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Case Report

Alternative Support Strategy for High-Risk, Elective Percutaneous Coronary Intervention: Venoarterial Extracorporeal Membrane Oxygenation in Advanced Pulmonary Hypertension and Right Ventricular Dysfunction

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ABSTRACT

Objectives: We report our initial experience utilizing venoarterial extracorporeal membrane oxygenation (VA-ECMO) in a patient undergoing high-risk percutaneous coronary intervention (HR-PCI) and review the literature for outcomes data with prophylactic use of VA-ECMO in this setting.

Background: VA-ECMO is most commonly used in patients in cardiogenic shock and status-post cardiac arrest. Data on use of VA-ECMO for elective, HR-PCI is limited.

Case description: A 77-year-old frail Caucasian male with a complex medical history to include COPD with baseline supplementary oxygen use, pulmonary hypertension, type 2 diabetes mellitus, and hypertension underwent treadmill stress testing due to worsening dyspnea on exertion. After 2 minutes, he developed profound hypotension along with diffuse ST depressions on ECG.

Results: Following admission for urgent invasive coronary angiography, the patient was found to have severe multivessel obstructive coronary artery disease. After a multidisciplinary discussion, he was not deemed to be a surgical candidate. Due to recurrent admissions for acute decompensated heart failure and non-ST-elevation myocardial infarction (NSTEMI) complicated by syncope and pulmonary hypertension, the patient ultimately underwent successful VA-ECMO supported HR-PCI of the proximal LAD and proximal-to-mid RCA using rotational atherectomy.

Conclusions: This case highlights the effectiveness of VA-ECMO supported HR-PCI for patients with both RV dysfunction and high-risk coronary anatomy requiring multi-vessel PCI with rotational atherectomy. VA-ECMO can be successfully used prophylactically for hemodynamic support during elective, HR-PCI. Further investigation should focus on identifying the optimal support strategy for these high-risk cases with regards to outcome, revascularization, and patient comfort.

Keywords: Venoarterial . Extracorporeal membrane oxygenation . High-risk PCI

Introduction

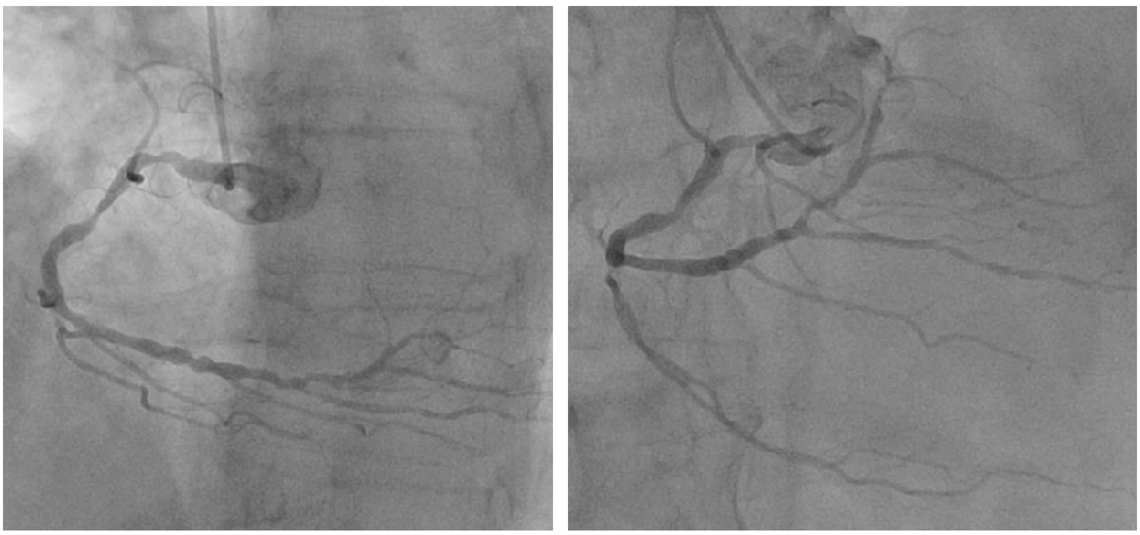
Given recent advancements in early detection of coronary artery disease (CAD), more patients are being placed on optimal medical therapy with the ultimate aim of preventing the need for coronary revascularization. As reported by Vetrovec in 2017, the use of PCI and bypass surgery is declining [1]. With regard to PCI, this decline is related to less restenosis and limited extent of CAD; however, this has increased the complexity of the patient population undergoing PCI following optimal medical management as most are older with complex coronary anatomy. To this extent, more patients are deemed high-risk for PCI, owing to a combination of complex clinical, hemodynamic, and anatomic characteristics, including patients who are poor surgical candidates, have had prior coronary artery bypass graft surgery (CABG), have poor left ventricular function, or decline surgery in favor of PCI [1-3].

Since high-risk PCI (HR-PCI) can cause hemodynamic instability via procedure-induced ischemia, prophylactic hemodynamic support is typically utilized in these cases, especially due to the great extent of vulnerable ischemic myocardium [3]. This allows time and support to safely achieve optimal revascularization and prevents intraprocedural hypotensive, low cardiac output episodes, which are a concern during atherectomy, stent deployment, and balloon inflation [1]. Multiple short-term mechanical circulatory hemodynamic support devices exist, including the intra-aortic balloon pump (IABP), Impella (ABIOMED Inc, Danvers, Massachusetts, USA), TandemHeart (Cardiac Assist Inc, Pittsburgh, Pennsylvania, USA), and venoarterial extracorporeal membrane oxygenation (VA-ECMO). These devices reduce both myocardial work and oxygen demand while maintaining adequate systemic and coronary perfusion [4]. VA-ECMO is most commonly used in patients with cardiac arrest and cardiogenic shock with or without myocardial infarction (MI) [2]. The literature is scarce when it comes to the use of VA-ECMO in elective HR-PCI. As such, data regarding the feasibility and outcomes utilizing this support strategy is limited.

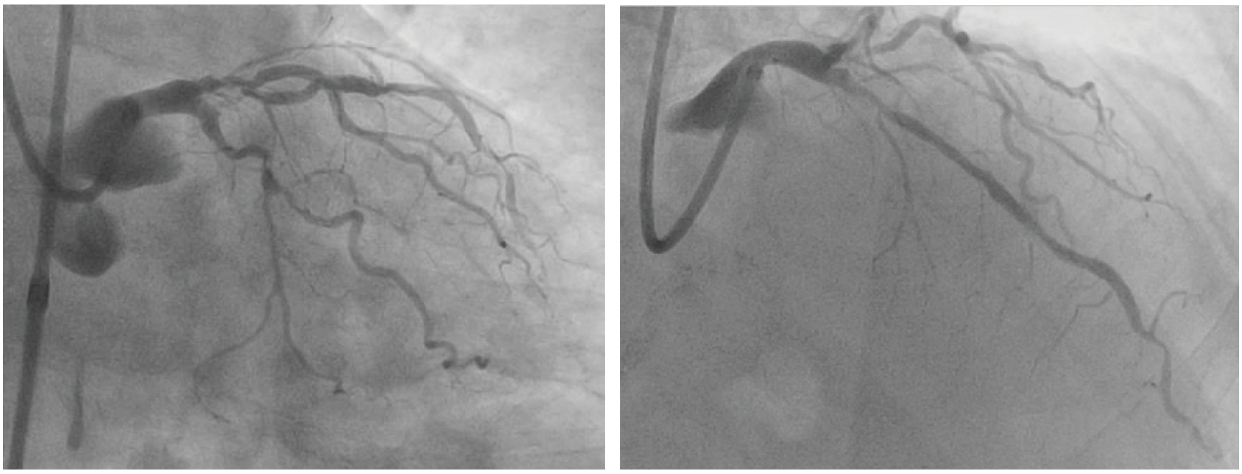
We describe a case of a complex, HR-PCI performed using VA-ECMO support in an elderly, frail male at a military treatment facility.

Case Presentation

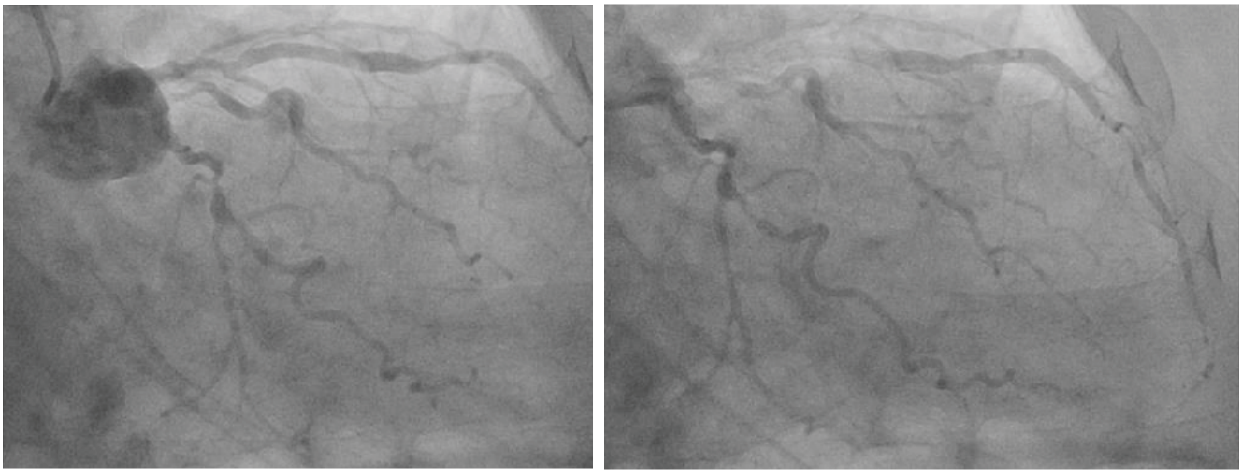
A 77-year-old frail Caucasian male with chronic obstructive pulmonary disease (COPD) with pulmonary hypertension on 2-3 liters of home oxygen, right ventricular (RV) dysfunction, history of pulmonary embolism (PE), type 2 diabetes mellitus, hypertension (HTN), and hyperlipidemia presented to the cardiology clinic for treadmill stress testing with myocardial perfusion imaging due to worsening dyspnea on exertion. After 2 minutes on the treadmill, he had significant dyspnea and presyncope. The patient was ill appearing, became very pale and diaphoretic and immediately after stopping exercise, he developed profound hypotension with blood pressure noted to be 58/34. ECG showed diffuse ST depressions and the patient was placed in the Trendelenburg position to maintain cerebral perfusion. Resuscitation began with intravenous hydration and phenylephrine was ready to be administered although ultimately, it was not required as the patient's mean arterial



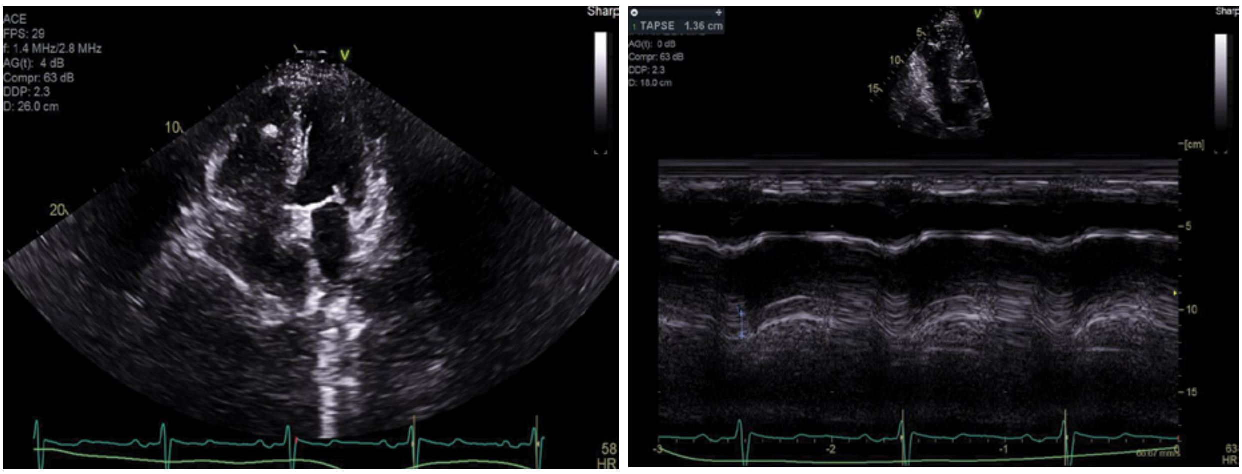
Figures 1A and 1B: Coronary angiogram showing 60% stenosis of the proximal RCA and 70% stenosis of the mid-RCA. RCA: right coronary artery.



Figures 2A and 2B: Coronary angiogram showing 70% stenoses of the proximal and distal LAD. LAD: left anterior descending artery.



Figures 3A and 3B: Coronary angiogram showing 80% stenosis of the mid-LCx and 80% ostial stenosis of OM1. LCx: left circumflex; OM1: obtuse marginal, 1st branch.



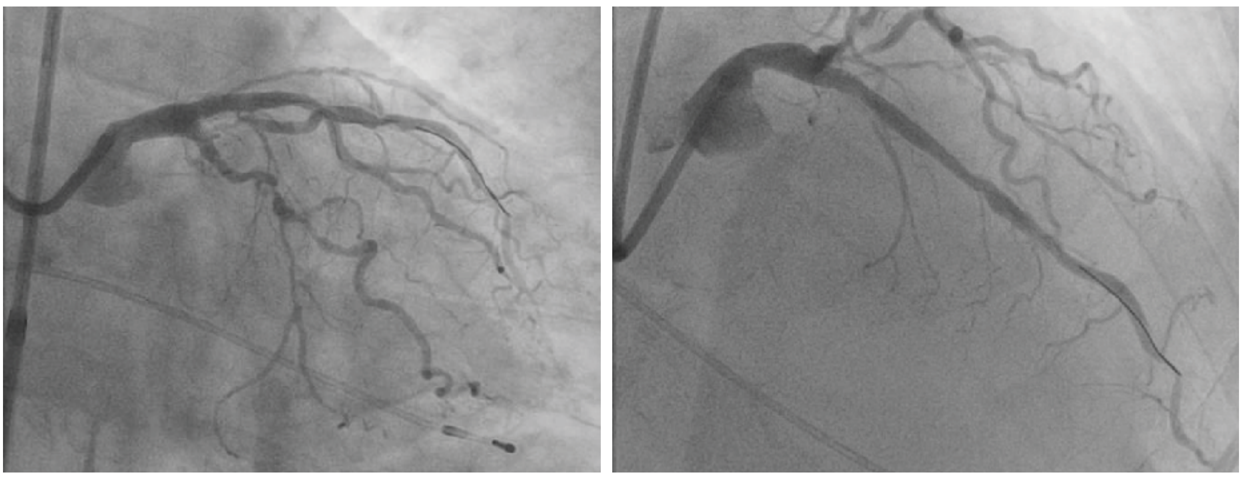
Figures 4A and 4B: Transthoracic echocardiogram apical 4 chamber view showing dilated RV. TAPSE measured at 1.36 cm, consistent with reduced RV systolic function. TAPSE: tricuspid annular planar systolic excursion.

pressure improved. Diffuse 1-mm downsloping ST depressions in the lateral precordial leads persisted for several minutes into recovery before slowly resolving.

The patient was admitted to the cardiology inpatient service and underwent urgent coronary angiography the following day, which demonstrated 60% stenosis of the proximal right coronary artery (RCA; Figures 1A/1B), 70% stenosis of the mid-RCA (Figures 1A/1B), 70% stenoses of the proximal and distal left anterior descending artery (LAD; Figures 2A/2B), 80% stenosis of the mid-left circumflex artery (LCx; Figure 3A), and 80% ostial stenosis of the first obtuse marginal branch (Figure 3B). Transthoracic echocardiogram showed preserved left ventricular ejection fraction of 66 to 72%, grade 1 diastolic dysfunction, and a dilated right ventricle with reduced systolic function as measured by tricuspid annular planar systolic excursion (TAPSE) of 1.36 cm (Figures 4A/4B). Right heart catheterization revealed low cardiac index at 1.7 L/min/m^2 (assumed Fick) and 1.8 L/min/m^2 (thermodilution), cardiac output of 3.6 L/min (assumed Fick) and 3.8 L/min (thermodilution), systemic vascular resistance 988 dynes-sec/cm^5 and precapillary pulmonary hypertension with mean pulmonary artery pressure of 28 mmHg, mean pulmonary artery wedge pressure 7 mmHg (end expiration), pulmonary vascular resistance of 5.9 Wood units (assumed Fick), and a pulmonary artery pulsatility index (PAPi) of 14.33. RV pressure was noted to be 51/6 mmHg with RV end diastolic pressure of 11 mmHg and mean right atrial pressure of 3 mmHg. Right ventricular stroke work index (RVSWI) was calculated to be 9.97 gm*m/m^2. There was no evidence of a left-to-right shunt. A work-up for etiology of his pulmonary hypertension was negative for chronic thromboembolic pulmonary hypertension and attributed to COPD.

The patient was discharged with plans for close follow-up as an outpatient to determine an appropriate revascularization strategy. He did endure an episode of syncope, which occurred simply while he was getting ready for bed without a prodrome. Due to recurrent admissions for acute decompensated heart failure and NSTEMI, complicated by syncope and pulmonary hypertension, he was referred to the local Heart Team (interventional cardiology, general cardiology, cardiothoracic surgery, and cardiac anesthesiology) for a multidisciplinary discussion regarding the optimal revascularization strategy. SYNTAX score was calculated to be 59 while STS score was calculated to be 6% for risk of mortality, and 27% for morbidity or mortality. The patient was deemed to not be a surgical candidate and elected for high-risk PCI in lieu of medical management. Given his co-morbidities, RV dysfunction, pulmonary hypertension, and severe multivessel obstructive CAD, VA-ECMO was chosen as the support strategy for HR-PCI.

A 25 French 55 cm ECMO cannula was advanced into the right atrium via the left common femoral vein and a 15 French 25 cm ECMO cannula was advanced into the right common iliac artery



Figures 5A and 5B: Successful PCI of the proximal LAD with a 3.5 x 24mm Promus Premier (everolimus-eluting) stent using rotational atherectomy with a 1.5mm burr. PCI: percutaneous coronary intervention.

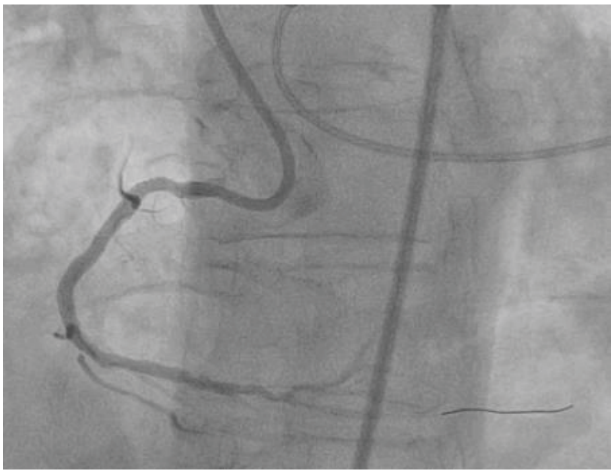


Figure 6: Successful PCI of the proximal-to-mid RCA with a 3.5 x 38mm Promus Premier (everolimus-eluting) stent.

via the right common femoral artery. Following placement of a temporary transvenous pacemaker, the patient underwent successful PCI of the proximal LAD with a 3.5 x 24 mm Promus Premier stent using rotational atherectomy with a 1.5mm burr (Figure 5) and PCI of the proximal-to-mid RCA with a 3.5 x 38mm Promus Premier stent (Figure 6). Intravascular ultrasound (IVUS) of the proximal LAD stent revealed a final minimal stent area of 10.2 mm^2. The arterial ECMO cannula was removed and hemostasis achieved using a Perclose ProGlide (Abbott Cardiovascular, Chicago, Illinois, USA) suture-mediated closure system. The venous sheath was removed with hemostasis achieved by manual compression. The patient was discharged on aspirin 81 mg and clopidogrel 75 mg daily. There were no complications post-procedure.

Discussion

Mechanical circulatory support (MCS) devices have been used for HR-PCI with most trials employing the IABP or Impella (BCIS-1, PROTECT II). Their use in appropriately selected patients during HR-PCI is supported by guidelines and a multisociety expert consensus document [5,6]. The TandemHeart device has limited use due to challenges with implantation via transseptal techniques and has not been assessed in randomized controlled trials [1,2]. VA-ECMO in elective HR-PCI also has not been evaluated in randomized controlled trials as its use has historically involved patients in cardiogenic shock and cardiac arrest with or without MI, where it has been shown to be effective [2].

Aside from case reports similar to this, there have only been a few manuscripts detailing single-center experience and outcomes of VA-ECMO support for complex HR-PCI. In a retrospective review published in 1993, Teirstein and colleagues investigated prophylactic versus standby cardiopulmonary support (CPS) for high risk percutaneous transluminal coronary angioplasty. There were 389 patients in the prophylactic CPS group and 180 in the standby CPS group. Procedural success was similar in both groups but patients in the prophylactic CPS group suffered femoral access site complications or required blood transfusions more than those in the standby CPS group ($p < 0.01$) [7]. Procedural mortality, however, was significantly higher in the standby group. Overall, they concluded that patients with extremely depressed left ventricular function (<20%) may benefit from institution of prophylactic CPS. In 2007, Vainer et al. investigated the feasibility of HR-PCI in hemodynamically unstable patients supported by modified cardiopulmonary bypass. Their study involved 15 patients (10 men, 5 women, mean age 72 +/- 9 years) who underwent surgical insertion and removal of perfusion cannulas with procedural success achieved in 14 of the 15 patients [8]. The study found that extracorporeal life support-supported PCI can be performed with promising short- and long-term clinical outcomes (3 cardiac deaths during a mean follow-up of 15 months). Similarly, for the first time in Korea, Cho and colleagues performed a retrospective review at their institution; analyzing 10 patients who had underwent elective percutaneous CPS-supported PCI. The study, published in 2011, showed that during a mean clinical follow-up period of 541 days, there were no cardiac-related deaths [9]. In a case study also published in 2011, Dardas et al reported 2 cases of ECMO-supported HR-PCI, involving rotablation of heavily calcified coronary arteries in patients with previous CABG and valve surgery [10]. Both interventions were successful but one of the 2 patients required surgical reconstruction of the superficial femoral artery following decannulation. In 2015, Tomasello and colleagues performed a single-center prospective study and enrolled 12 patients (8 males, 4 females, mean age 64 +/- 9 years) who underwent elective HR-PCI with ECMO support [11]. PCI was successful in all patients and there were no significant vascular or bleeding complications. Furthermore, there was no death or MI at 6-month follow-up. In 2018, Shaukat et al performed a retrospective, single-center review at their institution, examining 5 patients (all male, mean age 67 +/- 9 years) who underwent complex, HR-PCI with VA-ECMO support. Most procedures were unprotected left main PCIs and all were successful; however, 1 patient required surgical femoral artery repair. There were no major adverse cardiovascular or cerebrovascular events during hospital stay or at 1-year follow-up [2]. Finally, in 2020, van den Brink et al performed a two-center retrospective study and analyzed 14 patients who underwent VA-ECMO supported HR-PCI (13 males, 1 female, median age 69) [3]. PCI was successful in all patients but 1 patient died during hospitalization from refractory cardiac failure that was not attributed to either the PCI or VA-ECMO support. Two patients suffered ECMO-related complications, 1 developing a transient ischemic attack and the other developing a thrombus in the femoral vein used for ECMO cannulation.

In our case, VA-ECMO was used for support because of the patient's biventricular dysfunction, pulmonary hypertension, and high-risk coronary anatomy in lieu of the alternative support strategies aforementioned. TandemHeart was not available at our facility. Biventricular support with two Impella pumps (BiPella) was an equivalent option for PCI but significantly more expensive than VA-ECMO. Aside from cost effectiveness, our hospital also had local expertise in VA-ECMO and is a major referral center for the surrounding community. As there was significant ischemic burden at risk, a reliable biventricular support strategy was deemed necessary to facilitate rotational atherectomy and multivessel PCI. The patient was extremely frail with very limited cardiac reserve to survive any hemodynamic insult that could arise during plaque optimization techniques and intervention. It was believed that should the patient become hypoxic or ischemic, there would be immediate RV ischemia and hypoxic injury leading to reduced RV contractility and RV cardiac output. Consequently, this would lead to reduced LV preload, decreased LV cardiac output, and reduced systolic blood pressure, further reducing RV coronary perfusion and ultimately compounding into a rapid downward spiral of circulatory collapse on the cath lab table. Following a Heart Team discussion, there was agreement to use VA-ECMO and have robust support available in order to minimize the chances of a clinical catastrophe on inadequate LV support only. The patient underwent femoral access and following meticulous cannulation utilizing ultrasound guidance, micropuncture technique, and ultimately closure with a Perclose ProGlide, the 15 French arterial ECMO cannula was safely managed throughout the procedure. As RV dysfunction and pulmonary hypertension can be a lethal combination, VA-ECMO was our best option institutionally.

An advantage of VA-ECMO is that it provides full cardiopulmonary support, augmenting cardiac output with up to 7 liters of blood flow per minute, regardless of the native heart rhythm [2,4,10]. VA-ECMO also decongests and supports the right ventricle by draining the right atrium. In doing so, the circuit reduces carbon dioxide and adds oxygen to venous blood before returning blood to the arterial circulation.4 While the specifics of VA-ECMO implantation are beyond the scope of this report, it is apparent that high flow rates are achieved through the use of large-diameter cannulae, consequently increasing the risk of vascular complications. Among device-related complications, vascular injuries (dissection or perforation), bleeding events, hemolysis, infections, thromboembolism, limb ischemia, ischemic stroke, neurological complications, acute kidney injury, and pulmonary edema are the most common [4]. To mitigate vascular complications, attention must be devoted to meticulous large bore access, which should be performed only by highly trained operators. Lastly, it should be mentioned that LV unloading via peripheral ECMO is ineffective over time due to high systemic aortic flow, which tends to prevent opening of the aortic valve [1]. While this is typically not a concern with short-term use of VA-ECMO, additional therapy to unload the LV and decrease filling pressures may be necessary in the form of additional MCS, such as Impella or IABP, in the event weaning from VA-ECMO support becomes difficult. Aside from the lack of direct LV unloading and increased LV afterload, another limitation of ECMO involves the need for highly trained personnel in the catheterization laboratory, to include nursing support, a perfusionist, and possibly an anesthesiologist.

As it can be postulated that the number of HR-PCI cases will increase with time, the challenges behind planning for each case are fairly evident.

Patient safety is paramount and thus, optimal patient selection is critical, balancing the risks of the procedure with the benefits of revascularization (along with cost). Furthermore, choosing the appropriate hemodynamic support strategy is also important to consider as each comes with its own risks/benefits and advantages/disadvantages (level of support, specific implantation requirements/ skill, need for additional staff to be present or at least available). With advancements in not only therapeutics but also plaque modification techniques, more patients may elect to undergo HR-PCI to improve symptoms, quality of life, and potentially longevity [1]. This case and some of the studies mentioned undoubtedly highlight the fundamental role of the heart team in this difficult decision-making process.

Conclusions

This case highlights the feasibility of VA-ECMO support for patients with both RV dysfunction and high-risk coronary anatomy requiring multivessel PCI with rotational atherectomy. Recent literature shows that the outcome with this approach in regard to mortality and neurological outcome is favorable and complication rates are low if meticulously careful large bore access and closure techniques are implemented. The appropriate support strategy for HR-PCI cases will continue to be a critical decision for interventional cardiologists, balancing the risks/benefits of the various strategies while taking into account the level of support required based on the patient's co-morbidities. Further study is required to understand the optimal support strategy for these high-risk cases with regards to outcome, revascularization, and patient comfort.

Disclaimer

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