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Venoarterial Versus Venovenous Extracorporeal Membrane Oxygenation As Bridge to Lung Transplantation

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ABSTRACT

BACKGROUND Venovenous (VV) extracorporeal membrane oxygenation (ECMO) has been used as a bridge to lung transplantation with acceptable outcomes. We hypothesized that venoarterial (VA) ECMO, as part of a multidisciplinary ECMO program, yields similar outcomes as VV ECMO as a bridge in lung transplantation.

METHODS Records of all patients who had undergone ECMO with the intention to bridge to lung transplantation at University of California, Los Angeles, from January 1, 2012, to March 31, 2020, were reviewed. Baseline characteristics, in-hospital outcomes, long-term survival, and freedom from bronchiolitis obliterans syndrome were assessed.

RESULTS During this interval, 58 patients were placed on ECMO with the intention to bridge to lung transplantation: 27 on VV ECMO, and 31 on VA ECMO, with a median duration of 7 and 17 days of support, respectively ($P = .01$). Successful bridge to lung transplantation occurred in 21 VV patients (78%) and in 26 VA patients (84%). Incidence of primary graft dysfunction III at 72 hours in the VV and the VA cohorts was 0% and 4%, respectively ($P = .99$). In-hospital and 90-day survival of the VV and VA groups was 100% and 96%, respectively ($P = .99$). Survival of the 2 groups at 3 years was not significantly different from a contemporary cohort of lung transplant recipients not bridged with ECMO.

CONCLUSIONS VA and VV ECMO can both be used as a bridge to lung transplantation with high success, with short and medium-term survival similar to non-bridged lung transplant recipients. Both modes should be considered effective at bridging select candidates to lung transplantation.

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With the changes in the lung allocation system more than a decade ago, an increasing number of patients with fibrotic lung diseases are undergoing lung transplantation.[1] Secondary pulmonary arterial hypertension and/or right ventricular dysfunction, which are manifestations of advanced-stage disease that require bridge with extracorporeal membrane oxygenation (ECMO), develop in many patients with fibrotic lung diseases awaiting lung transplantation.[2] A large body of data supports the use of ECMO in lung transplant candidates who develop respiratory compromise while waiting for lung trnsplantation.[3-8] Most of these studies have used venovenous (VV) ECMO as a bridge to lung transplantation, with favorable outcomes in bridge efficiency and short- and medium-term outcomes.[6,9]

However, VV ECMO cannot effectively address the high pulmonary vascular resistance or the right ventricular dysfunction commonly present in patients with fibrotic or vascular lung diseases. These patients are best supported with venoarterial (VA) ECMO. However, there are limited data on the use of VA ECMO in lung transplant candidates as a bridge.[7,8] VA ECMO can be administered percutaneously through the common femoral artery and vein. The advantages of this approach are the ease and rapidity of insertion;

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however, the disadvantages may include difficulty in ambulation, limb complications, and "North-South syndrome."[10-12]

Given the limitations of femoral cannulation for VA ECMO, several groups have used the upper extremity for return of oxygenated blood,[13-16] approaches that have been associated with hyperperfusion and arm swelling.[13] Alternative approaches include central VA ECMO through a minianterior thoracotomy or sternotomy, which is associated with increased bleeding risk and may cause adhesions complicating the lung transplant operation.[17] Regardless of approach, experience with VA ECMO as a bridge to lung transplantation is limited.

We hypothesized that lung transplant candidates bridged with VA ECMO will have similar in-hospital outcomes and long-term survival as patients bridged with VV ECMO and nonbridged patients. The goal of this study is to provide insights into the characteristics of lung transplant candidates who were bridged with VV and VA ECMO in a high-volume center.

PATIENTS AND METHODS

The Institutional Review Board approved the waiver of informed consent for this retrospective study. We reviewed all patients who were placed on ECMO with the intent of bridging to lung transplantation at University of California, Los Angeles, from January 1, 2012, to March 31, 2020. The ECMO cohort included bridge-to-decision candidates who were not yet listed. We also examined a contemporary cohort of double-lung transplant recipients not bridged with ECMO to serve as a comparison. The following baseline characteristics were collected: age, sex, race, blood group, United Network for Organ Sharing diagnostic group, lung allocation score, waiting list duration, need for mechanical ventilation, and number requiring 100% fraction of inspired oxygen. Echocardiographic, hemodynamic, and laboratory variables included left ventricular ejection fraction, severe tricuspid regurgitation, right ventricular enlargement, right ventricular fractional area change, tricuspid annular plane systolic excursion, right atrial volume index, pulmonary artery systolic and diastolic pressures, pH, P_{CO_2}, P_{O_2}, total bilirubin, and creatinine. A vasoactive-inotropic score (VIS) before ECMO initiation was also calculated (VIS = dopamine + dobutamine + 100 x epinephrine + 100 x norepinephrine + 10 x milrinone + 10 x phenylephrine + 10,000 x vasopressin [U/kg/min], other vasoactive substances in ug/kg/min).[18]

ECMO STRATEGY AND MANAGEMENT. The decision to bridge a lung transplant candidate with ECMO was made by a multidisciplinary team consisting of a surgeon, intensivist, and pulmonologist. Patients with hypoxic or hypercapnic respiratory failure and pulmonary artery systolic pressure <55 mm Hg were treated with VV ECMO. Our preferred approach for VV ECMO is a single-site dual-lumen cannula (Avalon Elite, Maquet) inserted under transesophageal echocardiographic (TEE) guidance. Adjustments to Avalon cannulas were routinely completed with transthoracic echocardiographic guidance, but patients with poor windows required adjustment with TEE. Patients transferred from other hospitals with femoral VV ECMO were maintained on that strategy as long as they were ambulatory and without complications.

VA ECMO was initiated with the clinical judgment of the multidisciplinary team and included patients with hemodynamic instability, those requiring cardiopulmonary resuscitation, or who had pulmonary artery systolic pressures >55 mm Hg and evidence of right ventricular dysfunction. For femoral VA ECMO, a 7F or 9F distal perfusion catheter was placed routinely through a cut-down on the superficial femoral artery. In patients who developed complications from femoral VA ECMO or who we anticipated might not safely ambulate, central ECMO cannulation through a sternal-sparing right anterior thoracotomy was performed.[17] All cannulas were secured with up to ten 0-silk sutures and sterilely covered with a large Ioban (3M Science) dressing to reduce the risk of infection and cannula dislodgement during ambulation.

All ECMO patients were cared for by a multidisciplinary team consisting of an around-the-clock intensivist service, cardiothoracic surgeons, perfusionists, pulmonologists, respiratory therapists, and physical and occupation therapists. All patients were extubated or underwent tracheostomy with the goal for spontaneous ventilation. They were seen by physical and occupational therapists daily for ambulation. The anticoagulation protocol aimed for an activated clotting time of 180 to 200 seconds and was adjusted based on clinical needs.

TABLE 1 Extracorporeal Membrane Oxygenation Strategies

Variable	No. (%)
VV	(n = 27)
Avalon	24 (89)
Femoral	3 (11)
VA	(n = 31)
VV converted to VA ECMO	3 (10)
Peripheral VA	10 (32)
Peripheral VA to central VA ECMO	5 (16)
Primary central VA ECMO	13 (42)

ECMO, extracorporeal membrane oxygenation; VA, venoarterial; VV, venovenous.

TABLE 2 Demographics

Variable	Venovenous (n = 27)	Venoarterial (n = 31)	*P* Value
Age, y	44 ± 16	52 ± 14	.04
Male sex	13 (48)	16 (52)	.07
Race/ethnicity			.16
White	18 (67)	18 (60)	
Black	0 (0)	4 (13)	
Hispanic	9 (33)	7 (23)	
Pacific Islander	0 (0)	1 (3)	
Blood group			.12
A	12 (44)	14 (45)	
B	1 (4)	1 (3)	
AB	0 (0)	6 (19)	
O	14 (52)	10 (32)	
Diagnosis group			.01
A	2 (7)	0 (0)	
B	0 (0)	7 (23)	
C	8 (30)	3 (10)	
D	17 (63)	21 (67)	
Lung allocation score	86 ± 11	84 ± 9	.53
Time on waiting list, d	11 (1-497)	29 (3-487)	.07
Patients on ventilator before ECMO	20 (74)	11 (35)	<.01
Patients on 100% F_{IO_2}[a]	17 (71)	17 (57)	.28

[a]F_{IO_2} requirement data available in 24 venovenous and 30 venoarterial patients. Continuous data are presented as mean ± SD or median (range), and categorical data are presented as n (%). ECMO, extracorporeal membrane oxygenation; F_{IO_2}, fraction of inspired oxygen.

TABLE 3 Echocardiographic, Hemodynamic, and Laboratory Variables

Variable	Venovenous (n = 27)	Venoarterial (n = 31)	*P* Value
LVEF	0.65 ± 0.06	0.66 ± 0.10	.70
Severe TR	2 (9)	14 (48)	<.01
RV enlargement	4 (17)	22 (76)	<.01
RV fractional area change, %	37 ± 11	31 ± 13	.12
TAPSE, cm	2.0 ± 0.6	1.8 ± 0.6	.27
RA volume index, mL/m^2	19 (13-23)	36 (25-57)	<.01
PA pressure, mm Hg			
Systolic	43 ± 13	64 ± 27	<.01
Diastolic	21 ± 7	33 ± 16	<.01
pH[a]	7.25 (7.06-7.47)	7.31 (7.05-7.48)	.12
P_{O_2}, mm Hg[a]	81 (32-339)	83 (49-500)	.92
P_{CO_2}, mm Hg[a]	87 (45-163)	56 (27-171)	<.01
Total bilirubin, mg/dL[a]	0.5 (0.2-1.5)	0.7 (0.2-5.4)	.04
Creatinine, mg/dL[a]	0.7 (0.4-1.3)	1.1 (0.3-3.0)	<.01
Vasoactive-inotropic score[b]	8.5 (0-30)	15 (0-69)	.11

[a]pH, P_{O_2}, P_{CO_2}, and creatinine were available for 22 venovenous and 28 venoarterial patients. Total bilirubin was available for 19 venovenous and 25 venoarterial patients; [b]Vasoactive-inotropic score = dopamine + dobutamine + 100 × epinephrine + 100 × norepinephrine + 10 × milrinone + 10 × phenylephrine + 10,000 × vasopressin [U/kg/min], other vasoactive substances in ug/kg/min, data available in 21 venovenous and 29 venoarterial patients. Continuous data are presented as mean ± SD or median (range) and categorical data are presented as n (%). LVEF, left ventricular ejection fraction; PA, pulmonary artery; RA, right atrial; RV, right ventricle; TAPSE, tricuspid annular plane systolic excursion; TR, tricuspid regurgitation.

ECMO complications were classified into several groups: repeat TEE for repositioning of a single-site dual-lumen cannula, facial/upper extremity swelling requiring a change in cannulation strategy, bleeding requiring surgical exploration, surgical reexploration for cannula repositioning/replacement, North-South syndrome requiring a change in cannulation strategy, cerebrovascular accidents, and other vascular complications, including limb ischemia requiring fasciotomy, dislodgement of the distal perfusion catheter, and vessel injury.

LUNG TRANSPLANTATION. All patients bridged with ECMO received bilateral lung transplantation performed on cardiopulmonary bypass through a clamshell incision. Perioperative variables, including bypass time, allograft ischemic time, intraoperative packed red blood cell transfusion, primary graft dysfunction grade III at 24, 48, and 72 hours, and postoperative complications (ECMO, return to operating room for bleeding, atrial fibrillation, cerebrovascular accidents, renal failure requiring hemodialysis, and myocardial infarction), intensive care unit and hospital lengths of stay, and in-hospital and 90-day mortality were collected. We also examined 3-year survival and freedom from grade 1 bronchiolitis obliterans syndrome (BOS) as defined by United Network for Organ Sharing, including a contemporary cohort of double-lung transplant recipients as a comparison.

STATISTICAL ANALYSES. Normally distributed continuous variables are expressed as mean ± SD and were compared with the *t* test. Nonnormally distributed continuous variables are expressed as median (range) and were compared with the Wilcoxon rank sum test. Categorical variables are expressed as number (%) and were compared with the χ^2 test or the Fisher exact test if an expected frequency was <5. Three-year survival and freedom from BOS stage I after lung transplantation were examined by the Kaplan-Meier method and compared with the log-rank test. Given a low number of death events in the ECMO cohort, multivariable analysis was not conducted. Statistical analysis was performed with Stata 15.1 software (StataCorp), and $P < .05$ was statistically significant.

RESULTS

ECMO GROUP. During the study period, 58 patients were placed on ECMO with the goal of bridging to lung transplantation, of which 27 patients (47%) were VV and 31 (53%) were VA at the time of transplantation. Of the VV ECMO patients, a single-site dual-lumen cannula was used in 24, and 3 were cannulated with a bilateral femoral strategy. Three patients were initially treated with VV ECMO and then converted to VA ECMO (2

TABLE 4 Extracorporeal Membrane Oxygenation Characteristics

Variables	Venovenous (n = 27)	Venoarterial (n = 31)	*P* Value
Ambulatory patients	24 (89)	25 (81)	.48
Walk distance, feet[a]	70 (2-400)	200 (4-880)	<.01
Spontaneously breathing patients	20 (74)	27 (87)	.21
Time on ECMO, d	7 (1-269)	17 (1-134)	.01
ECMO complications			
Cannula repositioning with TEE	6 (22)	0 (0)	.01
SVC syndrome/upper extremity swelling	3 (11)	1 (3)	.33
Surgical reexploration	0 (0)	5 (16)	.06
North-South syndrome	0 (0)	1 (3)	.99
Cerebrovascular accident	0 (0)	1 (3)	.99
Other vascular complication	1 (4)	2 (6)	.99
Patients surviving to lung transplantation	21 (78)	26 (84)	.56

[a]Walk distance available in 21 venovenous and 25 venoarterial patients. Continuous data are presented as median (range), and categorical data are presented as n (%). ECMO, extracorporeal membrane oxygenation; TEE, transesophageal echocardiogram; SVC, superior vena cava.

TABLE 5 Lung Transplant Characteristics and In-hospital Outcomes

Variables	Venovenous (n = 21)	Venoarterial (n = 26)	*P* Value
Concomitant procedures			
Tricuspid valve repair	5 (24)	11 (42)	.18
Patent foramen ovale closure	1 (5)	7 (27)	.06
Others	4 (19)	4 (15)	.99
Allograft ischemic time, min	272 ± 83	343 ± 119	.03
Cardiopulmonary bypass time, min	188 ± 48	224 ± 84	.08
PRBC transfusion in the OR, units	4 ± 2	6 ± 4	.03
Primary graft dysfunction III			
At anytime	2 (10)	8 (30)	.08
At 72 hours	0 (0)	1 (4)	.99
Postoperative complications			
ECMO	0 (0)	3 (12)	.11
Reexploration for bleeding	1 (5)	2 (8)	.68
Atrial fibrillation	5 (24)	4 (15)	.47
Stroke	0 (0)	1 (4)	.99
Renal failure requiring dialysis	1 (5)	2 (8)	.68
Myocardial infarction	0 (0)	0 (0)	.99
New tracheostomy	2 (10)	3 (12)	.82
Length of stay, d			
Intensive care unit	12 (4-29)	12 (5-62)	.6
Hospital	19 (11-43)	18 (5-70)	.63
Patients discharged after lung transplant	21 (100)	25 (96)	.99

Continuous variables presented as mean ± SD or median (range), and categorical variables are presented as n (%). ECMO, extracorporeal membrane oxygenation; OR, operating room; PRBC, packed red blood cells.

peripheral and 1 central) for additional hemodynamic support. Ten patients were bridged directly with peripheral VA ECMO to lung transplantation. Five peripheral VA ECMO patients were converted to central ECMO for ambulation. Thirteen patients underwent primary central VA ECMO cannulation (Table 1).

The demographics of the VV ECMO and the VA ECMO groups are reported in Table 2. Echocardiographic, hemodynamic, and laboratory variables before ECMO initiation are summarized in Table 3. Patients bridged with VA ECMO were significantly older (52 ± 14 vs 44 ± 16 years, $P = .04$) and more likely to be among diagnosis group B (23% vs 0%, $P = .01$), with significantly higher pulmonary artery systolic (64 ± 27 vs 43 ± 13 mm Hg, $P < .01$) and diastolic (33 ± 16 vs 21 ± 7 mm Hg, $P < .01$) pressures. They were also less likely to be placed on a ventilator before ECMO initiation (35% vs 74%, $P < .01$). On echocardiography, VA ECMO patients had a higher proportion of severe tricuspid regurgitation (48% vs 9%, $P < .01$), moderate to severe RV enlargement (76% vs 17%, $P < .01$), and a higher right atrial volume index (36 vs 19 mL/m^2, $P < .01$). Before ECMO initiation, VV ECMO patients had a higher P_{CO_2} (87 [45-163] vs 56 [27-171] mm Hg, $P < .01$), whereas VA ECMO patients had higher creatinine (1.1 [0.3-3.0] vs 0.7 [0.4-1.3] mg/dL, $P < .01$) and total bilirubin (0.7 [0.2-5.4] vs 0.5 [0.2-1.5] mg/dL, $P = .04$).

ECMO PHASE. Most of the VV and VA ECMO bridged candidates were ambulatory (89% vs 81%, $P = .48$) and spontaneously breathing (74% vs 87%, $P = .21$) (Table 4), with VA ECMO patients able to ambulate longer distances (200 [4-880] vs 70 [2-400] feet/session, $P < .01$). The duration of VV ECMO and VA ECMO support was 7 (1-269) and 17 (1-134) days, respectively ($P < .01$). Patients supported with VV ECMO had a significantly higher incidence of cannula repositioning with TEE (22% vs 0%, $P < .01$), whereas the VA ECMO patients trended toward higher rates of surgical reexploration for bleeding (16% vs 0%, $P = .06$). Overall, 81% of patients placed on ECMO were successfully bridged to lung transplantation (78% VV vs 84% VA, $P = .56$). Six patients died before transplantation in the VV group: 4 of multisystem organ failure, 1 with brain death after respiratory arrest, and 1 electively withdrew support. Five patients in the VA group died before transplantation: 4 from multisystem organ failure, 1 from sepsis, and 1 with stroke and support withdrawal.

LUNG TRANSPLANT PHASE. All patients who survived the ECMO phase underwent double-lung transplantation, with operative and in-hospital outcomes reported in Table 5. Overall, 42% recipients required concomitant procedures (38% VV vs 61% VA, $P = .11$). While bypass times were similar (188 ± 48 vs 224 ± 84 minutes, $P = .08$), allograft ischemic times were significantly longer in the VA group (343 ± 119 vs 272 ± 83 minutes, $P = .03$) along with

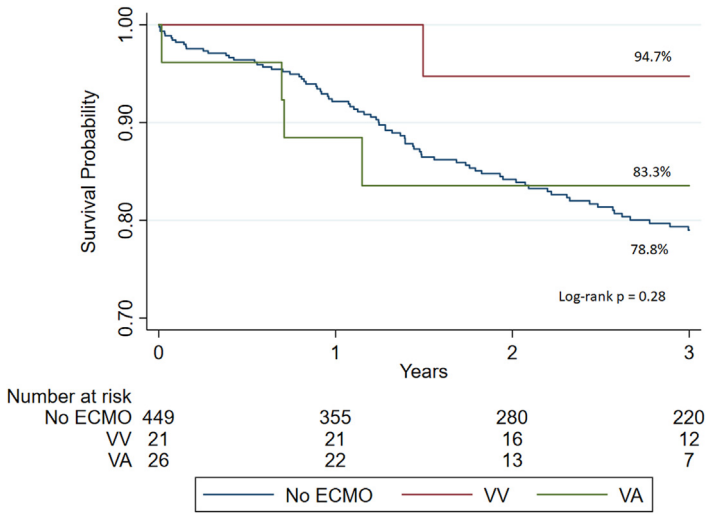

FIGURE 1 Three-year survival of lung transplant recipients bridged with venovenous (VV) or venoarterial (VA) extracorporeal membrane oxygenation (ECMO) and nonbridged recipients.

increased intraoperative packed red blood cell transfusions (6 ± 4 vs 4 ± 2 units, $P = .03$). The incidence of primary graft dysfunction III at 72 hours in the VV ECMO and VA ECMO group was similar (0% vs 4%, $P = .99$). One patient in the VA ECMO group remained on ECMO 72 hours after lung transplantation. The incidence of postoperative complications and intensive care unit and hospital lengths of stay were similar between the 2 groups. After transplantation, 100% of VV-bridged patients and 96% of VA-bridged patients survived to discharge and 90 days ($P = .99$). Three-year survival rates of nonbridged, VV-bridged, and VA-bridged double-lung transplant recipients are depicted in Figure 1, with survival of 94.7% in VV, 83.3% in VA, and 78.8% in nonbridged double-lung transplant recipients (log-rank $P = .28$). Three-year freedom from BOS stage I was 100% in the VA and 71% in the VV group (log-rank $P = .10$) (Figure 2).

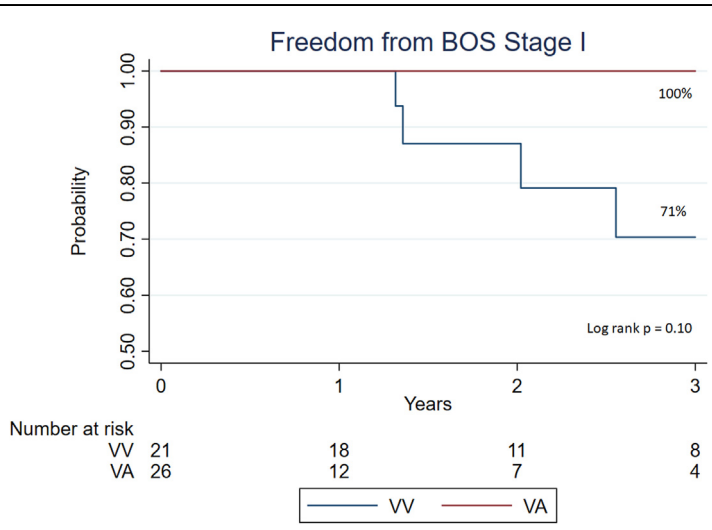

FIGURE 2 Freedom from bronchiolitis obliterans syndrome (BOS) stage I of lung transplant recipients bridged with venovenous (VV) vs venoarterial (VA) extracorporeal membrane oxygenation.

COMMENT

This study suggests that lung transplant candidates in need of extracorporeal support can be successfully bridged with VV or VA ECMO. The most common complication in the VV ECMO group was TEE-guided repositioning of a single-site dual-lumen cannula, whereas the most common complication in the VA ECMO group was surgical reexploration. Transplantation was successful in nearly 80% of patients bridged with VV or VA ECMO, with short- and medium-term outcomes similar to nonbridged lung transplant candidates.

ECMO therapy has become a standard tool in the armamentarium for bridging lung failure patients to successful transplantation. However, it encompasses a variety of cannulation techniques tailored to diverse patient needs. Most reported series of bridge to transplant (BTT) ECMO in lung transplant have been VV ECMO, which can meet the physiologic need of patients with isolated lung failure.[6,9] With the increasing number of lung transplant candidates with fibrotic and vascular lung diseases who develop right ventricular dysfunction and/or poor systemic perfusion, VA ECMO is being increasingly needed as a bridge strategy. Our study suggests that despite the physiologic differences between candidates needing VA and VV ECMO, bridging with VA ECMO can have similar short- and medium-term outcomes compared with VV ECMO. Moreover, both strategies can lead to similar survival as nonbridged patients. Findings of this study support the conclusions of other reports that properly selected patients bridged with ECMO can have similar outcomes as nonbridged patients. In a single-center study, Todd and colleagues[9] found that 12 patients bridged with ECMO (1 VA) all survived to hospital discharge and that 1-year survival was similar between bridged and nonbridged patients (100% vs 91%, $P = .24$). Hakim and colleagues[6] reported successful BTT in 87% of 30 ECMO patients (6 VA), with 3-year posttransplant survival of 80%.[6] Kukreja and colleagues[7] successfully bridged 42 of 62 listed patients (68%), with 1-year posttransplant survival similar to nonbridged patients. Tipograf and colleagues[8] successfully bridged 70 of 121 (59%) to lung transplantation, with no significant difference in posttransplant survival. At our center, 81% of 58 ECMO patients were

successfully bridged to lung transplantation, with nearly all of them surviving to hospital discharge. Survival at 3 years mirrored findings of other centers reporting their outcomes and was not different among VV, VA, or nonbridged recipients. Our higher successful BTT rates may be related to improved patient selection but can also be attributed to the synergy of our multidisciplinary care team who push for early ambulation, spontaneous breathing, and careful attention to diagnosing and managing complications.

We found that freedom from grade 1 BOS in lung transplant recipients bridged with VV-ECMO was comparable to rates reported by the International Society of Heart and Lung Transplantation registry.[19] However, a surprising finding was that none of the patients bridged with VA ECMO experienced BOS within 3 years of transplantation, which is difficult to explain. There may be some intrinsic factor in patients with pulmonary hypertension or right heart dysfunction treated with VA ECMO that reduces the incidence of BOS, or our findings may be explained by a small sample size with limited follow-up. To our knowledge, no literature exists examining the long-term risk of BOS in VA ECMO-bridged lung transplant recipients, so this finding warrants further investigation and is hypothesis-generating.

We have adopted the following framework for the lung transplant candidate who requires mechanical circulatory support for BTT: if the patient does not have pulmonary hypertension with right ventricular dysfunction, we pursue a strategy of dual-lumen internal jugular cannulation VV ECMO to facilitate ambulation. In the presence of pulmonary hypertension and right ventricular dysfunction or hemodynamic instability, we initially pursue femoral VA cannulation with routine distal perfusion catheter placement. If North-South syndrome develops, flows are inadequate, or ambulation cannot be achieved with peripheral ECMO, the patient is converted to central ECMO.[17]

Some reports suggest a correlation between the ECMO duration and clinical success.[7] Another report found no association between ECMO duration (median, 12 days; maximum, 24 days) and successful bridging to lung transplantation.[8] The current study highlights that a longer duration of ECMO support is feasible in lung transplant candidates as long as the cannulation strategy results in adequate physiologic support and facilitates ambulation. The longest duration of VA and VV ECMO in this study was 134 and 269 days, respectively, due to recipient presensitization. It should be noted that sensitization was preexistent and did not occur during the ECMO run. It is encouraging to note that ECMO can be used as a bridge for the increasing number of highly sensitized lung transplant candidates who may need a bridge.

We have learned several lessons over the years that merit explicit mention. First, patients in need of cardiac and respiratory support should be offered VA ECMO expeditiously. In our limited experience, transitioning from VV ECMO to VA ECMO is usually complicated by end-organ dysfunction that only a few patients have the reserve to recover from.

Second, in patients on femoral VA ECMO with complications such as North-South syndrome or inability to walk, we have resorted to central VA ECMO without delay to ensure good end-organ perfusion and daily ambulation.

Third, the central goal of the extracorporeal support is to restore the patient's normal physiologic status, including daily ambulation, spontaneous breathing, and enteral nutrition, so that that they remain good candidates for lung transplantation. Ambulating critically ill patients on VA ECMO may be difficult, but a committed multidisciplinary team can excel in such efforts with institutional support.

Finally, a dedicated multidisciplinary team consisting of physicians, nurses, advanced practice nurses, perfusionists, respiratory therapists, occupational and physical therapists, and social workers is integral to the success of an ECMO program caring for patients needing organ transplantation.

Limitations include the retrospective, observational, and single-center nature of this study. We may be underpowered to detect differences in baseline characteristics, short-term outcomes, and survival. Although we report the outcomes of all patients placed on ECMO with the intention to BTT, the high lung transplantation rates suggest that we were selective and can potentially expand our criteria for both VV and VA ECMO deployment in end-stage lung disease patients. These outcomes may also not be reproducible at other centers without a similar lung transplant and ECMO team composition/experience.

In conclusion, we found that despite the inherent physiologic differences between patients requiring VV vs VA bridging, both strategies can lead to similar transplant outcomes when pursued in a comprehensive ECMO center. Furthermore, outcomes in bridged patients compare favorably to nonbridged patients, indicating that need for mechanical support, even when VA ECMO is required, should not in isolation impact a patient's lung transplant candidacy.

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