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Research Article

In-Hospital Versus outside Hospital Cannulation for Venoarterial Extracorporeal Membrane Oxygenation

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Abstract

Background: Postcardiotomy shock (PCS) is a rare but serious complication after cardiac surgery and may be treated with venoarterial extracorporeal membrane oxygenation (VA-ECMO). Frequently, patients with PCS are transferred from outside hospitals (OSH) to tertiary centers for further care. We sought to investigate whether mortality differed between OSH versus in-hospital cannulation at the tertiary center (INH). **Methods:** We retrospectively studied patients treated with VA-ECMO for PCS at our institution between January 2017 through June 2022. We compared the two cohorts based on where cannulation occurred: INH and OSH. Primary outcome was 30-day mortality. Multivariate logistic regression models were used to identify risk factors for 30-day mortality. **Results:** A total of 105 patients with PCS were treated with VA-ECMO at our center (52% INH cannulation and 48% OSH cannulation). Sixty-eight percent (71/105) were centrally cannulated and 32% (34/105) peripherally cannulated. Overall, 30-day mortality was 59% (62/105). There was no statistical difference between patients cannulated at OSH versus INH with regards to 30-day mortality (66% vs 53%, p=0.167), survival to decannulation (52% vs 62%, p=0.310), or survival to discharge (34% vs 47%, p=0.167). Multivariate analysis identified age, BMI, and post-operative dialysis as risk factors for 30-day mortality. **Conclusion:** There was no difference in 30-day mortality among patients cannulated INH versus OSH. Risk factors for 30-day mortality include older age, higher BMI, and postoperative dialysis. These data support the idea that critically ill patients with PCS should be placed on additional circulatory support and transferred to a tertiary center as soon as possible.

Abbreviations: CABG: Coronary artery bypass graft; CCL: Cardiac catheterization laboratory; CKD: Chronic kidney disease; CPB: Cardiopulmonary bypass; IABP: Intra-aortic balloon pump; ICU: Intensive care unit; INH: In-hospital; MCS: Mechanical circulatory support; OR: Operating room; OSH: Outside hospital; PCS: Post-cardiotomy shock; VA-ECMO: Venoarterial extracorporeal membrane oxygenation

Introduction

Postcardiotomy shock (PCS) remains a critical complication after cardiac surgery and portends high mortality. It may occur in up to 6% of patients after cardiac operations. Despite aggressive treatment including high-dose vasopressors and temporary mechanical circulatory support (MCS), mortality remains as high as 75% [1]. Venoarterial extracorporeal membrane oxygenation

(VA-ECMO) is a mainstay treatment for PCS, used in up to nearly 4% of patients after cardiac surgery, but associated complications such as bleeding, limb ischemia, or stroke make it high risk [2]. Despite increased use of VA-ECMO over the last couple decades, mortality remains high [3]. It is a technology that requires many resources and experience and results in many patients being transferred to tertiary centers for either initiation, or management after initiation at outside facilities.

There are many studies investigating VA-ECMO for PCS including timing of initiation, cannulation techniques, and risk factors [1,4–6]. Several studies have reported experiences transferring critically ill patients to tertiary centers, with an increasing number of reports on patients on VA-ECMO support [7–13]. No studies have focused on the implications of transferring patients with PCS who have already been cannulated for VA-ECMO at outside facilities. The objective of this study was to compare outcomes for patients with PCS treated with VA-ECMO who were either cannulated in a tertiary center or cannulated at an outside hospital (OSH) and subsequently transferred to a tertiary center.

Methods

Study design

This study was approved by the Institutional Review Board of the University of Minnesota Medical Center (protocol #1703M11301). Requirement for consent was waived due to the retrospective nature of the study. Adult patients (age ≥ 18 years old) who underwent cardiac surgery and subsequently developed PCS and were treated with VA-ECMO between January 2017 through June 2022 were identified in an internally and prospectively kept institutional ECMO registry. This included patients who were cannulated at an OSH and transferred to our tertiary center for further management. Cannulation techniques included percutaneous peripheral cannulation in the cardiac catheterization laboratory (CCL) or intensive care unit (ICU), or central cannulation or peripheral surgical cutdown in the operating room (OR). The decision to initiate VA-ECMO support was at the discretion of the surgeon; there were no standardized protocols for VA-ECMO initiation. Postcardiotomy shock was defined as shock after cardiac intervention by median sternotomy or thoracotomy without evidence of alternative causes such as sepsis or hemorrhage. We excluded lung transplant and left ventricular assist device (LVAD) recipients but included heart transplant recipients. The electronic medical record was retrospectively reviewed to confirm the index cardiac operation and determine cardiac surgery end-time, use of additional MCS prior to VA-ECMO initiation, cardiopulmonary bypass (CPB) time, aortic cross clamp time, circulatory arrest time, laboratory values at time of ECMO initiation, discharge location, and 30-day readmission. Calculated variables included total time on VA-ECMO, and time from cardiac surgery to VA-ECMO initiation. Delay in VA-ECMO initiation was defined as initiation of support after the index operation was done and the patient had left the OR. Patients were divided into two cohorts based on where cannulation occurred: in-hospital (INH) or OSH.

Statistical methods

All statistical analyses were performed using SAS statistical software, version 9.4 (SAS Institute Inc., Cary, NC, USA). A p-value of <0.05 was considered statistically significant. Baseline characteristics were reported by a mean ± standard deviation for continuous variables and percentage for categorical variables. Univariate analysis comparing INH vs OSH cannulation were done using Chi-square test or Fisher's Exact tests for any cell count less than 5 for categorical variables, and two-sample Wilcoxon tests for continuous variables as they were not normally distributed. Primary outcome was 30-day mortality. Multivariate logistic regression models were used to identify predictors of 30-day mortality in those treated with VA-ECMO for PCS. Kaplan-Meier plots were generated to estimate 30-day and 1-year mortality for the INH vs OSH cannulation cohorts and were assessed using the log-rank test.

Results

A total of 105 patients on VA-ECMO for PCS were treated at our center. Fifty-five (52%) patients were cannulated at our center (INH), and 50 (48%) were cannulated at an OSH and subsequently transferred to our center. All patients except for one had their cardiac operation and VA-ECMO initiated at the same facility. (Figure 1) depicts the locations of the referring hospitals. Overall median age was 62 years [IQR 52-69]; there were 24 patients (22.9%) ages 70-87 years old. (Table 1) shows the univariate analysis comparing baseline characteristics between the two cohorts. Patients cannulated at OSH were older ($p=0.004$) and had lower rates of chronic kidney disease (CKD) ($p<0.001$), peripheral arterial disease (PAD) ($p=0.005$), and prior venous thromboembolism (VTE) ($p=0.027$).

Figure 1: Map of Minnesota and surrounding states depicting the locations of referring centers who transferred patients with PCS on VA-ECMO. There were an additional six referring hospitals in the Minneapolis/St. Paul metropolitan area.

	Overall (n=105)	**INH (n=55)**	**OSH (n=50)**	***p* value**
Age (years), median [IQR]	62 [52-69]	58 [46-66]	65 [59-70]	0.004
Sex, n (%)				0.599
Female	32 (30.5%)	18 (32.7%)	14 (28.0%)	
Male	73 (69.5%)	37 (67.3%)	36 (72.0%)	
Race, n (%)				0.295
White	89 (84.8%)	45 (81.8%)	44 (88.0%)	
Black	5 (4.8%)	3 (5.5%)	2 (4.0%)	
Asian	3 (2.9%)	2 (3.6%)	1 (2.0%)	
Unknown	4 (3.8%)	1 (1.8%)	3 (6.0%)	

BMI (kg/m^2), median [IQR]	30.0 [25.2-34.4]	29.3 [25.2-32.8]	31.5 [25.1-35.6]	0.209
Hypertension, n (%)	78 (76.5%)	38 (69.1%)	40 (85.1%)	0.057
Diabetes, n (%)	30 (29.4%)	17 (30.9%)	13 (27.7%)	0.720
Smoking history, n (%)	28 (27.5%)	18 (32.7%)	10 (21.3%)	0.266
CAD, n (%)	71 (69.6%)	37 (67.3%)	34 (72.3%)	0.579
Heart failure, n (%)	45 (44.1%)	27 (49.1%)	18 (38.3%)	0.274
Atrial fibrillation, n (%)	31 (30.4%)	18 (32.7%)	13 (27.7%)	0.579
Cerebrovascular disease, n (%)	18 (17.6%)	12 (21.8%)	6 (12.8%)	0.232
COPD, n (%)	11 (10.8%)	5 (9.1%)	6 (12.8%)	0.750
CKD, n (%)	28 (27.5%)	25 (45.5%)	3 (6.4%)	<0.001
PAD, n (%)	24 (23.5%)	19 (34.5%)	5 (10.6%)	0.005
VTE, n (%)	16 (15.7%)	13 (23.6%)	3 (6.4%)	0.027
Prior MI, n (%)	19 (18.6%)	13 (23.6%)	6 (12.8%)	0.160
Legend: BMI: body mass index; CAD: coronary artery disease; ECMO: extracorporeal membrane oxygenation; INH: in-hospital; IQR: interquartile range; MI: myocardial infarction; OSH: outside hospital; PAD: peripheral arterial disease; VTE: venous thromboembolism				

Table 1: Baseline characteristics of patients with postcardiotomy shock treated with VA-ECMO

Table 2 shows differences in perioperative characteristics. Overall, 71/105 (68%) patients were centrally cannulated and 34/105 (32%) had peripheral cannulation; this was similar between the two cohorts (central cannulation at INH 65.5% vs OSH 68.0%, p=0.782). There were similar trends in the facility location of where VA-ECMO cannulation occurred (p=0.162); most patients were cannulated in the OR (72.7% INH vs 88% OSH), with slightly higher percentage being cannulated in the ICU or CCL at INH. There were differences in additional temporary MCS utilized between the two groups (p=0.033); those cannulated at OSH had higher use of intra-aortic balloon pump (IABP), (p=0.048). Index operation differed between the two groups (p<0.001); most patients cannulated at OSH had undergone coronary artery bypass graft (CABG) (40.0%) and multi-procedure operations (22.0%), while those cannulated INH had undergone multi-procedure operations (25.5%), OHT (23.6%), or aortic operations (20.0%). More patients from OSH had redo sternotomy, approaching significance (12% vs 1.8%, p=0.052). Postoperative cardiac arrest events were similar between the two groups (INH 12.7% vs 18.0% OSH, p=0.453). There were no differences in CPB, cross clamp, or circulatory arrest times between the two groups. There were no differences in delay of VA-ECMO initiation, or median lactate, creatinine, aspartate transaminase (AST), or alanine transaminase (ALT) at initiation between the two cohorts. Median time on VA-ECMO was 102.1 hours [IQR 61.3-183.8]; there was no difference between the two groups (p=0.312).

	Overall (n=105)	**INH (n=55)**	**OSH (n=50)**	***p* value**
CPB time, minutes, median [IQR]	237 [157-322]	240 [157-322]	236 [161-330]	0.773
Aortic cross clamp time, minutes, median [IQR]	135 [92-200]	141 [97-200]	123 [87-177]	0.309
Circulatory arrest time, minutes, median [IQR]	26 [21-41]	34 [26-42]	23 [18-33]	0.214
Type of operation, n (%)				<0.001
CABG	23 (21.9%)	3 (5.5%)	20 (40.0%)	
Valve	21 (20.0%)	12 (21.8%)	9 (18.0%)	
Aortic	19 (17.1%)	11 (20.0%)	7 (14.0%)	
Combination operation	27 (25.7%)	15 (27.3%)	12 (24.0%)	
Orthotopic heart transplant	13 (12.4%)	13 (23.6%)	0	
VSD repair	2 (1.9%)	1 (1.8%)	1 (2.0%)	
Pulmonary open thrombectomy	1 (1.0%)	0	1 (2.0%)	
Repeat sternotomy, n (%)	7 (6.7%)	1 (1.8%)	6 (12.0%)	0.052
Cardiac arrest, n (%)	16 (15.2%)	7 (12.7%)	9 (18.0%)	0.453
IABP, n (%) None Pre-operative Post-operative	 91 (86.7%) 2 (1.9%) 12 (11.4%)	 50 (90.9%) 2 (3.6%) 3 (5.5%)	 41 (82.0%) 0 9 (18.0%)	0.048
Impella, n (%) None Pre-operative Post-operative	 99 (94.3%) 3 (2.9%) 3 (2.9%)	 54 (98.2%) 1 (1.8%) 0	 45 (90.0%) 2 (4.0%) 3 (6.0%)	0.132
VA-ECMO				
Delay in VA-ECMO initiation, n (%)	38 (36.2%)	21 (38.2%)	17 (34.0%)	0.656
Hours in delay, median [IQR]	20.1 [9.8-60.6]	22.2 [11.1-68.3]	12.1 [9.5-35.6]	0.297
Duration on VA-ECMO, hours, median [IQR]	102.1 [61.3-183.8]	111.1 [62.3-217.9]	98.0 [58.0-176.7]	0.312
Cannulation location Operating room Intensive care unit Cardiac catheterization laboratory	 84 (80.0%) 7 (6.7%) 14 (13.3%)	 40 (72.7%)6 (10.9%) 9 (16.4%)	 44 (88.0%) 1 (2.0%) 5 (10.0%)	0.162

Central VA-ECMO, n (%)	70 (66.7%)	36 (65.5%)	34 (68.0%)	0.782
Arterial lactate at VA-ECMO initiation, median, mmol/L	10.2 [6.2-15.0]	11.4 [7.1-16.0]	8.9 [5.1-12.1]	0.068
Creatinine at VA-ECMO initiation, median, mg/dL	1.38 [0.97-2.01]	1.52 [0.99-2.17]	1.19 [0.89-1.80]	0.084
AST at VA-ECMO initiation, median, U/L	148 [80-644]	143 [85-642]	183 [61-725]	0.574
ALT at VA-ECMO initiation, median, U/L	58 [26-246]	73 [24-233]	57 [27-346]	0.755

Legend: AST: aspartate transaminase; ALT: alanine transaminase; CABG: coronary artery bypass graft; CPB: cardiopulmonary bypass; VA-ECMO: venoarterial extracorporeal membrane oxygenation; INH: in-hospital; IQR: interquartile range; OSH: outside hospital; PAD: peripheral arterial disease; VSD: ventricular septal defect

Table 2: Perioperative characteristics for patients with postcardiotomy shock treated with VA-ECMO

For the entire cohort, 30-day mortality was 59% (62/105); this was equal to in-hospital mortality (Table 3). Fifty-seven percent (60/105) survived to decannulation, and 41.0% (43/105) survived to discharge. For those age ≥ 70 years, 6/24 (25%) survived to discharge. There was no statistical difference between patients cannulated at OSH versus INH with regards to 30-day mortality (66% vs 53%, p=0.167), survival to decannulation (52% vs 62%, p=0.310), or survival to discharge (34% vs 47%, p=0.167). Postoperative length of stay was longer for those cannulated INH compared to OSH (17 days vs 12 days, p=0.021). For those who survived to discharge, overall the mean postoperative length of stay was significantly longer (41.8 days vs 8.7 days, p<0.001). There were no differences in postoperative complications including stroke, acute limb ischemia, tracheostomy, or dialysis, and no differences in discharge location. Multivariate analysis identified age (OR 1.04, CI 1.00-1.08, p=0.040), BMI (1.20, CI 1.09-1.32, p<0.001), and post-operative dialysis (OR 4.26, CI 1.59-11.45, p=0.004) as risk factors for increased 30-day mortality (Table 4). Kaplan-Meier estimates for 30-day survival between INH vs OSH were 49% vs 36% (p=0.126) (Figure 2), and for 1-year survival, 38% vs 30% (p=0.163), respectively (Figure 3).

	Overall (n=105)	**INH (n=55)**	**OSH (n=50)**	***p* value**
New postoperative dialysis	56 (53.3%)	34 (61.8%)	22 (44.0%)	0.068
Stroke	24 (22.9%)	16 (29.1%)	8 (16.0%)	0.111
Acute limb ischemia	10 (9.5%)	5 (9.1%)	5 (10.0%)	>0.99
Tracheostomy	7 (6.7%)	5 (9.1%)	2 (4.0%)	0.441
LOS, days, median [IQR]	14 [6-33]	17 [7-42]	12 [5-22]	0.210
Decannulated, n (%)	60 (57.1%)	34 (61.8%)	26 (52.0%)	0.310
Survived to discharge, n (%)	43 (41.0%)	26 (47.3%)	17 (34.0%)	0.167
30-day mortality, n (%)	62 (59.0%)	29 (52.7%)	33 (66.0%)	0.167
Discharge location, n (%)				0.386
Home	10 (9.5%)	7 (12.7%)	3 (6.0%)	
LTACH	10 (9.5%)	7 (12.7%)	3 (6.0%)	
TCU/ARF	22 (21.0%)	11 (20.0%)	11 (22.0%)	
Psychiatric unit	1 (1.0%)	1 (1.8%)	0	

Legend: ARF: acute rehab facility; **INH:** in-hospital; **IQR:** interquartile range; **LOS:** length of stay; **LTACH:** long term acute care hospital; **TCU:** transitional care unit

Table 3: Postoperative characteristics for patients with postcardiotomy shock treated with VA-ECMO

Variable	OR	95% CI	*p*-value
Age (years)	1.05	1.00-1.10	0.043
Female sex	2.81	0.68-11.61	0.154
BMI (kg/m^2)	1.13	1.01-1.26	0.027
Hypertension	0.83	0.18-3.91	0.815
Diabetes	0.45	0.12-1.67	0.232
Smoking	1.15	0.29-4.61	0.844
Heart failure	0.47	0.13-1.64	0.236
OSH cannulation	2.16	0.61-7.62	0.232
Central VA-ECMO	0.66	0.61-7.62	0.232
VA-ECMO duration (days)	1.00	0.99-1.00	0.477
Postoperative dialysis	5.57	1.46-21.19	0.012
Cardiac arrest	1.85	0.30-11.30	0.506
Delay in VA-ECMO initiation	1.43	0.36-5.59	0.506
Lactate (mmol/L)	1.11	0.99-1.24	0.078
Creatinine (mg/dL)	1.97	0.65-5.92	0.228
CPB time (min)	1.00	1.00-1.01	0.632
Stroke	3.51	0.86-14.33	0.080
Reduced model with significant variables			
Age (years)	1.04	1.00-1.08	0.040
BMI (kg/m^2)	1.20	1.09-1.32	<0.001
Diabetes	0.32	0.11-0.94	0.038
Postoperative dialysis	4.26	1.59-11.45	0.004
Legend: BMI: body mass index; **CPB:** cardiopulmonary bypass; **VA-ECMO:** venoarterial extracorporeal membrane oxygenation; **OSH:** outside hospital			

Table 4: Multivariate logistic regression identifying predictors of 30-day mortality for patients treated with VA-ECMO for PCS.

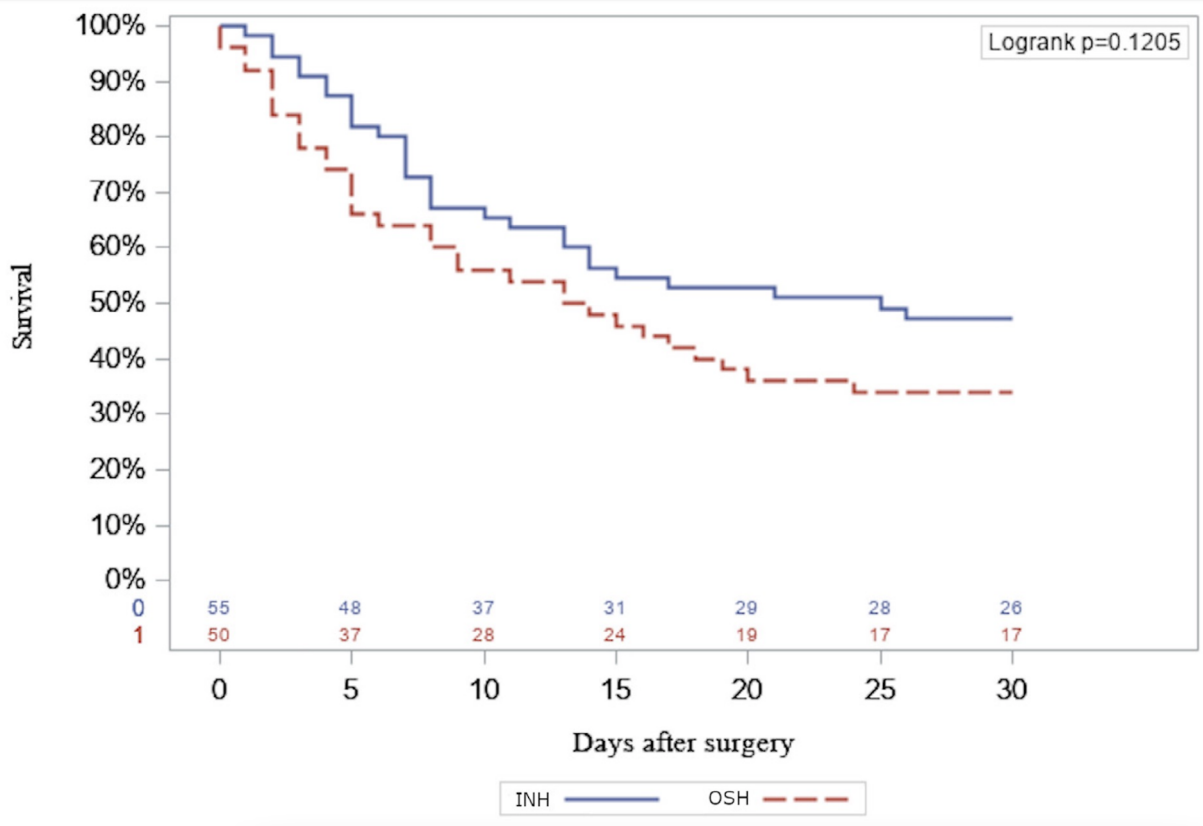

Figure 2: 30-day survival for those cannulated at OSH vs INH. 30-day survival estimates: INH: 49%, OSH: 36%.

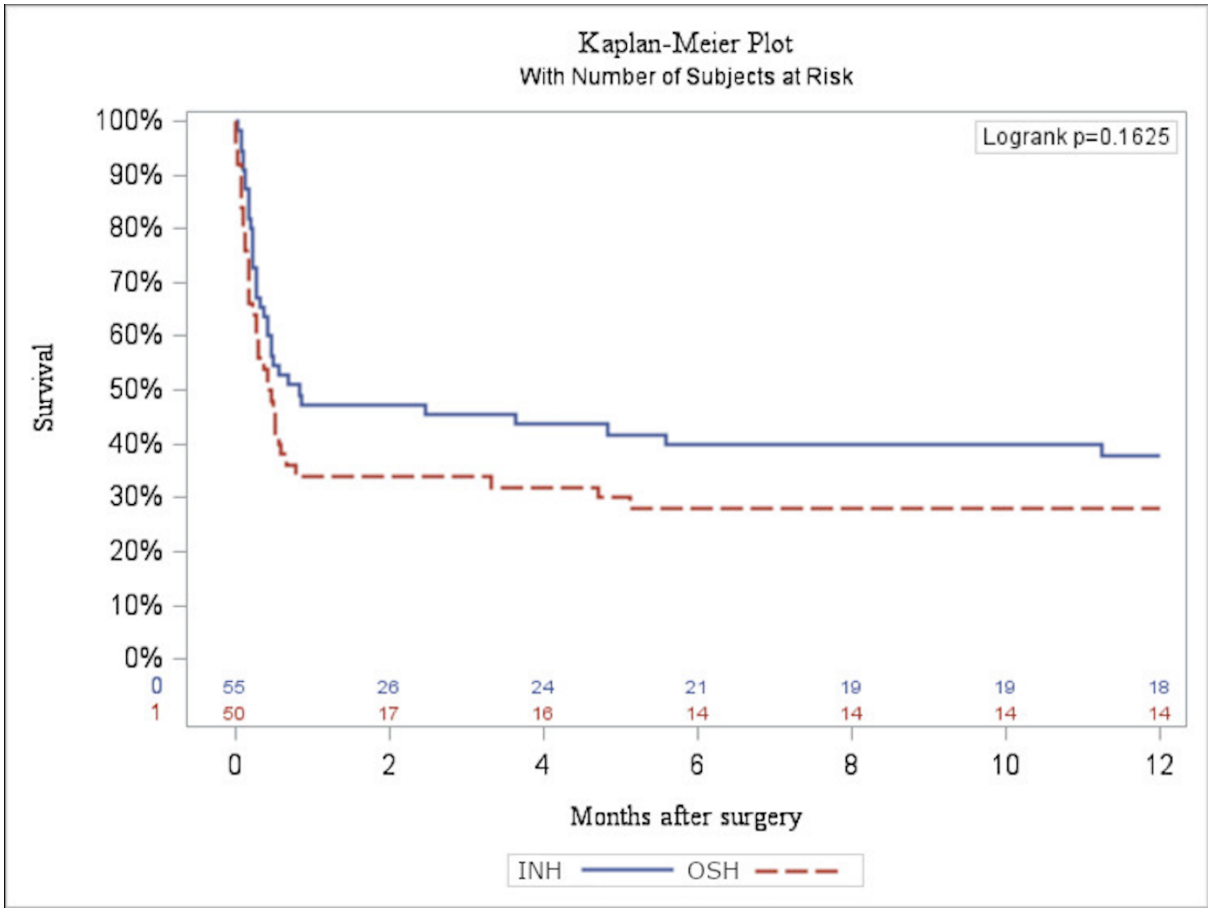

Figure 3: 1-year survival for those cannulated at OSH vs INH. 1-year survival estimates: INH: 38%, OSH: 30%.

Comment

Post-cardiotomy shock remains a clinical challenge that heralds high mortality. There is variability in the accepted timing and institution of VA-ECMO for patients with PCS. In the current study we report a 59% 30-day mortality among patients with PCS treated with VA-ECMO, and a 41% survival to discharge, consistent with the current literature [1,2,4,5,14–17]. The impact on survival appears to be greatest within the first 30-days. We showed 30-day mortality was associated with older age, higher BMI, and postoperative dialysis. We found no statistical difference for mortality between patients who were cannulated for VA-ECMO at OSH versus INH. These data support initiation of VA-ECMO at outside facilities and transferring patients to tertiary centers for further management without the risk of compromising outcomes. Additionally, we believe our results emphasize the need for earlier initiation of VA-ECMO in patients with PCS (i.e., lower serum lactate or lower vasoactive-inotropic scores).

Despite no standardized protocol to guide the timing to initiate VA-ECMO support for PCS, our data suggest that our tertiary center and surrounding referring centers have similar practices when VA-ECMO is initiated for PCS with regards to timing and laboratory markers of end-organ perfusion at time of cannulation. OSH were more likely to use IABP prior to escalation to VA-ECMO but there was similar preference for central over peripheral VA-ECMO cannulation across the two groups. Interestingly the current study did not find a statistical association between mortality and increased serum lactate or creatinine at time of cannulation, contrary to several previous studies [4,5,16,17]. This is likely explained by the small study size or a study that was not designed adequately to compare VA-ECMO initiation at a range of various laboratory markers of end-organ perfusion. Lactate levels were consistently high across our study cohort with a mean of 10.2 mmol/L at time of VA-ECMO initiation, regardless of whether cannulation was INH or OSH. Several studies have shown a survival benefit of ECMO initiation at lower lactate levels, all

at nearly half of the mean lactate in this study (4-6.45 mmol/L) [4,5,16,17]. This reveals an area of potential improvement for both small and large centers in our region. Additionally, we did not find an association between mortality and delay in VA-ECMO initiation, also likely attributed to the small sample size. Saha and colleagues at Columbia University previously reported a survival benefit with earlier initiation of VA-ECMO for PCS, and other studies suggest the same [4,17]. They reported trends in their institutional practice and found that in more recent years, VA-ECMO is initiated more commonly during the index operation, at lower lactate and creatinine levels, and at lower vasoactive-inotropic scores (i.e., lower vasopressor or inotrope requirements). These changes are a result of implementing a standardized approach for VA-ECMO for PCS [18].

Surprisingly, we found only one patient with PCS who was transferred to our tertiary center prior to VA-ECMO cannulation. We suspect that if VA-ECMO is being considered for PCS treatment, waiting to transfer patients for cannulation may delay the necessary support, especially if the distance between centers is large. Alternatively, if resources at the referring hospital are unable to support VA-ECMO initiation, transfer may be the quicker option, although these cannot be distinguished in the current study. Prior evidence in favor of early initiation of VA-ECMO for PCS as well as the data reported in the current study support initiation of VA-ECMO for PCS if feasible at an OSH with transfer to a tertiary center as soon as possible.

Numerous studies have demonstrated that transferring critically ill patients can be done safely, and there's a survival benefit when complex patients are transferred to a tertiary care center [7–11]. A small number of these include patients on VA-ECMO for various non-PCS etiologies, but there is little data regarding transfer of VA-ECMO for PCS [8,12,13]. Biancari and colleagues published an analysis of the international multicenter postcardiotomy ECMO registry and reported that centers that had treated at least 50 VA-ECMO PCS patients during the eight-year study period had lower mortality compared to smaller-volume institutions [5]. Their study did not explicitly state whether patients were cannulated at the same institution or transferred on VA-ECMO, but clearly experience managing complex patients is an important aspect of initiating and maintaining advanced support for PCS. Teman and colleagues published outcomes on patients with PCS who were transferred to their tertiary center for further intervention and management [7]. Their study population differed from the current analysis given that patients were primarily transferred with alternative modes of temporary MCS having been initiated; only five patients were transferred to their institution on VA-ECMO for PCS treatment. Ultimately nine more patients were cannulated for VA-ECMO after transfer. They did not specify whether patients were on central or peripheral VA-ECMO but reported no complications during transfer and suggested that early initiation of support is crucial for preservation of end-organ function, regardless of the type of MCS.

Despite the ability to transfer patients on VA-ECMO, the decision to initiate VA-ECMO requires a multi-disciplinary approach. Centers must consider many factors that impact outcomes including age and other comorbidities, as well as the many resources necessary for VA-ECMO management. Work to generate standardized protocols for PCS VA-ECMO could aid both small and large centers in terms of optimal timing to escalate support to VA-ECMO, cannulation strategies, duration of support, and more. The 2020 multi-society expert consensus on extracorporeal life support for PCS presents a comprehensive analysis with recommendations regarding all aspects of MCS for PCS and may help guide these decisions for tertiary and referring centers [19]. As previously referenced, the institutional protocol at Columbia University has demonstrated significantly improved mortality since implementation [18]. Given the increased use of VA-ECMO for PCS without improved outcomes and persistently high mortality, it is worthwhile determining where we can intervene to make a difference for these patients [3].

Our study is subject to certain limitations given its retrospective design and data from a single institution. Selection bias is certainly at play given our inability to include patients with PCS who were either not initiated on additional support or were initiated but not transferred given instability or futility. We also opted to include heart transplant patients which could have introduced some degree of confounding given the potential differences between the two groups. This study cannot comment on the use of VA-ECMO compared to other modes of temporary MCS for PCS treatment, although prior studies have suggested VA-ECMO is associated with worse outcomes compared to other MCS modalities [6]. We did not have data to investigate other important aspects of transferring these high acuity patients such as time from VA-ECMO initiation to transfer, time during active transport, or mode of transfer. These are certainly points of discussion across the literature and potential sources for intervention to improve outcomes among those transferred on VA-ECMO.

In conclusion, critically ill patients with refractory shock after cardiac surgery should be initiated on additional circulatory support and transferred to a tertiary center as soon as possible. Regional collaboration among institutions is crucial and advances in technology have made VA-ECMO transfer to tertiary centers feasible in the modern era. Finally, work to standardize protocols to guide PCS management and escalation of care could improve outcomes.

Conflict of Interest Statement and Funding Statement:

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