Published in final edited form as:

Ann Thorac Surg. 2009 September ; 88(3): 711–718. doi:10.1016/j.athoracsur.2009.04.007.

Short- and Long-Term Survival of Patients Transferred to a Tertiary Care Center on Temporary Extracorporeal Circulatory Support

Jonathan W. Haft, MD, Francis D. Pagani, MD, PhD, Matthew A. Romano, MD, Christina L. Leventhal, MS, D. Bradley Dyke, MD, and Jennifer C. Matthews, MD

Section of Cardiac Surgery and Division of Cardiovascular Medicine, University of Michigan, Ann Arbor, Michigan

Abstract

Background—Mechanical circulatory support (MCS) with temporary, extracorporeal assist devices restores hemodynamics in patients with refractory cardiogenic shock. These devices are frequently used in community hospitals, with subsequent referral to tertiary care centers. We sought to determine the outcomes of such referrals and identify prognostic variables that may influence management decisions.

Methods—We performed a single-institution retrospective review of 59 consecutive patients transferred on temporary, extracorporeal MCS from 1997 to 2008. Demographics, medical history, laboratory data, and clinical status were obtained, with survival determined from the medical record and the Social Security Death Index. Univariable and multivariable analysis were performed and survival estimates were determined using the Kaplan-Meier method.

Results—Median age was 49.6 years (range, 14 to 77 years). Forty-five patients (76%) were supported for postcardiotomy failure, and 34 (58%) required biventricular support. Twenty-five (42%) survived to hospital discharge, 11 after cardiac recovery (44%), 9 with long-term implantable MCS devices (39%), and 5 after heart transplantation (22%). Eight patients discharged with implantable MCS devices underwent heart transplantation and 1 remains alive on long-term implantable MCS support. Survival was 42% $\pm$ 6% at 1 year and 38% $\pm$ 6% at 5 years. Age and renal function were independent predictors of death.

Conclusions—Nearly half of all patients transferred on temporary extracorporeal MCS survive to discharge. Most of the long-term survivors received a heart transplant. Age and renal function were independent predictors of death, suggesting that survival is maximized by considering eligibility for cardiac transplantation.

Cardiogenic shock can be associated with conditions such as acute myocardial infarction, viral myocarditis, postpartum cardiomyopathy, and postcardiotomy heart failure. Mortality is extremely high, particularly when refractory to intraaortic balloon counterpulsation and inotropic support [1,2]. Mechanical circulatory support using blood pumps to support or replace cardiac function have been increasingly used as a bridge to heart transplantation or as destination therapy for selected patients unsuitable for transplant [3]. However, implantable ventricular assist devices (VADs) require lengthy operative procedures for insertion and use expensive technology currently available in only specialized higher-volume centers.

Address correspondence to Dr Haft, Cardiovascular Center 5144, 1500 E Medical Center Dr, Ann Arbor, MI 48109; haft@umich.edu. Presented at the Forty-fifth Annual Meeting of The Society of Thoracic Surgeons, San Francisco, CA, Jan 26–28, 2009.

Dr Pagani discloses that he has a financial relationship with Thoratec Corp and Terumo Corp; Dr Dyke with Thoratec Corp.

Implantation of these devices to the geographically broad and poorly selected population of patients in cardiogenic shock is impractical.

Temporary extracorporeal assist devices, with lower costs and easier implantation procedures, are frequently used for patients in cardiogenic shock, particularly in hospitals that do not routinely insert implantable VADs or perform cardiac transplantation [4]. Many of these patients are transferred to regional transplant centers. We sought to determine the outcomes of these patients and to specifically identify prognostic variables for both short-term and long-term survival.

Material and Methods

A retrospective review was performed of all patients transferred to the University of Michigan while being supported by temporary extracorporeal assist devices implanted at referring hospitals. Patients were identified from a prospectively collected database of all referrals to the cardiothoracic intensive care unit or the coronary care unit. Devices included ABIOMED BVS5000 and AB5000 ventricular assist systems (ABIOMED Inc, Danvers, MA) and Biomedicus centrifugal pumps (Medtronic Inc, Minneapolis, MN). Patients supported by extracorporeal membrane oxygenation (ECMO) were excluded to preserve the homogeneity of the cohort.

Transportation vehicles included ground ambulance, helicopter, and fixed-wing aircraft. University of Michigan flight nurses and a cardiopulmonary perfusionist cared for the patients during transport. Management protocols of patients on temporary extracorporeal support have evolved during the time of this study and are too variable for presentation.

Patients were considered for an implantable VAD if they were felt to have unrecoverable heart failure and were a suitable candidate for heart transplantation. Patients with signs of ventricular recovery were evaluated for explantation of the temporary support device. Flows were typically reduced to 1 L/min during echocardiographic imaging and invasive hemodynamic monitoring with a pulmonary artery catheter. If cardiac output, intracardiac filling pressures, and ventricular function appeared sustainable on minimal inotropic infusions, patients were explanted. Some patients were explanted without weaning trials because of bleeding or neurologic complications precluding further anticoagulation and ongoing extracorporeal support.

Data on demographics, medical history, etiology of heart failure, hemodynamic status, and laboratory values were obtained from the medical record. Survival status was obtained from the medical record or from the Social Security Death Index [5] accessed on January 13, 2009. Waiver of informed consent was granted by the Institutional Review Board, who approved collection, analysis, and reporting of the data.

Data analysis was performed using SAS 9.1 software (SAS Institute, Cary, NC). Categorical data were compared with Fisher exact tests for 2×2 tables or otherwise with the Pearson χ^2 test. Continuous data were evaluated for normality and between-group comparisons were performed using the *t* test for normal data or the Mann-Whitney test for nonnormal data. Data are expressed as mean $\pm$ standard error of the mean or median (25th, 75th percentile) as appropriate.

For the purposes of further comparison, continuous data were dichotomized at the sample median. Odds ratios with 95% confidence intervals for univariable predictors ($p < 0.05$) of in-hospital death were generated from logistic regression analysis. Multivariable logistic regression was then used to identify independent ($p < 0.05$) predictors of in-hospital death. All

variables with a value of $p \leq 0.15$ on univariable analysis were entered into multivariable regression in a stepwise fashion.

The likelihood ratio test (nested models) and the Akaike's information criterion (for nonnested models) were used during variable selection and model development to determine optimal fit. Kaplan-Meier survival curves were then created to evaluate in-hospital and long-term survival. Long-term survival was defined as free from death, regardless of intervening implantable mechanical support or cardiac transplant. Because of high early postoperative mortality, Wilcoxon p values are provided along with the log-rank test for survival curve comparison.

Results

From 1997 to 2008, 59 patients underwent implantation of temporary extracorporeal VADs at other facilities and were transferred to the University of Michigan Medical Center (Fig 1). Demographics and clinical characteristics are reported in Table 1. Most patients were white men with ischemic heart disease. The indications for mechanical cardiac support are depicted in Figure 2, with 45 (76%) requiring support after other cardiac operations. Biventricular support was provided for 58% of patients, and renal replacement therapy was initiated within 24 hours of transfer in 27%. Hemodynamics and laboratory values on arrival are summarized in Table 2, demonstrating significant end-organ injury.

Univariable Predictors of In-Hospital Death

Overall survival to hospital discharge was 42% (25 of 59), and 56% required either long-term implantable VADs or heart transplantation (Fig 3). Median duration of temporary support was 8 days for patients weaned from extracorporeal support and 6 days for those bridged to an implantable VAD. Variables associated with increased odds for in-hospital death are summarized in Tables 1 and 2. The strongest univariable predictors were advanced age (continuous and dichotomous), renal dysfunction (continuous and dichotomous), history of diabetes, and need for intravenous vasoconstrictor support. The most frequent causes of death were multisystem organ failure, stroke, and sepsis.

Independent Predictors of In-Hospital Death

The 23 variables in Tables 1 and 2 with a univariable $p \leq 0.15$ for death were entered into multivariable logistic regression analysis. Independent predictors of in-hospital death included advanced age, affording an odds ratio for death of 7.9 (1.9, 33), and renal dysfunction, with an odds ratio for death of 6.2 (2.0, 20) per mg/dL of creatinine.

Long-Term Survival After Extracorporeal Mechanical Support

Figure 4A shows the Kaplan-Meier survival curve for the entire cohort. Relatively few late deaths are noted, and most patients discharged alive survive for at least 5 years. When patients are dichotomized by age and renal function, important and significant differences are noted in survival (Figs 4B and C), with the greatest effect on survival stratification occurring within 1 month.

Comment

Early initiation of mechanical circulatory support in cardiogenic shock can restore hemodynamic stability and prevent irreversible end organ injury. Technologic advances in the field of ventricular assist devices have produced implantable pumps with both excellent biocompatibility and durability [6,7]. However, these devices require complex implantation procedures and trained personnel for postoperative surveillance, currently limiting their

application to regional centers with high volume. In addition, their costs preclude widespread application to a moribund population with high mortality rates.

When cardiogenic shock occurs in patients in medical centers without implantable VAD programs, temporary extracorporeal devices with their lower costs and easier implant procedures can be initiated. Once hemodynamic variables are stabilized, these patients can be transferred to regional centers with expanded resources. Transportation with complex extracorporeal support devices across long distances can be hazardous to both the patient and caregivers and carries extensive costs. Thus, identification of variables that are highly predictive of death may reduce unnecessary transfers of high-risk individuals, improving resource utilization. Patients identified at low risk for death should be expeditiously transferred to a transplant facility, potentially improving outcomes.

Several regional transplant centers have previously described their experience with this patient population. Morris and colleagues [8] reported 28 patients transferred to the University of Pennsylvania on extracorporeal assist devices. Compared with our cohort, more of their patients required support after elective cardiac operations, and survival was only 32%. This may reflect a slightly older population (54 years), with a higher prevalence of diabetes (50%) and low preoperative ejection fractions. All survivors underwent transplantation, either because of center philosophy or a highly selected referral of unrecoverable hearts. Statistical analysis of predictors was not performed, and follow-up was limited to 1 year.

Gonzalez-Stawinski and colleagues [9] reported the Cleveland Clinic experience of 39 patients. Similar to our cohort, more than half of the survivors required implantable long-term assist devices or transplantation. Variables associated with death included age, female gender, history of coronary disease and myocardial infarctions, diabetes, and complex surgical procedures other than coronary artery bypass grafting. Multivariable analysis could not be performed because of inadequate sample size, and long-term survival was not described.

Hernandez and colleagues [10] reported the survival of patients requiring VAD implantation after additional cardiac operations, using the Society of Thoracic Surgeons National Cardiac Database. Their survival was 54%, which was significantly better than our experience; however, their cohort included important differences. These patients were not necessarily transferred to tertiary care centers after implant procedures, both intracorporeal and extracorporeal devices were included, and patients were more likely to receive VADs after an elective operation. In addition, patients who received heart transplants on the same hospital admission were excluded, selecting out patients with irreversible heart failure. The paucity of patients in cardiogenic shock preoperatively likely accounts for the observed difference in survival compared with our report.

In this single-center analysis of 59 individuals, more than 50 demographic, clinical, and laboratory variables were evaluated to identify independent predictors of in-hospital death in patients transferred from referring centers with extracorporeal mechanical support. Although several univariable predictors were identified, only age and renal function remained independently predictive of death on multivariable analysis. At 1 month, survival for patients of advanced age or with poor renal function, or both, was less than half that of patients aged younger than 50 years or with a serum creatinine level below 1.5 mg/dL. These risk factors would be expected, suggesting worse outcomes with either patients with more advanced acquired cardiovascular disease or those with severe organ damage from late initiation of mechanical support.

We also describe excellent long-term survival, with few late deaths in patients discharged alive. Although our approach has always been to accept any referral for cardiogenic shock, we may defer transfer of patients whose age and renal function predict in-hospital death, particularly

when distance or weather influence safety and cost of transportation. We also demonstrated that most patients could not be weaned from temporary extracorporeal support and required an implantable VAD or transplant for survival. Younger patients with better renal function had improved survival, which suggests that their candidacy for heart transplantation may have influenced the decision process and contributed to our findings. Certainly, some patients died as a result of unrecoverable heart failure but were felt to be unsuitable for transplant or implantable circulatory support. Therefore, patients requiring temporary extracorporeal mechanical circulatory support devices who might be candidates for heart transplantation should ideally be referred to the regional center with the experience and resources to offer the multitude of options.

Within the last several years, newer technology aimed at mechanically supporting cardiogenic shock has become available [11,12]. Several of these devices, including TandemHeart (CardiacAssist, Pittsburgh, PA) and Impella (ABIOMED Inc) are designed for percutaneous support and are implemented outside of the operating room, broadening the application of mechanical support for cardiogenic shock. Because most of our survivors required transplant or implantable assist devices, it is important to remember that temporary mechanical support is a bridge, either to ventricular recovery or long-term cardiac replacement. When ventricular recovery is less certain, input from regional transplant centers is essential in properly selecting patients for this therapy.

Several important limitations of this study are noteworthy, including its retrospective nature and the biases that are inherent in this type of report. In addition, this is a single-institution experience and may not translate across centers with different populations, resources, and experience. Although we were able to perform multivariable analysis, the small sample size likely underestimates the importance of additional prognostic variables.

Importantly, this review is limited to patients transferred to our facility from our referral base. Additional extracorporeal assist devices are undoubtedly implanted from these hospitals, but for a variety of reasons, the patients are not transferred. Most likely, variables from these patients would populate the extremes in our series, in which transfer was less likely to positively influence the outcome. Many of these patients are either less ill, resulting in early ventricular recovery leading to successful discharge, or severely moribund, prompting referring physicians to defer transfer of an apparently unsalvageable situation. Without knowledge of these patients, our study represents only a portion of the temporary circulatory support population, potentially biasing our findings. The outcomes of this analysis are similar to other reports, however, and the independent predictors are clinically reasonable, suggesting a valid sample of patients was used for risk factor analysis.

In conclusion, approximately 40% of patients transferred to a regional transplant center on temporary extracorporeal assist devices are discharged from the hospital alive, with excellent long-term survival. Older age and renal dysfunction are independent predictors of death. More than half of surviving patients do not have adequate ventricular recovery, necessitating implantation of long-term cardiac assist devices or heart transplantation. To improve outcomes, hospitals implanting temporary extracorporeal assist devices should communicate with regional transplant centers about the appropriateness of interhospital transfer once hemodynamic stability is achieved.

References

1. Hausmann H, Potapov EV, Koster A, et al. Prognosis after the implantation of an intraaortic balloon pump in cardiac surgery calculated with a new score. *Circulation* 2002;106:I-203–6. [PubMed: 12354734]

2. Samuels LE, Kaufman MS, Thomas MP, Holmes EC, Brockman SK, Wechsler AS. Pharmacological criteria for ventricular assist device insertion following postcardiotomy shock: experience with the Abiomed BVS system. *J Card Surg* 1999;14:288–93. [PubMed: 10874615]
3. Deng MC, Edwards LB, Hertz MI, Rowe AW, Kormos RL. Mechanical circulatory support device database of the International Society of Heart and Lung Transplantation: First annual report–2003. *J Heart Lung Transplant* 2003;22:653–62. [PubMed: 12821162]
4. Jett KE. Abiomed BVS 5000: experience and potential advantages. *Ann Thorac Surg* 1996;61:301–4. [PubMed: 8561594]
5. Cowper DC, Kubal JD, Maynard C, Hynes DM. A primer and comparative review of major U.S. mortality databases. *Ann Epidemiol* 2002;12:462–8. [PubMed: 12377423]
6. Miller LW, Pagani FD, Russell SD, et al. HeartMate II Clinical Investigators. Use of a continuous-flow device in patients awaiting heart transplantation. *N Engl J Med* 2007;357:885–96. [PubMed: 17761592]
7. Haj-Yahia S, Birks EJ, Rogers P, et al. Midterm experience with the Jarvik 2000 axial flow left ventricular assist device. *J Thorac Cardiovasc Surg* 2007;134:199–203. [PubMed: 17599509]
8. Morris RJ, Pochettino A, O'Hara M, Gardner TJ, Acker MA. Emergent mechanical support in the community: Improvement with early transplant center referral. *J Heart Lung Transplant* 2005;24:764–8. [PubMed: 15949738]
9. Gonzalez-Stawinski GV, Chang AS, Navia JL, et al. Regional referral system for patients with acute mechanical support: experience at the Cleveland Clinic Foundation. *ASAIO J* 2006;52:445–9. [PubMed: 16883126]
10. Hernandez AF, Grab JD, Gammie JS, et al. A Decade of short-term outcomes in post cardiac surgery ventricular assist device implantation: data from the Society of Thoracic Surgeons' National Cardiac Database. *Circulation* 2007;116:606–12. [PubMed: 17646586]
11. Burkhoff D, Cohen H, Brunckhorst C, O'Neill WW. Tandem-Heart Investigators Group. A randomized multicenter clinical study to evaluate the safety and efficacy of the Tandem-Heart percutaneous ventricular assist device versus conventional therapy with intraaortic balloon pumping for treatment of cardiogenic shock. *Am Heart J* 2006;152:469.e1–8. [PubMed: 16923414]
12. Seyfarth M, Sibbing D, Bauer I, et al. A randomized clinical trial to evaluate the safety and efficacy of a percutaneous left ventricular assist device versus intraaortic balloon pumping for treatment of cardiogenic shock caused by myocardial infarction. *J Am Col Cardiol* 2008;52:1584–8.

Fig 1.
Referral of patients to a regional transplant center on temporary extracorporeal mechanical circulatory support from 1997 to 2008.

Fig 2.

Flow chart shows indications for extracorporeal mechanical circulatory support. (CABG = coronary artery bypass grafting; MI = myocardial infarction; VAD = ventricular assist device.)

Fig 3.

Flow chart shows outcomes of patients transferred on temporary extracorporeal mechanical circulatory support. (VAD = ventricular assist device.)

Fig 4.

(A) Kaplan-Meier survival curve for entire cohort. Survival is defined as freedom from death regardless of intervening implantable ventricular assist device or transplant. (B) Kaplan-Meier survival curves stratified by patients aged 50 years or younger (dashed line) and those older than 50 (black line). (C) Kaplan-Meier survival curve stratified by serum creatinine level exceeding 1.5 mg/dL (dashed line) and 1.5 mg/dL or less (black line).

Table 1

Patient Demographics and Clinical Characteristics

Variable ^a	Entire Cohort (n = 59)	Survivors (n = 25)	In-Hospital Deaths (n = 34)	p Value	OR for Death (95% CI) ^b
Age, y	49.6 ± 1.7	44 ± 2.4	54 ± 2.2	0.008	1.06 (1.02–1.11)
Age > 50 y	31 (53)	7 (28)	24 (71)	0.002	6.2 (2.0–19)
Male	39 (66)	15 (60)	24 (71)	0.42	
White	50 (85)	22 (88)	28 (82)	0.30	
BMI, kg/m ²	30.0 ± 0.7	28.4 ± 0.9	31.2 ± 1.0	0.036	1.11 (1.0–1.3)
BSA, m ²	2.1 ± 0.03	1.99 ± 0.05	2.11 ± 0.05	0.063	
Diabetes mellitus	22 (37)	3 (12)	19 (56)	<0.001	9.3 (2.3–37)
COPD	3 (5)	1 (4)	2 (6)	>0.99	
Hypertension	35 (59)	13 (52)	22 (65)	0.42	
Ischemic etiology	49 (83)	19 (76)	30 (88)	0.30	
Prior MI	25 (42)	10 (40)	15 (44)	0.80	
Prior sternotomy	6 (10)	2 (8)	4 (12)	>0.99	
Postcardiotomy shock	45 (76)	16 (64)	29 (85)	0.071	
Acute MI	37 (63)	16 (64)	21 (62)	>0.99	
IABP	14 (24)	4 (17)	10 (29)	0.36	
Extracorporeal MCS				0.075	
Biventricular	34 (57.6)	11 (44)	23 (67)		
LVAD	21 (35.6)	13 (52)	8 (24)		
RVAD	4 (6.8)	1 (4)	3 (9)		
Any RV support	38 (64.4)	12 (48)	26 (76)	0.031	3.5 (1.2–11)
Era of implant				0.98	
1997–2000	10 (17)	4 (16)	6 (18)		
2001–2003	15 (25)	7 (28)	8 (23)		
2004–2006	15 (25)	6 (24)	9 (26)		
2006–2008	19 (32)	8 (32)	11 (32)		
Days from admit to implant	1 (0.0, 3.0)	1.0 (0.0, 2.0)	1.0 (0.0, 5.0)	0.21	
Total days at OSH	3 (1.5, 6.0)	2.0 (1.0, 4.0)	4.0 (2.0, 6.0)	0.079	
Days from implant to transfer	1.0 (1.0, 2.0)	1.0 (1.0, 1.0)	1.0 (1.0, 3.0)	0.34	

^aData are shown for the entire cohort as well as those who survived to discharge and in-hospital deaths. Categorical data are presented as number (%). Continuous data are shown as mean $\pm$ standard error of mean, or median (25th, 75th).

^bOdds ratios (OR) and 95% confidence intervals (CI) are shown for univariable predictors ($p < 0.05$).

BMI = body mass index; BSA = body surface area; COPD = chronic obstructive pulmonary disease; IABP = intraaortic balloon pump; LVAD = left ventricular assist device; MCS = mechanical circulatory support; MI = myocardial infarction; OSH = outside hospital; RVAD = right ventricular assist device.

Table 2

Hemodynamic Parameters and Laboratory Values

Variable ^a	Entire Cohort (n = 59)	Survivors to Discharge (n = 25)	In-Hospital Deaths (n = 34)	p Value	OR for Death (95% CI) ^b
Heart rate, beats/min	87 ± 2.6	92 ± 4.1	84 ± 3.5	0.12	...
MAP, mm Hg	82 (69, 97)	87.8 (72.3, 99.3)	80.3 (67.3, 95.0)	0.96	...
Temperature, C°	37.2 (36.5, 37.7)	37.5 (36.8, 37.8)	37.1 (36.5, 37.6)	0.12	...
RA pressure, mm Hg	17 (14, 23)	16 (14, 21)	19 (14, 26)	0.56	...
PAP, mm Hg	27 (21, 35)	24 (18, 34)	29 (21, 37)	0.17	...
Systolic	40 (29, 52)	32 (22, 52)	42 (32, 53)	0.099	...
Diastolic	20 (16, 27)	20 (16, 26)	21 (15, 31)	0.48	...
LVAD flow, L/min	4.8 (4.3, 5.2)	4.8 (4.3, 5.2)	4.9 (4.3, 5.1)	0.95	...
RVAD flow, L/min	4.8 (4.1, 5.2)	5.0 (4.5, 5.3)	4.8 (4.0, 5.2)	0.29	...
PaO ₂ /FIO ₂ ratio	122 (74, 177)	131 (80, 188)	105 (62, 172)	0.30	...
PEEP, cm H ₂ O	5 (5, 8)	5 (5, 8)	5 (5, 8)	0.66	...
Level of pH	7.40 ± 0.013	7.42 ± 0.016	7.38 ± 0.020	0.14	...
Urine output, mL/8 h	670 (225, 1215)	750 (470, 1000)	360 (115, 1600)	0.13	...
CVVH ≤ 24 h	16 (27)	1 (6)	15 (94)	<0.001	18.2 (2.2–150)
Inotrope	32 (54)	14 (44)	18 (56)	0.58	...
Vasopressor	34 (58)	9 (27)	25 (74)	0.024	4.0 (1.3–13)
Vasodilator	14 (24)	7 (50)	7 (50)	0.36	...
BUN, mg/dL	23 (16.5, 34)	19 (16, 29)	28 (18, 36)	0.099	...
Creatinine, mg/dL	1.5 (1, 2.3)	1.1 (0.9, 1.5)	2.1 (1.2, 2.8)	<0.001	5.1 (1.9–14)
Creatinine > 1.5 mg/dL	28 (48)	5 (18)	23 (82)	<0.001	8.4 (2.5–28)
Glucose, mg/dL	140 (108.5, 154.5)	123 (106, 142)	147 (113, 174)	0.11	...
AST, IU/L	390 (140, 1126)	259 (131, 581)	611 (153, 2300)	0.054	...
ALT, IU/L	83 (48, 270)	73 (49, 115)	113 (48, 819)	0.21	...
Bilirubin, mg/dL	1.4 (0.9, 3.1)	1.1 (0.80, 1.8)	2.1 (1.2, 4.0)	0.016	1.3 (0.98–1.8)
INR, sec	1.2 (1.1, 1.5)	1.1 (1.0, 1.3)	1.3 (1.1, 1.7)	0.13	...
White count, K/mm ³	11.2 (8.0, 13.7)	11.6 (8.1, 12.6)	11.1 (7.6, 15.6)	0.71	...
Platelets, K/mm ³	95 (69, 125)	125 (99, 148)	75 (59, 104)	0.001	0.98 (0.97–0.99)

^aData are shown for the entire cohort as well as those who survived to discharge and in-hospital deaths. Categorical data are presented as number (%). Continuous data are expressed as mean $\pm$ standard error of mean or median (25th, 75th).

^bOdds ratios (OR) are shown with 95% confidence intervals (CI) for variables with a $p \leq 0.05$ on univariable analysis.
 ALT = alanine aminotransferase; AST = aspartate aminotransferase; CVVH = continuous venovenous hemofiltration; FIO₂ = fraction of inspired oxygen; INR = international normalized ratio; LVAD = left ventricular assist device; MAP = mean arterial pressure; PaO₂ = partial pressure of arterial oxygen; PAP = pulmonary artery pressure; PEEP = positive end-expiratory pressure; RA = right atrial; RVAD = right ventricular assist device.