Percutaneous Venoarterial Extracorporeal Membrane Oxygenation for Refractory Cardiogenic Shock Is Associated with Improved Short- and Long-Term Survival

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Mortality due to refractory cardiogenic shock (RCS) exceeds 50%. Venoarterial extracorporeal membrane oxygenation (VA-ECMO) has become an accepted therapy for RCS. The aim of our study was to evaluate outcomes of patients with RCS treated with percutaneous VA-ECMO (pVA-ECMO). Retrospective review of patients supported with VA-ECMO at our institution in 2012–2013. Clinical characteristics, bleeding, vascular complications, and outcomes including survival were assessed. A total of 37 patients were supported with VA-ECMO for RCS. The majority of VA-ECMO (76%) was placed in the catheterization laboratory. Nearly half (49%) of the patients presented with acute myocardial infarction. Seven patients (19%) underwent insertion of pVA-ECMO in the setting of cardiopulmonary resuscitation with mechanical chest compression device. Median duration of support was 5 days. Index hospitalization, 30-day, and 1-year survival were 65%, 65%, and 57%, respectively. Survival rate for discharged patients was 87.5% with a median follow-up of 450 days. Refractory cardiogenic shock supported with pVA-ECMO is associated with an improved survival in patients with a traditionally poor prognosis. *ASAIO Journal* 2016; 62:397–402.

Key Words: cardiogenic shock, extracorporeal membrane oxygenation

Cardiogenic shock (CS) remains the leading cause of death in patients hospitalized with acute myocardial infarction (AMI) and is associated with hospital mortality rates approaching 50%.[1,2] It complicates 8.6% of ST-segment elevation MIs (STEMI) and 2.5% of non-ST segment elevation MIs (NSTEMI).[3] Numerous other conditions can lead to CS, including postcardiotomy shock, stress-induced cardiomyopathies, end-stage cardiomyopathy, acute valvular regurgitation, myocarditis, and sustained arrhythmias.[4–6]

Medical therapy with inotropic agents and vasopressors is often ineffective for adequate hemodynamic support.[5,7] Intra-aortic balloon counterpulsation (IABP), which has been the most widely used form of mechanical circulatory support (MCS),[2] was recently shown not to reduce 30-day mortality in patients with CS complicating AMI in the IABP-SHOCK II trial.[8] A variety of temporary MCS devices are currently available, including paracorporeal or extracorporeal ventricular assist devices (VADs), percutaneous VAD (pVAD), total artificial heart, and venoarterial extracorporeal membrane oxygenation (VA-ECMO).[7]

Due to improvements in cannulation techniques and oxygenator technology, as well as device miniaturization,[9,10] VA-ECMO has gained attention as a viable therapeutic option for patients in refractory cardiogenic shock (RCS).[7,9] VA-ECMO implementation may be performed either by peripheral or central cannulation; however peripheral VA-ECMO allows intraoperative chest closure, reduces VA-ECMO-related bleeding, and facilitates its use in the intensive care unit during cardiopulmonary resuscitation.[6]

At our institution, a *Shock Team* has implemented the use of percutaneous VA-ECMO (pVA-ECMO) in patients with RCS. We describe the results of 37 consecutive RCS patients presenting during a 2-year period interval that underwent MCS with pVA-ECMO and were managed by a multidisciplinary shock team.

Methods

We performed a retrospective analysis of patients with RCS managed by pVA-ECMO at the Minneapolis Heart Institute (MHI), Abbott Northwestern Hospital from January 2012 to December 2013. Demographics, baseline clinical characteristics, laboratory, and echocardiographic variables were obtained if available from electronic medical records. Each patient's clinical course was reviewed and evaluated for bleeding (major bleeding was defined as a hemoglobin drop >3 gm/dl) and major vascular complications (defined as those requiring vascular repair) were tracked. Outcomes including 30-day and long-term survival, duration of ECMO support, ECMO explantation rates, length of stay, proportion of patients bridged-to-transplant or bridge-to-left ventricular assist device (LVAD), and the need for renal replacement therapy during the index admission were obtained and assessed.

Shock Team

The MHI at Abbott Northwestern Hospital has pioneered a STEMI (level 1) program since establishing in 2003 a regional transfer system for patients requiring emergent percutaneous coronary intervention (PCI).[11] Based on the level 1 model, a

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multidisciplinary shock team was established to implement the use of pVA-ECMO in patients with RCS. The *Shock Team* comprises advanced heart failure cardiologists, interventional cardiologists, cardiothoracic surgeons, intensivists, vascular surgeons, perfusionists, pharmacists, and ECMO-trained nursing staff (**Figure 1**). The *Shock Team* mirrored the approach of the level 1 STEMI model and benefited from its robust structure to treat patients with RCS.[11,12] The advanced heart failure team is routinely called to the cardiac catheterization laboratory to evaluate patients in RCS when they are failing support with at least two vasoactive agents. The decision to proceed with ECMO placement is made in conjunction with an interventional cardiologist. We subscribed to conventional Extracorporeal Life Support Organization (ELSO) guideline contraindications including: 1) conditions incompatible with normal life if the patient recovers; 2) preexisting conditions which affect the quality of life (*e.g.*, central nervous system status, end-stage malignancy, risk of systemic bleeding with anticoagulation); 3) age and size of patient; and 4) futility: patients who are too sick, have been on conventional therapy too long, or have a fatal diagnosis. In these emergent cases, most patients are unable to participate in the decision-making process. Hence, we have a discussion with the family regarding the patient's wishes.

Once VA-ECMO support is successfully initiated, the patient is transferred to the cardiac intensive care unit, where the advanced heart failure team assumes primary management with 24-hr coverage. Daily multidisciplinary rounds are performed on all VA-ECMO patients. A perfusionist is present at the initiation of VA-ECMO support and remains available at the bedside throughout the ECMO course. Venoarterial extracorporeal membrane oxygenation circuit is explanted by either a vascular or cardiothoracic surgeon.

A doctor in pharmacy (Pharm D) manages anticoagulation with heparin or bivalirudin based on established partial thromboplastin time (PTT)-based nomograms. Both low-intensity (PTT goal 45–65 seconds) and high-intensity (PTT goal 65–85 seconds) protocols are available, and its use is left to the discretion of the managing physician, based on perceived bleeding and thrombosis risk, and the concomitant use of anticoagulants and/or antiplatelet agents. At our institution, bivalirudin is managed by pharmacists with an institutional approved, automated protocol. Bivalirudin continuous infusion is started by protocol at 0.04 mg/kg/hr, without a bolus, and titrated to goal a PTT in 0.005–0.02 mg/kg/hr increments. The PTT levels are obtained 4 hr after initiation, 4 hr after dose adjustments, and twice daily thereafter to assure maintenance of therapeutic levels. Our PTT goal ranges are defined as a lower intensity range of 45 to 65 seconds or a high-intensity range of 60 to 80 seconds. Internal auditing of our protocol's performance after LVAD implantation demonstrated that an PTT >45 seconds was attained in 40% of patients by 4 hr, 80% by 8 hr, and 100% of patients were at goal by 24 hr. The decision to use bivalirudin rather than heparin for anticoagulation during ECMO can be related to patient response to heparin, such as inadequate anticoagulant effect or falling platelet count, or may be used empirically in those with a history of heparin-induced thrombocytopenia (HIT), preexisting thrombocytopenia, or a known low antithrombin activity.

Peripheral Extracorporeal Membrane Oxygenation Technique and Circuit

In most cases, VA-ECMO initiation is performed in the catheterization laboratory, through the femoral venoarterial approach by a percutaneous method using the modified

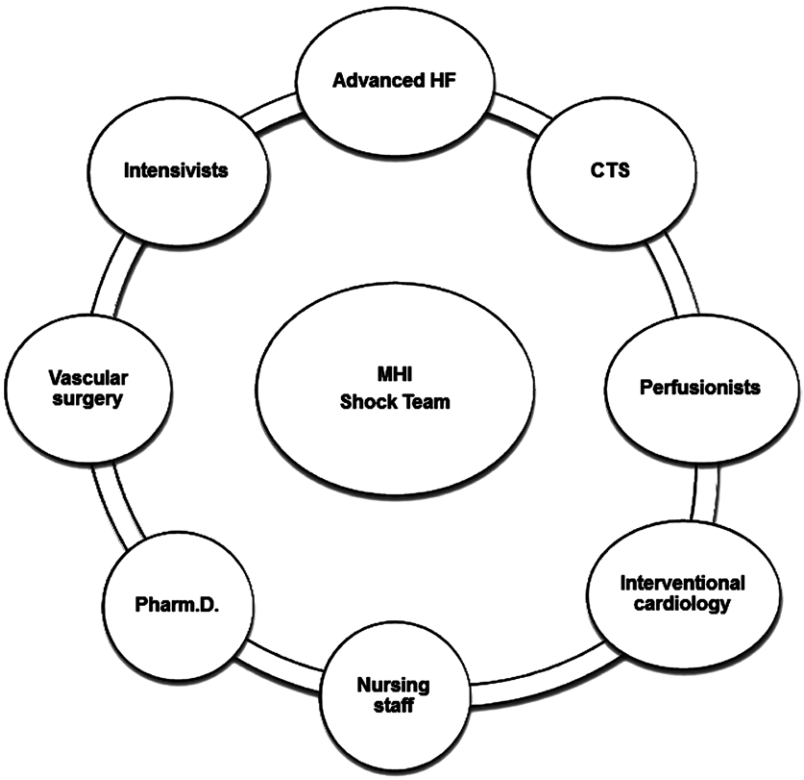

Figure 1. Minneapolis Heart Institute (MHI) *Shock Team*. CTS, cardiothoracic surgeons; HF, heart failure.

Seldinger technique.[13] Anatomical landmarks are utilized in planning anterograde and retrograde arterial cannulation as well as venous cannulation. Limited femoral angiography through a 5 French (Fr) micropuncture catheter, limited distal aortography with run off, or arterial and venous ultrasound is utilized for proper retrograde common femoral arterial and anterograde superficial femoral access. A 6 Fr 24 cm Arrowflex sheath is inserted for anterograde perfusion catheter into the superficial femoral artery. After obtaining retrograde access *via* the common femoral artery, a series of progressive dilations are performed over an Amplatz extra stiff or superstiff wire to allow the placement of a 16–24 Fr ECMO cannula. After careful deairing and completion of the arterial ECMO circuit, the side arm of the retrograde ECMO cannula is connected by tubing to the side arm of the anterograde Arrowflex sheath to provide distal perfusion. In a similar fashion, the venous cannula is inserted starting with a series of dilators over an Amplatz extra stiff or super stiff wires to allow the placement of a 22–26 Fr venous cannula. Both the arterial and venous ECMO cannulas are then secured at the insertion site using a purse string suture technique.

During the study period, the Thoratec CentriMag Blood Pump (Levinotrix CentriMag. Acquired by Thoratec, Pleasanton, CA in 2011) and the Jostra Rota Flow pump (Maquet Cardiopulmonary AG, Hirrlingen, Germany) were utilized. The Quadrox-D (Maquet, Jostra Medizintechnik AG, Hirrlingen, Germany) has been the oxygenator of choice at our center. Patients received a heparin bolus in the catheterization laboratory, followed by continuous anticoagulation with either heparin or bivalirudin in the intensive care unit. Patients were considered for decrement in ECMO support after 24 hr of hemodynamic stability and presence of arterial pulsatility. Echocardiography-guided weaning was performed at the bedside according to our protocol. Before the initiation of wean, PTT was obtained and if less than 65 seconds, 3,000 units of unfractionated heparin bolus was given. Baseline echocardiography is obtained at a given speed to evaluate left ventricular systolic function. Pump flow is weaned by 0.5–1 L every 5 minutes down to 1.5 L of support, where vitals signs are obtained and echocardiography performed. Hemodynamic monitoring including Fick cardiac output is also assessed. Criteria for decannulation included: mean arterial pressure (MAP) maintained > 60 mm Hg, left ventricular ejection fraction > 20 % and cardiac index > 2.2 L/minute/m^2. In case of decreasing MAP, weaning process is stopped and flows are increased to the original initial values.

Statistics

Data was collected using Microsoft Excel for Mac 2011 (version 14.4.9, Redmond, Washington). Statistical analyses were performed with SPPS ver. 19.0 for Windows (SPSS Inc., Chicago, IL). Categorical variables are expressed as percentages. Continuous variables are expressed as mean ± standard deviation (SD).

Results

During the 2012–2013 period, 37 patients were placed on support with pVA-ECMO. RCS etiologies are shown in **Figure 2**. Acute myocardial infarction was the etiology of RCS in 49% of the cases. The remaining patients presented with acute decompensated heart failure (16%), postcardiotomy shock (13%), and other etiologies (22%) including: LVAD pump thrombosis, acute pulmonary embolism, right ventricular failure, primary graft failure after heart transplantation, mixed CS coupled with sepsis, and PCI requiring hemodynamic support. Clinical characteristics of our patient population are shown in **Tables 1** and **2**.

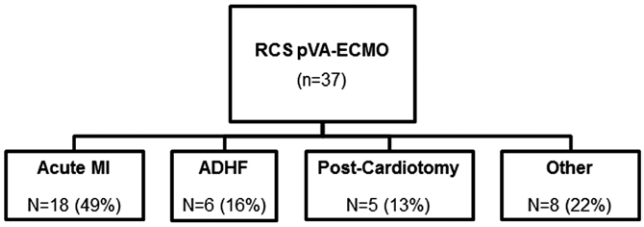

Figure 2. Refractory cardiogenic shock (RCS) etiologies. ADHF, acute decompensated heart failure; MI, myocardial infarction; pVA-ECMO, percutaneous venoarterial extracorporeal membrane oxygenation.

Fifty-seven percent of patients (n = 21) were transferred from an outside facility. Cardiac arrest was documented in 43% of the patients at some point during their pre-ECMO implantation clinical course. Cardiopulmonary resuscitation (CPR, compressions) was reported in 13 (35.1%) of the cohort. Seven patients (19%) underwent insertion of pVA-ECMO in the setting of cardiopulmonary resuscitation with mechanical chest compression device (LUCAS). Two patients had active CPR initiated before arrival to the catheterization laboratory, while the remainder suffered cardiac arrest during or just before coronary angiography (**Table 3**). Median duration of ECMO support was 5 days.

Among the 37 patients, 20 patients (54%) had an IABP placed. Precutaneous venoarterial extracorporeal membrane oxygenation was placed in the catheterization laboratory in 28/37 (75.7%) patients, and in the operating room in 8/37 (21.6%) patients. Bedside initiation of pVA-ECMO was undertaken in one patient with severe acute respiratory distress syndrome who developed hemodynamic instability. In regards to anticoagulation, bivalirudin was documented at the time of ECMO initiation in 24 (64.9%), with the remaining cases being managed with unfractionated heparin. Information on pump flow was available for 15 patients. Average pump flow in this group was 4.6 L/ minute at the time of implantation and at 24 hr. Twenty-three (62.2%) patients had at least one inotrope and/or vasopressor administered on admission, with an average use of approximately three agents (2.91). At the time of pVA-ECMO implantation all patients (100%) had at least one inotrope and/or vasopressor being administered, with an

Table 1. Baseline Characteristics

Variable	n = 37
Age (years)—mean (SD)	61 (12.0)
Male gender—n (%)	28 (76)
White—n (%)	34 (94)
History of coronary artery disease—n (%)	13 (35)
Prior myocardial infarction—n (%)	8 (22)
Diabetes mellitus—n (%)	7 (19)
Hypertension—n (%)	19 (51)
Chronic kidney disease—n (%)	5 (13.5)

SD, standard deviation.

Table 2. Clinical Characteristics on Presentation and During Index Hospitalization

Variable	n = 37
Transferred from outside facility—n (%)	21 (57)
Cardiac arrest—n (%)	16 (43)
Other mechanical support—n (%)	22 (59.5)
IABP	20
Impella	1
LVAD	1
Location of ECMO placement—n (%)	
Operation room	8 (21.6)
Catheterization laboratory	28 (75.7)
Bedside	1 (2.7)

ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon counterpulsation; LVAD, left ventricular assist device.

average of 3.4 agents. At 24 hr after pVA-ECMO implantation, 30 (81.1%) had at least one inotrope and/or vasopressor being administered, with an average of 2.2 agents.

Eighteen patients had AMI (49%), among which 12 were due to definite STEMI, one case due to acute coronary syndrome in the setting of newly detected left bundle branch block, and five cases due to non-STEMI. The most common culprit vessels among all AMI cases were the right coronary artery (5 cases), followed by the left main (4 cases), and the left circumflex and left anterior descending artery with 3 cases each. Fourteen (14 out of 18) AMI cases had evidence of multivessel coronary artery disease. Seventeen (17 out of 18) underwent an attempt at revascularization, among which 9 underwent successful single vessel PCI, 5 underwent multivessel PCI, 2 had failed attempts at PCI, 1 underwent coronary artery bypass grafting and 1 had CABG followed by PCI.

The mean left ventricular ejection fraction based on initial echocardiogram was 30%. Fifty-six percent (n = 20) had qualitative evidence of right ventricular dysfunction (RVD), among which nine patients had severe RVD per echocardiographic visual estimation. Peak median lactate was 5.9 mmol/L (3.4, 8.5) and peak median troponin (cTn) was 46 ug/L (14.0, 116.6). Detailed laboratory analyses and echocardiographic data are shown in **Table 4**. Selected laboratory measurements were compared from time of pVA-EMCO implantation (baseline value) to 24 hr after implantation (**Table 5**). At 24 hr after implantation, both pH and lactate had significantly improved (pH: 7.37 *vs.* 7.45, $p < 0.001$; and lactate: 4.4 *vs.* 2.3 mmol/L, $p < 0.001$).

Table 3. Patients with Insertion of pVA-ECMO in the Setting of RCS and Cardiopulmonary Resuscitation with Mechanical Chest Compression Device (LUCAS) (n = 7)

Variable	n = 7
Age (years)—mean (SD)	61 (12.0)
Male—n (%)	5 (71)
RCS secondary to acute MI—n (%)	6 (86)
Duration of VA-ECMO support—median (days) (25th, 75th percentiles)	4 (3, 5)
VA-ECMO explanted—n (%)	7 (100)
Index hospitalization survival—n (%)	6 (86)

MI, myocardial infarction; pVA-ECMO, percutaneous venoarterial extracorporeal membrane oxygenation; SD, standard deviation; RCS, refractory cardiogenic shock.

Table 4. Laboratory Results During Index Hospitalization

Variable	n = 37
Creatinine—median (25th, 75th percentiles)	
Initial value (mg/dl)	1.23 (0.97, 2.06)
Discharge value (mg/dl)	1.02 (0.80, 1.99)
Peak lactate—median (25th, 75th percentiles) (mmol/L)	5.9 (3.4, 8.5)
Hemoglobin—median (25th, 75th percentiles)	
Initial value (g/dl)	13.5 (11.3, 15.1)
Lowest inpatient value (g/dl)	7.5 (6.7, 8.3)
Troponin (upper-reference limit: 0.034 ug/L)—median (25th–75th percentiles) (n = 29)	
Initial value (ug/L)	1.66 (0.19, 26.6)
Peak value (ug/L)	46.0 (14.0, 116.6)

Seventy-eight percent (n = 29) of patients had significant bleeding (defined as a hemoglobin drop >3 gm). Ninety-two percent (n = 34) of the patients required packed red-blood cell (PRBC) transfusions. The median (25th–75th percentile) PRBC transfusion requirement was 7.5[4,12] units, ranging from 1 to 32 units among patients receiving transfusions. Six patients required over 20 PRBC transfusions throughout their index hospitalizations (case 1, femoral artery repair; case 2, complicated with hematomas, rhabdomyolysis, and required fasciotomy; case 3, large pericardial effusion with tamponade; case 4, femoral artery hemorrhage requiring repair; case 5, post-AMI ventricular septal defect; case 6, mixed cardiogenic and septic shock in the context of infective endocarditis).

Thirty percent of patients (n = 11) required renal replacement therapy during the index hospitalization, but only one patient was discharged on chronic hemodialysis. Five patients (13.5%) had major vascular complications, defined as the need for vascular intervention before VA-ECMO decannulation. Three patients (8%) were diagnosed with a cerebrovascular event (*i.e.*, stroke) during their index hospitalization. Computed tomography (CT) of the head was performed in 14 patients (37.8%). Significant CT abnormalities were reported in three cases: 1) hematoma without infarct, 2) old left thalamic infarction, and 3) intracerebral hemorrhage.

Index hospitalization, 30-day, and 1-year survival were 65%, 65%, and 57%. respectively. Kaplan–Meir mortality curve is shown in **Figure 3**. Among those who were discharged from initial hospitalization, survival rate was 87.5% (21/24) with a median follow-up time of 450 days. Outcomes are shown in **Table 6**. Among the seven patients who underwent insertion of pVA-ECMO in the setting of cardiopulmonary resuscitation with mechanical chest compression device (LUCAS), 6 (86%) survived the index hospitalization (**Table 3**).

Discussion

In this study, we demonstrate that RCS managed with pVA-ECMO using a multidisciplinary shock team is associated with improved survival in patients with a traditionally poor prognosis, with an inpatient and 30-day survival of 65%, and a 1-year survival of 57%. Notably, survival rate in patients who were discharged from the index hospitalization was excellent (87.5% with a median follow-up 450 days), which suggests that these patients appear to do well if they are able to survive the initial insult. In addition, insertion of

Table 5. Serial Laboratory Values

	Baseline Value at pVA-ECMO Implantation	24 hr Value After pVA-ECMO Implantation	*p* Value
pH—median (25th, 75th percentiles)	7.37 (7.32, 7.42)	7.45 (7.38, 7.48)	<0.001
AST—median (25th, 75th percentiles) (IU/L)	170 (91, 265)	144.5 (87.5, 419)	0.92
ALT—median (25th, 75th percentiles) (IU/L)	76 (32, 141)	85 (33.5, 202)	0.62
Total bilirubin—median (25th, 75th percentiles) (mg/dl)	1.5 (0.9, 2.0)	1.8 (1.2, 2.4)	0.015
Lactate—median (25th, 75th percentiles) (mmol/L)	4.4 (2.2, 5.9)	2.3 (1.3, 3.0)	<0.001

ALT, alanine aminotransferase; AST, aspartate aminotransferase; pVA-ECMO, percutaneous venoarterial extracorporeal membrane oxygenation.

pVA-ECMO in the setting of cardiopulmonary resuscitation with mechanical chest compression is feasible and associated with good inpatient survival.

According to the most recent ELSO registry data 4,042 adult patients that underwent cardiac extracorporeal life support (ECLS) had a 40% (1,636 patients) survival to discharge or transfer (Data as shown on ECLS Registry Report International Summary January, 2014 in elso.org). Bisdas and colleagues studied a large database with 174 patients that underwent ECMO support *via* a femoral cannulation; of which 143 (82%) had VA-ECMO with 30-day survival was 39%.[14] Roussel *et al*. described their experience with 15 consecutive patients that underwent VA-pECMO, of which seven (47%) were implanted in the catheterization laboratory with 53% successfully weaned from the device and 30-day survival of 47%.[15] Bakhtiary *et al*. also described their experience with VA-ECMO for the treatment of CS among 45 patients. In their series, 29 (64%) patients had VA-ECMO instituted by peripheral cannulation of the common femoral artery and vein, while 8 (18%) patients underwent cannulation in the subclavian artery and femoral vein, and 8 (18%) underwent central cannulation.[16] In-hospital survival was 29% (13 out of 45) and 30-day survival was 47% (21 out of 45).

Smedira and colleagues reported the Cleveland Clinic experience in 202 patients with cardiac failure, in which VA-ECMO was instituted by peripheral cannulation (common femoral artery and vein) in 153 (76%) of patients, in contrast to 49 (24%) *via* central cannulation. In their study, survival at 24, 48, and 72 hr after initiation of ECMO was 90%, 83%, and 76%, respectively, and by 7-, 14-, and 30-day survival was 58%, 45%, and 38%, respectively.[17] In patients with postcardiotomy shock, Slottosch *et al*. studied 77 patients who had received peripheral ECMO after surgery, and reported a 30-day survival of 30%.[6] In another study of postcardiotomy shock, Rastan *et al*. reported an in-hospital survival of 24.8% and 30-day overall cumulative survival of 31.3%.[18] However in this study 60.8% of the patients underwent central cannulation, and only 39.2% had peripheral cannulation.

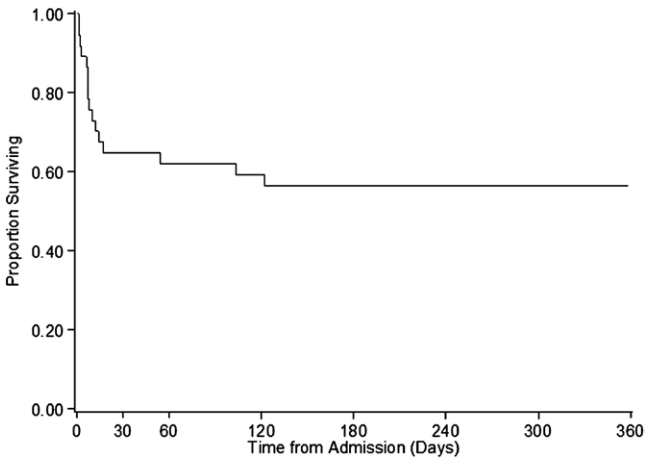

Figure 3. Kaplan–Meir survival curve of patients who underwent percutaneous venoarterial extracorporeal membrane oxygenation for refractory cardiogenic shock (n = 37). Thirty-day survival: 65%.

Timely initiation of VA-ECMO in the setting of RCS provides superior hemodynamic support to the vasoactive drugs, facilitates "controlled" PCI when indicated, and allows the heart to rest after significant ischemic insults and in selected patients may provide a bridge to more durable mechanical support. Our experience compares favorably to other peripheral ECMO series, but our superior outcomes may be at least partially related to relatively early initiation of VA-ECMO before end organ dysfunction developed, which could be supported by only moderate elevation of lactate levels. Timing of VA-ECMO insertion for RCS could be further tested in a randomized clinical trial. The decision to institute VA-ECMO is challenging, as clinicians balance the advantage of circulatory support *versus* the risk of potentially devastating complications. Although our data do not definitely establish the benefit of early VA-ECMO implantation in patients requiring multiple inotropes/vasopressors, our experience illustrates how early VA-ECMO in a less-ill population may present a favorable risk/benefit profile. Hence, clinicians should consider initiating VA-ECMO earlier in the patient's course, in light of the outcomes observed.

In a recent meta-analysis of 1866 adult patients supported by VA-ECMO, Cheng *et al*. reported that approximately 32% of patients developed vascular complications as noted by the cumulative rates of ischemia (16.9%), fasciotomy or compartment syndrome (10.3%), and amputation (4.7%).[19] In our study, five patients (13.5%) had major vascular complications requiring intervention before decannulation. Our data showed a

Table 6. Outcomes

Variable	N = 37
Duration of VA-ECMO support—median (25th, 75th percentile) (days)	5 (3, 6)
VA-ECMO explanted—n (%)	26 (70)
Length of stay—median (25th, 75th percentile) (days)	13 (8, 28)
Index admission survival—n (%)	24 (65)
Bridge to transplant—n (%)	1 (3)
Bridge to LVAD—n (%)	4 (11)
Renal replacement therapy during index admission—n (%)	11 (30)

LVAD, left ventricular assist device; VA-ECMO, venoarterial extracorporeal membrane oxygenation.

lower incidence of acute kidney injury requiring renal replacement therapy (30%), compared to 46% in Cheng's meta-analysis, which again may reflect our proactive approach to the provision of robust circulatory support before the emergence of multisystem organ failure. In our cohort, almost all patients required blood transfusion (92%), with a median transfusion requirement of 7.5 units of PRBCs, which was mainly driven by 6 out of 37 patients. This is slightly less than what Cheng reported in his review of six studies with an average number of units of PRBCs transfused ranged from 12.7 to 29.

Limitations

Our study has several limitations including its retrospective, single-center nature. Furthermore, data were abstracted from electronic medical records and variables of interest such as invasive hemodynamic measurements were not consistently available and therefore not reported. In addition, infectious complications were not collected as part of this study.

Conclusions

Refractory cardiogenic shock managed with pVA-ECMO and a multidisciplinary shock team is a feasible approach that is associated with improved survival in patients with a traditionally poor prognosis and acceptable rate of complications. This modality appears to be effective even in the sickest patients undergoing active cardiopulmonary resuscitation, when applied in a timely manner. Future prospective studies are needed to validate this approach on a larger cohort of patients in order to better understand and evaluate outcomes in patients with RCS treated with pVA-ECMO.

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