approach to optimize both the intraoperative and postoperative care in a woman with severe pulmonary hypertension and RV dysfunction undergoing bilateral lung transplantation using the ProtekDuo cannula as combined V-V ECMO and RV support as well as for venous drainage in the venoarterial (V-A) ECMO. In this technique, after administration of heparin, an 18 Fr Fem-Flex cannula (Edwards Lifesciences, Irvine, CA) was placed in the ascending aorta, then blood was drained through both the right atrial and pulmonary arterial lumens of the ProtekDuo cannula draining to the venous aspect of the circuit and returning to the outflow cannula in the aorta as intraoperative central V-A ECMO cannulation. After the V-A ECMO was initiated, their patient experienced hemodynamic stability and adequate decompression of the heart, which allowed for bilateral, sequential native pneumonectomy, and donor lung transplantation. After transplantation, the arterial cannula was removed and V-V ECMO was reinstated through the ProtekDuo, basically using the V-P configuration.

Many interesting configurations may be possible using the ProtekDuo and usually evolve due to medical necessities. In our case, the patient suffered from hypoxia and it was not possible to further increase flows through the ProtekDuo which may have been good enough to achieve adequate oxygenation for this patient. In the COVID patients, it has become our institutional standard to do dual-site cannulation with 25 Fr femoral venous drainage and a short 23 Fr right internal jugular return cannula in order to keep the cannulation simple for remote cannulations from where we often have to retrieve such patients. Not needing fluoroscopy, keeping staffing, and their exposure to COVID-19 to a minimum was our main consideration when starting this approach for the duration of the pandemic. In addition, the cannula size is large enough to always achieve adequate flows in the range of \( >6 \) L per min (L/min). This is usually enough to even oxygenate severely obese patients with a high body mass index (BMI). The 31 Fr ProtekDuo cannula that was used in this patient did not provide adequate flow. We considered placing a 25 Fr drainage cannula as recently described\textsuperscript{[3]} and returning the arterialized blood through both ports leading the arterialized blood to the right atrial and pulmonary arterial lumens, a configuration that could be best described as V-VP ECMO. However, based on a literature search, this has to the best of our knowledge not yet been attempted or described. It was unclear which effect could be achieved and with which impact on the RV. We anticipated it would be similar to the Avalon or Crescent cannulae. An alternative would have been to place multistage femoral drainage and a long femoral return cannula both in the inferior vena cava (IVC) to create a fem-fem configuration. However, in our view, this would have considerably increased the risk for IVC thrombosis when having two
large cannulae there, especially in view of the patient presenting with bleeding complications for which he could not be anticoagulated at the time. Further studies on anticoagulation, the degree of the incidence of hemolysis, and extend of possible degradation of the Von Willebrand factor are needed to compare femoro-femoral versus femoro-jugular configurations. In addition, we wanted to keep the procedural risk low. Adding only one cannula at this point seemed reasonable and less time-consuming in a clinical, not stable, hypoxemic patient compared to placing two and having to remove the ProtekDuo. At this point, we decided to use both the ProtekDuo lumens for arterial return. The patient did not display any complications to this newly-created configuration. Frequent transthoracic echocardiograms did not show any impact on the RV and flows. In addition, oxygenation was significantly improved, helping to wean the patient off ProtekDuo-ECMO after 44 days with 29 days on the modified configuration. The patient survived, and was, after a short stay on the ward, transferred to a rehabilitation unit and then home.

CONCLUSION

A ProtekDuo-based RVAD generally can be used for oxygenation in V-V ECMO configuration but flows are limited due to the flow physics of the cannula diameter and length. In patients with high BMI, additional flow by upsizing the diameter of the drainage and arterial return becomes necessary. The arterial blood return through both the lumens of the ProtekDuo is feasible without any complications observed and significantly improved oxygenation. However, it adds the need for an additional drainage cannula and the overall complexity of the circuit.

Declaration of patient consent
As per the INTEGRIS Health policy, IRB approval is not required for case reports. However, this case has been anonymized to protect the patient’s personal information.

Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Budd AN, Kozarek K, Kurihara C, Bharat A, Reynolds A, Kretzer A. Use of ProtekDuo as veno-arterial and veno-venous extracorporeal membrane oxygenation during bilateral lung transplantation. J Cardiothorac Vasc Anesth 2019;33:2250-4.
2. Ruhparwar A, Zubarevich A, Osswald A, Raake PW, Kreusser MM, Grossekettler L, et al. ECPELLA 2.0-Minimally invasive biventricular groin-free full mechanical circulatory support with Impella 5.0/5.5 pump and ProtekDuo cannula as a bridge-to-bridge concept: A first-in-man method description. J Card Surg 2020;35:195-9.
3. Maybauer MO, El Banayosy A, Hooker RL, Vanhooser DW, Harper MD, Mihu MR, et al. Percutaneous venoarterial extracorporeal membrane oxygenation as a bridge to double valve implantation in acute biventricular heart failure with profound cardiogenic shock. J Card Surg 2019;34:1664-6.