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Clinical Outcomes of Early Extubation Strategy in Patients Undergoing Extracorporeal Membrane Oxygenation as a Bridge to Heart Transplantation

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ABSTRACT

Background: Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) might be considered a bridge therapy in patients who are expected to have short waiting times for heart transplantation. We investigated the clinical outcomes of patients who underwent VA-ECMO as a bridge to heart transplantation and whether the deployment of an early extubation ECMO strategy is beneficial.

Methods: Between November 2006 and December 2018, we studied 102 patients who received VA-ECMO as a bridge to heart transplantation. We classified these patients into an early extubation ECMO group (n = 24) and a deferred extubation ECMO group (n = 78) based on the length of the intubated period on VA-ECMO (≤ 48 hours or > 48 hours). The primary outcome was in-hospital mortality.

Results: The median duration of early extubation VA-ECMO was 10.0 (4.3–17.3) days. The most common cause for patients to be put on ECMO was dilated cardiomyopathy (65.7%) followed by ischemic cardiomyopathy (11.8%). In-hospital mortality rates for the deferred extubation and early extubation groups, respectively, were 24.4% and 8.3% (*P* = 0.147). During the study period, in the deferred extubation group, 60 (76.9%) underwent transplantation, while 22 (91.7%) underwent transplantation in the early extubation group. Delirium occurred in 83.3% and 33.3% of patients from the deferred extubation and early extubation groups (*P* < 0.001) and microbiologically confirmed infection was identified in 64.1% and 41.7% of patients from the two groups (*P* = 0.051), respectively.

Conclusion: VA-ECMO as a bridge therapy seems to be feasible for deployment in patients with a short waiting time for heart transplantation. Deployment of the early extubation ECMO strategy was associated with reductions in delirium and infection in this population.

Keywords: Early Extubation; Heart Transplantation; Extracorporeal Membrane Oxygenation; Cardiogenic Shock

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INTRODUCTION

The prevalence of heart failure is continuously increasing worldwide and, accordingly, patients suffering from advanced heart failure with refractory symptoms despite optimal medical treatment and device therapy who require either a durable left ventricular assist device (LVAD) or a transplanted heart to survive also constitute a significant number of individuals.[1-4] However, the number of heart donors is limited, and many critically ill patients are not receiving such treatment in a timely fashion.[5,6] For these patients, recently, temporary mechanical circulatory support (MCS) options such as percutaneous ventricular assist devices (VADs), surgically implanted extracorporeal VADs, and veno-arterial extracorporeal membrane oxygenation (VA-ECMO) systems have become increasingly used as bridges to heart transplantation (HT).[5-8]

In Korea, high suicide rates and accidents leading to death lead to the existence of a relatively short time before an adequate donor heart may be available once the patient is placed on the waiting list with an INTERMACS profile 1 or 2 designation. Also, priority status is given when VA-ECMO is applied, making it the selection of choice for temporary MCS rather than other options, while insurance issues in Korea push for the same.[7,9] Prior studies have reported that such strategies might be feasible, but only case reports could be found demonstrating whether an early extubation ECMO approach is beneficial in patients awaiting HT, although several studies have indicated the merit of early extubation ECMO in patients who received veno-venous ECMO while waiting for lung transplantation.[10,11] Therefore, we sought to investigate the clinical outcomes of patients who received VA-ECMO as a bridge to transplantation and compared them between those receiving early extubation ECMO and deferred extubation ECMO, respectively.

METHODS

Study population

The current study was a retrospective, single-center, observational study involving patients who underwent VA-ECMO as a bridge to HT between November 2006 to December 2018 at Samsung Medical Center in Seoul, Korea. All study participants were 18 years or older and were expected to receive optimal medical treatment according to current guidelines.[1,2] VA-ECMO was indicated when a patient experienced refractory cardiogenic shock equivalent to INTERMACS profile 1 or 2 and was placed on the national organ transplant registry with the intention of undergoing HT.[12] A total of 102 patients were eligible for inclusion in this study. The final decision to implant VA-ECMO was determined by an experienced medical team, and the VA-ECMO apparatus itself was inserted at the bedside or in a catheterization laboratory by cardiovascular surgeons or interventional cardiologists.

Implantation of the VA-ECMO device and management

The management of VA-ECMO was thoroughly introduced previously.[13] In short, a VA-ECMO device was inserted by percutaneous cannulation using the Seldinger technique or surgical cannulation using the cut-down method. A 14- to 17-French arterial cannula and a 20- to 24-French venous cannula were used. Femoral vessels were usually utilized as vascular access sites. The Capiox® Emergency Bypass System (Terumo, Inc., Tokyo, Japan) and the Permanent Life Support system (Maquet, Rastatt, Germany) were available in our hospital at the time of the study. In the event of distal limb ischemia after arterial cannulation, a catheter was

inserted distal to the cannulation site for limb perfusion. Pump speed was adjusted to obtain a cardiac index of greater than 2.2 L/min/body surface area (m²), a mean arterial pressure of more than 65 mmHg, and a central mixed venous saturation of more than 70%. Intravenous heparin was infused to maintain an activated clotting time ranging from 150 to 180 seconds unless life-threatening bleeding was observed. Successful weaning was defined as the disconnection of the patient from ECMO without reinsertion or death within 24 hours.

Data collection, definition, and clinical outcomes

We obtained additional information retrospectively by reviewing patient medical records from the Samsung Medical Center ECMO registry. When the same laboratory data were measured several times before ECMO insertion, the laboratory value measured at the time nearest to ECMO insertion was used. The duration of intensive care unit (ICU) stay during the whole admission period and the length of hospital stay after discharge from the ICU were measured in days. The durations on mechanical ventilation, of ICU stay, and of hospital stay after transplantation were additionally collected in patients who successfully underwent HT.

A patient was defined as being part of the early extubation ECMO group if their intubated period was 48 hours or less during the time period of VA-ECMO. For patients who received durable LVAD, the duration of early extubation ECMO was calculated as only until the time LVAD implantation was finished. Previous studies considered early extubation ECMO as either being not intubated at any time or having a relatively short duration of mechanical ventilation, but no specific time cutoff was able to be identified.[14-17] Therefore, we hypothesized that the definition of early extubation ECMO as being when a patient is intubated for 48 hours or less would have significant clinical meaning reflecting current definitions of ventilator-associated pneumonia.[18]

Delirium was diagnosed according to the Confusion Assessment Method for the ICU (CAM-ICU) and was measured both before and after HT.[19] Infection cases were defined as those in which blood, sputum, urine, skin swab, or relevant cultures were positive and associated symptoms manifested, requiring antibiotics.[20]

The primary outcome was in-hospital mortality, while secondary outcomes included HT success rate, ECMO successful removal rate, delirium occurrence, infection, and ICU stay duration.

Statistical analysis

Categorical variables are presented as numbers and relative frequencies and their group differences were compared using the chi-squared test or Fisher's exact test as appropriate. Continuous variables are presented as means ± standard deviations or medians (25th–75th percentiles) and their group differences were compared using a Student's *t*-test or the Mann-Whitney U test where appropriate. Survival curves after HT were estimated by means of the Kaplan–Meier method and compared using a log-rank test. Statistical analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY, USA) and R version 3.5.3 (R Foundation for Statistical Computing, Vienna, Austria) software programs, with $P < 0.05$ considered to be statistically significant.

Ethics statement

The present study protocol was reviewed and approved by the Institutional Review Board (IRB) of Samsung Medical Center (approval No. 2019-05-002). The requirement for informed consent was waived by the IRB of Samsung Medical Center because of the retrospective nature of the study.

RESULTS

Study population

Among 102 patients presenting with refractory cardiogenic shock treated with VA-ECMO for bridge to transplantation, 67 were diagnosed with dilated cardiomyopathy (65.7%), 12 were diagnosed with ischemic cardiomyopathy (11.8%), nine were diagnosed with acute myocardial infarction (8.8%), four were diagnosed with myocarditis (3.9%), three were diagnosed with hypertrophic cardiomyopathy (2.9%), and seven were diagnosed with other causes (6.9%). Patients were classified either into the early extubation ECMO group (n = 24) or deferred extubation ECMO group (n = 78), as shown in **Fig. 1**. Eleven patients died before HT in the deferred extubation group and two patients died before HT in the early extubation group. Separately, seven deferred extubation group patients were able to be weaned from ECMO, and two patients in the early extubation group underwent durable LVAD before being successfully transplanted. **Table 1** shows the baseline clinical and laboratory characteristics of the subjects at the time of VA-ECMO initiation. As compared with the deferred extubation group, patients in the early extubation group were more likely to be male and to undergo left ventricular decompression and less likely to have diabetes mellitus or a history of cerebrovascular disease.

Clinical outcomes

The number of patients who were in the early extubation ECMO group is presented in **Fig. 2** according to the duration on ECMO without mechanical ventilation in days with a median duration of 10.0 (4.3–17.3) days. The total period during which patients from both groups were on ECMO is indicated in **Supplementary Fig. 1**. Clinical outcomes were presented in **Tables 2** and **3**. Two patients (8.3%) died during the index hospitalization in the early extubation ECMO group, while 19 patients (24.4%) died during the same period in the
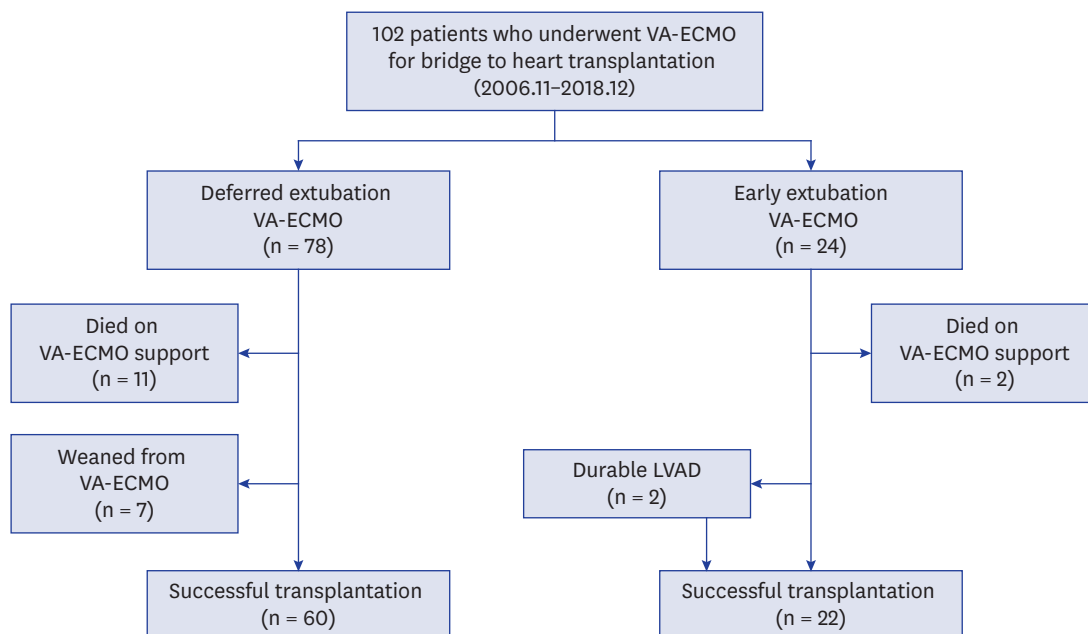
Fig. 1. Study population. Flow chart of patients, who received VA-ECMO as a bridge to heart transplantation. The patients were classified into either early extubation group or deferred extubation group depending on the length of period intubated.
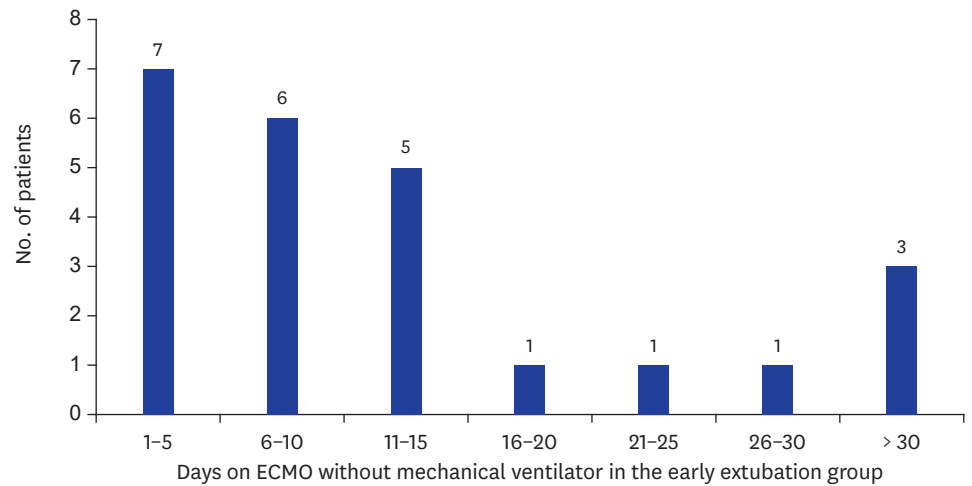VA-ECMO = veno-arterial extracorporeal membrane oxygenation.

Table 1. Baseline characteristics

Variables	Deferred extubation ECMO (n = 78)	Early extubation ECMO (n = 24)	P value
Clinical history			
Age, yr	46.8 ± 14.6	52.8 ± 11.6	0.064
Male	52 (66.7)	22 (91.7)	0.016
Body mass index, kg/m²	23.0 ± 3.8	22.5 ± 3.0	0.526
Diabetes mellitus	22 (28.2)	12 (50.0)	0.048
Hypertension	18 (23.1)	9 (37.5)	0.161
Dyslipidemia	5 (6.4)	3 (12.5)	0.388
History of malignancy	1 (1.4)	2 (8.7)	0.142
History of smoking	27 (34.6)	12 (50.0)	0.175
Chronic kidney disease	3 (3.8)	0 (0.0)	1.000
Peripheral vascular disease	1 (1.3)	0 (0.0)	1.000
History of cerebrovascular disease	14 (17.7)	0 (0.0)	0.036
History of myocardial infarction	14 (17.9)	4 (16.7)	1.000
History of revascularization	17 (21.8)	6 (25.0)	0.783
Cardiopulmonary resuscitation	21 (26.9)	1 (4.2)	0.018
Etiology			
Acute myocardial infarction	7 (9.0)	2 (8.3)	1.000
Ischemic cardiomyopathy	8 (10.3)	4 (16.7)	0.470
Dilated cardiomyopathy	50 (64.1)	17 (70.8)	0.628
Myocarditis	4 (5.1)	0 (0.0)	0.570
Hypertrophic cardiomyopathy	3 (3.8)	0 (0.0)	1.000
Others	6 (7.7)	1 (4.2)	1.000
Clinical status			
Systolic blood pressure, mmHg	68.7 ± 37.9	81.9 ± 20.9	0.332
Heart rate, bpm	89.7 ± 44.6	96.6 ± 26.9	0.925
Laboratory			
Hemoglobin, g/dL	11.4 ± 1.9	12.2 ± 2.2	0.127
Platelets, × 10⁹/L	169.4 ± 81.7	226.0 ± 136.4	0.087
Sodium, mEq/L	129.7 ± 8.2	127.9 ± 5.5	0.342
Total bilirubin, mg/dL	3.0 ± 3.3	3.5 ± 3.9	0.685
Aspartate aminotransferase, IU/L	205.0 ± 458.9	188.6 ± 260.4	0.944
Alanine aminotransferase, IU/L	210.0 ± 437.1	214.8 ± 402.3	0.782
Creatinine, mg/dL	2.0 ± 1.7	1.7 ± 0.8	0.506
Echocardiography			
Left ventricular ejection fraction, %	22.6 ± 10.7	20.2 ± 6.6	0.555
ECMO management			
Left heart decompression	38 (48.7)	18 (75.0)	0.034
Distal perfusion establishment	39 (50.0)	14 (58.3)	0.495

Data are presented as mean ± standard deviation or number (%).
ECMO = extracorporeal membrane oxygenation.

deferred extubation group ($P = 0.147$). Successful HT rates during ECMO support were 91.7% (n = 22) and 76.9% (n = 60) in patients classified as early extubation and deferred extubation, respectively ($P = 0.147$). Additionally, the rates of patients who were successfully weaned from ECMO either by HT or recovery were 91.7% (n = 22) and 85.9% (n = 67), respectively ($P = 0.728$). Delirium occurred in eight (33.3%) early extubation group patients and 65 (83.3%) deferred extubation group patients ($P < 0.001$). Infection of any site was found in 10 (41.7%) and 50 (64.1%) patients, respectively ($P = 0.051$). In particular, hospital-acquired pneumonia was seen in five (20.8%) and 34 (43.6%) patients of the early extubation and deferred extubation groups ($P = 0.045$). The total ICU stay durations were 21.5 (16.3–40.3) and 27.5 (20.0–45.5) days and the periods of hospital stay after ICU were 22.0 (15.8–33.5) and 17.0 (8.8–43.3) days, respectively, with no statistically significant differences.

Among patients who were successfully bridged to HT, delirium occurrence rates were 13.6% (n = 3) and 66.7% (n = 40) infection rates were 40.9% (n = 9) and 46.7% (n = 28) and hospital-

Fig. 2. Duration of ECMO without mechanical ventilation in the early extubation group. A total of 24 patients were in the early extubation ECMO group. The length of period on early extubation ECMO for each patient ranged from 1 to 44 days with a median duration of 10.0 (4.3–17.3) days.
ECMO = extracorporeal membrane oxygenation.

Table 2. Clinical outcomes of the study population

Outcomes	Deferred extubation ECMO (n = 78)	Early extubation ECMO (n = 24)	P value
In-hospital mortality	19 (24.4)	2 (8.3)	0.147
Successful bridging to HT	60 (76.9)	22 (91.7)	0.147
Successful ECMO weaning	67 (85.9)	22 (91.7)	0.728
ICU stay, day	27.5 (20.0–45.5)	21.5 (16.3–40.3)	0.104
Hospital stay after ICU, day	17.0 (8.8–43.3)	22.0 (15.8–33.5)	0.386
Delirium during hospitalization	65 (83.3)	8 (33.3)	< 0.001
Infection during hospitalization	50 (64.1)	10 (41.7)	0.051
HAP during hospitalization	34 (43.6)	5 (20.8)	0.045

ECMO = extracorporeal membrane oxygenation, HT = heart transplantation, ICU = intensive care unit, HAP = hospital-acquired pneumonia.

Table 3. Clinical outcomes in patients who were successfully bridged to heart transplantation

Outcomes	Successful bridging to HT in deferred extubation ECMO (n = 60)	Successful bridging to HT in early extubation ECMO (n = 22)	P value
Delirium before HT	40 (66.7)	3 (13.6)	< 0.001
Infection before HT	28 (46.7)	9 (40.9)	0.642
HAP before HT	23 (38.3)	5 (22.7)	0.187
Mechanical ventilation after HT, day	2.0 (1.0–7.0)	1.0 (1.0–2.3)	0.003
ICU stay after HT, day	16.0 (11.0–30.3)	11.0 (8.8–14.3)	0.001
Hospital stay after HT, day	43.0 (28.0–71.8)	35.0 (27.3–50.5)	0.163

Data are presented as median (interquartile range) or number (%).
HT = heart transplantation, ECMO = extracorporeal membrane oxygenation, HAP = hospital-acquired pneumonia, ICU = intensive care unit.

acquired pneumonia rates were 22.7% (n = 5) and 38.3% (n = 23) respectively for early extubation and deferred extubation patients (P < 0.001, P = 0.642, and P = 0.187). After HT, patients were on mechanical ventilation for 1.0 (1.0–2.3) and 2.0 (1.0–7.0) days, respectively (P = 0.003). Early extubation group patients stayed in the ICU and hospital after HT for 11.0 (8.8–14.3) and 35.0 (27.3–50.5) days, while deferred extubation group patients did so for 16.0 (11.0–30.3) and 43.0 (28.0–71.8) days (P = 0.001 and P = 0.163).
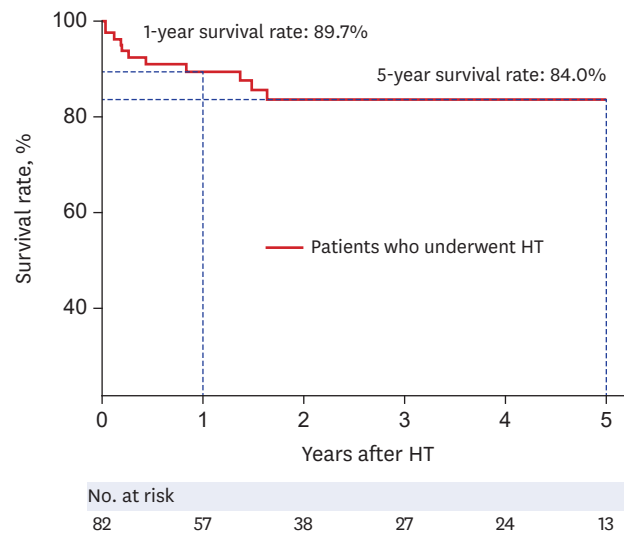
Fig. 3. Survival of patients bridged to HT with veno-arterial extracorporeal membrane oxygenation. Kaplan-Meier curve in heart transplantation recipients is shown, demonstrating a 1-year survival rate of 89.7% and a 5-year survival rate of 84.0% during the median follow up period of 637.5 (281.5–1548.8) days.
HT = heart transplantation.

Survival curves, as depicted in **Fig. 3**, showed a survival rate of 89.7% in the first year after HT. The estimated five-year survival rate determined using the Kaplan-Meier method was 84.0% with a median follow-up duration of 637.5 (281.5–1,548.8) days.

DISCUSSION

In the present study, we sought to investigate the clinical outcomes of VA-ECMO as a bridge therapy in patients with refractory cardiogenic shock who were expected to have short waiting times for HT and compared them among early extubation and deferred extubation VA-ECMO strategy groups. The main findings were as follows. First, the short-term and long-term survival rates of VA-ECMO as bridge therapy in settings with relatively short expected times to transplantation are acceptable given the results of previous HT cohort research. Second, the early extubation ECMO strategy is feasible even in patients who used VA-ECMO as a bridge to transplantation. Third, the in-hospital mortality rate was numerically lower while delirium occurrence and infection, especially hospital-acquired pneumonia, were significantly lower in the early extubation group than in the deferred extubation group. Fourth, subgroup analysis including successfully transplanted patients showed that postoperative days on mechanical ventilation and ICU stay length in days were also significantly lower in the early extubation group.

The shortage of donor hearts and the increasing number of patients on the waiting list for HT mandates some form of MCS be deployed in a subset of candidates.[5,6,21] Durable LVAD might be considered as a bridge to HT since it allows for recovery from organ damage and an improvement in patient quality of life.[22] However, the high costs of LVAD therapy and resulting insurance reimbursement issues together with limited efficacy evidence and concerns regarding posttransplant mortality also exist.[23-25] Comparable outcomes in recipients with pretransplant temporary MCS are increasingly being reported and many centers have begun applying VA-ECMO before HT.[7,26] In our study, survival analysis using

the Kaplan–Meier method also demonstrated a one-year survival rate of 89.7%, which is comparable to that of nonbridged transplant recipients.[23] Currently, successful bridging to transplantation has been reported on in previous studies with rates ranging from 44% to 76.3%.[7,27] However, in this study, 82 (80.4%) out of 102 patients were able to survive until HT with an even higher survival rate of 91.7% in the early extubation VA-ECMO group. A recent investigation reported a success rate of 91.2% attributed in part to the high volume of procedures conducted and the management protocols specific to the institution involved in the study, but, according to the implications of our study, the outcome could have been more influenced by most patients being subjected to early extubation ECMO, since a fairly large number of them were extubated shortly after VA-ECMO commencement.[26] While it seems plausible for VA-ECMO to be used as a bridge therapy, adopting the early extubation ECMO strategy might provide even better clinical outcomes and encourage temporary MCS such as VA-ECMO to be more widely used in urgent situations before definitive therapy.

The early extubation ECMO strategy has previously been deployed in patients waiting for lung transplantation with studies conducted as early as 2010.[17] A few other subsequent studies revealed promising results with higher survival rates after discharge and shorter periods of hospital stay and mechanical ventilation.[14-16] Allowing for spontaneous breathing to occur during VA-ECMO application has some merits as compared with mechanical ventilation, as it helps to prevent ventilator-induced diaphragm dysfunction and ventilator-/intubation-associated pneumonia, reduce delirium and facilitate improved rehabilitation and interactions with medical staff.[10] Likewise, the strategy has been attempted in patients undergoing high-risk percutaneous coronary intervention or suffering from refractory cardiogenic shock, but no studies involving a population bridged to transplantation were found.[28-30] Therefore, we investigated whether the use of an early extubation ECMO strategy is beneficial in patients who received VA-ECMO as a bridge to HT and found that early extubation VA-ECMO was associated with reductions in the rates of delirium and infection. A subgroup analysis with successfully transplanted patients also showed the existence of less postoperative days on mechanical ventilation and reduced ICU stay length in the early extubation group, presumably leading to reductions in medical costs and complications related to prolonged hospitalization.

The feasibility of early extubation VA-ECMO might be controversial since many patients who are intubated may have just indications. With no definite protocols concerning indications of intubation and mechanical ventilation before VA-ECMO application, many patients are routinely intubated before the procedure and possibly are not extubated for reasons such as keeping their priority status on the waiting list. However, at our institution, 19 patients were not intubated at all, undergoing VA-ECMO insertion only with local anesthesia while communicating with the medical staff. In a study conducted in a Russian hospital, 84.1% of patients were able to be extubated within one hour after the commencement of VA-ECMO and only 17.0% were reintubated.[26] Of the intubated patients in our study, 47 (56.6%) were established as such to protect the airway in situations of altered mental status resulting in cardiopulmonary resuscitation or elective procedures. This, along with the fact that five patients were able to be extubated within 48 hours, suggests that the early extubation ECMO strategy might be applicable in a broader spectrum of patients with close monitoring of the patient's status and early detection of hemodynamic compromise to minimize situations of cardiopulmonary resuscitation.

Our study had several limitations that should be highlighted. First, this study was a single-center study from a tertiary referral center and thus had a significant potential for inherent

selection and referral biases. Second, we may not be able to exclude the influence of a time difference, as the early extubation ECMO strategy was mainly used after 2016 in our institution. Also, due to the study's observational design, it should be noted that it is not totally exempt from the criticism that patients who were originally in better condition were subjected to the early extubation ECMO strategy, leading to better outcomes. Third, due to the retrospective and observational nature of this study, there were no pre-defined indications for early extubation. However, we attempted to aggressively extubate as early as possible whenever the patient was of clear consciousness and passed the test for weaning from the ventilator which are probably the cases when most other patients on mechanical ventilators are extubated. Finally, the small sample size of this study might have limited its statistical precision. Despite seemingly significant differences in numbers, statistical significance was not achieved in in-hospital mortality or survival curves by means of the Kaplan-Meier method.

In conclusion, VA-ECMO as a bridge therapy seems to be feasible in candidates waiting for HT and the early extubation ECMO strategy was specifically associated with a lower in-hospital mortality rate and reductions in both delirium and infection onset in this population. Further investigation is needed to clarify the optimal patient selection criteria for early extubation VA-ECMO and to elucidate the best timing of VA-ECMO to allow such a strategy to be successfully employed.

SUPPLEMENTARY MATERIAL

Supplementary Fig. 1
The percentage of patients according to the total duration of ECMO in both groups. A total of 24 and 78 patients were in the early extubation and deferred extubation ECMO group, respectively. The total length of period on ECMO of patients in each group is presented above. The median duration for early extubation group was 10.5 (4.8–15.8) days while it was 10 (6–16.8) days for the deferred extubation group.

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REFERENCES

1. Yancy CW, Jessup M, Bozkurt B, Butler J, Casey DE Jr, Colvin MM, et al. 2017 ACC/AHA/HFSA Focused Update of the 2013 ACCF/AHA Guideline for the Management of Heart Failure: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Failure Society of America. *Circulation* 2017;136(6):e137-61.
   PUBMED | CROSSREF

2. Ponikowski P, Voors AA, Anker SD, Bueno H, Cleland JG, Coats AJ, et al. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur Heart J* 2016;37(27):2129-200.
   PUBMED | CROSSREF

3. Bui AL, Horwich TB, Fonarow GC. Epidemiology and risk profile of heart failure. *Nat Rev Cardiol* 2011;8(1):30-41.
   PUBMED | CROSSREF

4. Chaudhry SP, Stewart GC. Advanced heart failure: prevalence, natural history, and prognosis. *Heart Fail Clin* 2016;12(3):323-33.
   PUBMED | CROSSREF

5. Lund LH, Edwards LB, Dipchand AI, Goldfarb S, Kucheryavaya AY, Levvey BJ, et al. The registry of the International Society for Heart and Lung Transplantation: thirty-third adult heart transplantation report-2016; focus theme: primary diagnostic indications for transplant. *J Heart Lung Transplant* 2016;35(10):1158-69.
   PUBMED | CROSSREF

6. Kirklin JK, Cantor R, Mohacsi P, Gummert J, De By T, Hannan MM, et al. First annual IMACS report: a global International Society for Heart and Lung Transplantation Registry for Mechanical Circulatory Support. *J Heart Lung Transplant* 2016;35(4):407-12.
   PUBMED | CROSSREF

7. Barge-Caballero E, Almenar-Bonet L, Gonzalez-Vilchez F, Lambert-Rodríguez JL, González-Costello J, Segovia-Cubero J, et al. Clinical outcomes of temporary mechanical circulatory support as a direct bridge to heart transplantation: a nationwide Spanish registry. *Eur J Heart Fail* 2018;20(1):178-86.
   PUBMED | CROSSREF

8. Werdan K, Gielen S, Ebelt H, Hochman JS. Mechanical circulatory support in cardiogenic shock. *Eur Heart J* 2014;35(3):156-67.
   PUBMED | CROSSREF

9. Park C, Jee YH, Jung KJ. Age-period-cohort analysis of the suicide rate in Korea. *J Affect Disord* 2016;194:16-20.
   PUBMED | CROSSREF

10. Langer T, Santini A, Bottino N, Crotti S, Batchinsky AI, Pesenti A, et al. "Awake" extracorporeal membrane oxygenation (ECMO): pathophysiology, technical considerations, and clinical pioneering. *Crit Care* 2016;20(1):150.
    PUBMED | CROSSREF

11. Wu J, Huang M. How do we maximize the humanistic care of a long-range (36-day) venoarterial extracorporeal membrane oxygenation and successfully bridged to heart transplantation? *J Clin Anesth* 2019;58:105-6.
    PUBMED | CROSSREF

12. Stevenson LW, Pagani FD, Young JB, Jessup M, Miller L, Kormos RL, et al. INTERMACS profiles of advanced heart failure: the current picture. *J Heart Lung Transplant* 2009;28(6):535-41.
    PUBMED | CROSSREF

13. Park TK, Yang JH, Choi SH, Song YB, Hahn JY, Choi JH, et al. Clinical impact of intra-aortic balloon pump during extracorporeal life support in patients with acute myocardial infarction complicated by cardiogenic shock. *BMC Anesthesiol* 2014;14(1):27.
    PUBMED | CROSSREF

14. Lang G, Kim D, Aigner C, Matila J, Taghavi S, Jaksch P, et al. Awake extracorporeal membrane oxygenation bridging for pulmonary retransplantation provides comparable results to elective retransplantation. *J Heart Lung Transplant* 2014;33(12):1264-72.
    PUBMED | CROSSREF

15. Fuehner T, Kuehn C, Hadem J, Wiesner O, Gottlieb J, Tudorache I, et al. Extracorporeal membrane oxygenation in awake patients as bridge to lung transplantation. *Am J Respir Crit Care Med* 2012;185(7):763-8.
    PUBMED | CROSSREF

16. Crotti S, Iotti GA, Lissoni A, Belliato M, Zanierato M, Chierichetti M, et al. Organ allocation waiting time during extracorporeal bridge to lung transplant affects outcomes. *Chest* 2013;144(3):1018-25.
    PUBMED | CROSSREF

17. Olsson KM, Simon A, Strueber M, Hadem J, Wiesner O, Gottlieb J, et al. Extracorporeal membrane oxygenation in nonintubated patients as bridge to lung transplantation. *Am J Transplant* 2010;10(9):2173-8.
    PUBMED | CROSSREF

18. Kalil AC, Metersky ML, Klompas M, Muscedere J, Sweeney DA, Palmer LB, et al. Management of adults with hospital-acquired and ventilator-associated pneumonia: 2016 Clinical Practice Guidelines by the Infectious Diseases Society of America and the American Thoracic Society. *Clin Infect Dis* 2016;63(5):e61-111.
    PUBMED | CROSSREF

19. Guenther U, Popp J, Koecher L, Muders T, Wrigge H, Ely EW, et al. Validity and reliability of the CAM-ICU flowsheet to diagnose delirium in surgical ICU patients. *J Crit Care* 2010;25(1):144-51.
    PUBMED | CROSSREF

20. Seymour CW, Liu VX, Iwashyna TJ, Brunkhorst FM, Rea TD, Scherag A, et al. Assessment of clinical criteria for sepsis: for the third international consensus definitions for sepsis and septic shock (Sepsis-3). *JAMA* 2016;315(8):762-74.
    PUBMED | CROSSREF

21. Kirklin JK, Naftel DC, Pagani FD, Kormos RL, Stevenson LW, Blume ED, et al. Sixth INTERMACS annual report: a 10,000-patient database. *J Heart Lung Transplant* 2014;33(6):555-64.
    PUBMED | CROSSREF

22. Aleksova N, Chih S. The role of durable left ventricular assist devices in advanced heart failure: would my patient benefit? *Can J Cardiol* 2017;33(4):540-3.
   PUBMED | CROSSREF

23. Urban M, Pirk J, Dorazilova Z, Netuka I. How does successful bridging with ventricular assist device affect cardiac transplantation outcome? *Interact Cardiovasc Thorac Surg* 2011;13(4):405-9.
   PUBMED | CROSSREF

24. Baras Shreibati J, Goldhaber-Fiebert JD, Banerjee D, Owens DK, Hlatky MA. Cost-effectiveness of left ventricular assist devices in ambulatory patients with advanced heart failure. *JACC Heart Fail* 2017;5(2):110-9.
   PUBMED | CROSSREF

25. Patel N, Kalra R, Doshi R, Bajaj NS, Arora G, Arora P. Trends and cost of heart transplantation and left ventricular assist devices: impact of proposed federal cuts. *JACC Heart Fail* 2018;6(5):424-32.
   PUBMED | CROSSREF

26. Poptsov V, Spirina E, Dogonasheva A, Zolotova E. Five years' experience with a peripheral veno-arterial ECMO for mechanical bridge to heart transplantation. *J Thorac Dis* 2019;11(Suppl 6):S889-901.
   PUBMED | CROSSREF

27. Chung JC, Tsai PR, Chou NK, Chi NH, Wang SS, Ko WJ. Extracorporeal membrane oxygenation bridge to adult heart transplantation. *Clin Transplant* 2010;24(3):375-80.
   PUBMED | CROSSREF

28. Kass M, Moon M, Vo M, Singal R, Ravandi A. Awake extracorporeal membrane oxygenation for very high-risk coronary angioplasty. *Can J Cardiol* 2015;31(2):227.e11-3.
   PUBMED | CROSSREF

29. Liu S, Ravandi A, Kass M, Elbarouni B. A case of awake percutaneous extracorporeal membrane oxygenation for high-risk percutaneous coronary intervention. *Cureus* 2017;9(4):e1191.
   PUBMED | CROSSREF

30. Kacer J, Lindovska M, Surovcik R, Netuka I, Mlejnsky F, Grus T, et al. Refractory cardiogenic shock due to extensive anterior STEMI with covered left ventricular free wall rupture treated with awake VA-ECMO and LVAD as a double bridge to heart transplantation - collaboration of three cardiac centres. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub* 2015;159(4):681-7.
   PUBMED | CROSSREF