Brief Report

Expanded extracorporeal membrane oxygenation bridge to heart and lung transplant candidate selection does not impact outcomes compared to traditional candidate selection criteria

Abdul Wahab[1], Andrew C. Hanson[2], Steve Peters[3], Mauricio A. Villavicencio[4], Sahar A. Saddoughi[4,5], Sadia Z. Shah[6], Philip J. Spencer[4], Cassie C. Kennedy[3], Kelly M. Pennington[3]

[1]Department of Internal Medicine, Mayo Clinic Health Systems-Mankato, Mankato, MN, USA; [2]Department of Biostatistics, Mayo Clinic, Rochester, MN, USA; [3]Department of Internal Medicine, Division of Pulmonary/Critical Care and Lung Transplant Medicine, Mayo Clinic, Rochester, MN, USA; [4]Department of Surgery, Division of Cardiac Surgery, Mayo Clinic, Rochester, MN, USA; [5]Department of Surgery, Division of Thoracic Surgery, Mayo Clinic, Rochester, MN, USA; [6]Department of Internal Medicine, Division of Pulmonary/Critical Care Medicine, Mayo Clinic, Jacksonville, FL, USA

Correspondence to: Kelly M. Pennington, MD. Division of Pulmonary/Critical Care and Lung Transplant Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA. Email: Pennington.Kelly@mayo.edu.

Abstract: Extracorporeal membrane oxygenation is used as a bridge to transplant (ECMO-BTT) in selected patients. The objective of this study was to determine whether 1-year post-transplant and post-ECMO survival are impacted by traditional compared to expanded selection criteria. We performed a retrospective study of patients >17 years who received ECMO as bridge to transplant (BTT) or bridge to transplant decision for lung or combined heart and lung transplantation at the Mayo Clinic Florida and Rochester. Institutional protocol excludes patients >55 years, maintained on steroids, unable to participate in physical therapy, with body mass index >30 or <18.5 kg/m^2, non-pulmonary end-organ dysfunction, or unmanageable infections from ECMO-BTT. For this study, adherence to this protocol was considered traditional whereas exceptions to the protocol were considered expanded selection criteria. A total of 45 patients received ECMO as bridge therapy. Out of those 29 patients (64%) received ECMO as bridge to transplant and 16 patients (36%) as bridge to transplant decision. The traditional criteria cohort consisted of 15 (33%) patients and expanded criteria cohort consisted of 30 (67%) patients. In the traditional cohort, 9 (60%) of 15 patients were successfully transplanted compared to 16 (53%) of 30 patients in the expanded criteria cohort. No difference in being delisted or dying on the waitlist (OR: 0.58, CI: 0.13–2.58), surviving to 1-year post-transplant (OR: 0.53, CI: 0.03–9.71) or 1-year post-ECMO (OR: 0.77, CI: 0.0.23–2.56) was observed between the traditional criteria and expanded criteria cohorts. At our institution, we did not see differences in odds of 1-year post-transplant and post-ECMO survival between those who met traditional criteria compared to those who did not. Multicenter, prospective studies are needed to evaluate the impact of ECMO-BTT selection criteria.

Keywords: Bridge to transplant; extracorporeal membrane oxygenation (ECMO); heart and lung transplant

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Introduction

Lung transplant is a lifesaving treatment for end-stage lung disease. In the United States, approximately 2,000 lung transplants are performed annually with nearly 5,000 patients on the lung transplant waiting list (1). Organ availability limits the number of lung transplants that can be performed; therefore, lung transplant candidates are carefully selected to ensure that organs are allocated to

Table 1 Exclusion criteria based on institutional ECMO-BTT Protocol*

Age: >55 years
BMI: >30 or <18.8 kg/m^2
Maintained on steroids equivalent to prednisone >10 mg/day and unable to be weaned off
Unable to participate in physical therapy or unable to achieve six-minute walk distance >200 m
Creatinine clearance <50 mL/min
Untreatable Cardiac disease
Unmanageable infections

*, In the absence of absolute contraindications to transplantation (e.g., active malignancy, active substance use etc.). ECMO-BTT, extracorporeal membrane oxygenation bridge to transplant, BMI, body mass index.

patients with the greatest need and survival probability. Extracorporeal membrane oxygenation (ECMO) has been used as a bridge to transplantation (ECMO-BTT) in patients who would otherwise succumb to respiratory failure. ECMO-BTT has traditionally been associated with significantly lower survival rates and more complications compared to those not requiring ECMO-BTT (2). With increasing use of ECMO-BTT over the past two decades, retrospective studies have reported improving survival outcomes (3,4). Along with extensive clinical experience and advances in ECMO technology, some postulate that strict candidate selection is associated with improved ECMO-BTT outcomes (5). In the absence of absolute contraindications for lung transplant, traditional ECMO-BTT or bridge-to-transplant decision candidate selection is influenced by chronologic age, body mass index (BMI), physical frailty, non-pulmonary end-organ dysfunction (renal, hepatic, cardiac), and allosensitization (6,7).

The primary objectives of this study were to determine whether 1-year post-transplant survival and post-ECMO survival, and other important ECMO and transplant-related outcomes were impacted by traditional candidate selection criteria compared to expanded criteria.

Methods

We performed a retrospective cohort study utilizing an institutionally developed natural language processing software (Advanced Text Explorer) to identify patients older than 17 years who had clinical notes between January 1, 2009, and July 1, 2021, in the Mayo Clinic Florida and Rochester electronic medical records containing the words "ECMO" and "lung transplant". The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Mayo Clinic Institutional Review Board (IRB No. 21-010789). All included patients or their legally authorized representatives had provided a prior research authorization consenting to use of their medical records for research purposes. Each chart was then individually reviewed to determine if the patient met study inclusion or exclusion criteria. Patients were categorized as ECMO bridge to transplantation if they had an active transplant listing status, and bridge to transplant decision with no active listing status prior to ECMO cannulation. ECMO-BTT or bridge to transplant decision candidacy was assessed by a multidisciplinary team according to the institutional ECMO-BTT protocol (version dated 3/17/2020), which excludes patients from ECMO-BTT if they are >55 years, maintained on steroids (equivalent to prednisone >10 mg/day), unable to participate in physical therapy or unable to achieve 6-minute walk distance (6MWD) >200 meters prior to hospitalization, have a BMI >30 or <18.5 kg/m^2, end-organ dysfunction (including creatinine clearance <50 ml/min), untreatable cardiac disease, or unmanageable infections (*Table 1*). Exceptions to the protocol are permitted on a case-by-case basis based on the assessment by a multidisciplinary team. These exceptions are granted after review by the medical and surgical transplant team for patients who do not have other therapeutic options in the absence of absolute contraindications to transplant (i.e., lack of psychosocial support, active substance use, active malignancy etc). At our institution patients are evaluated for ECMO eligibility even if they are not active on transplant wait list. For this study, adherence to this protocol was considered traditional selection criteria whereas exceptions to the protocol were considered expanded selection criteria. We included patients who were placed on ECMO (either veno-venous or veno-arterial) as a bridge to either lung, heart-lung transplantation, or decision to transplant. Combined organ candidates were also included. We excluded patients who were being considered for "re-do" lung or heart-lung transplant.

During the time frame of the study (2009–2021), there were no significant changes in institutional ECMO management practices. Type of anticoagulation utilized (heparin to bivalirudin) and antibiotic prophylaxis use shifted.

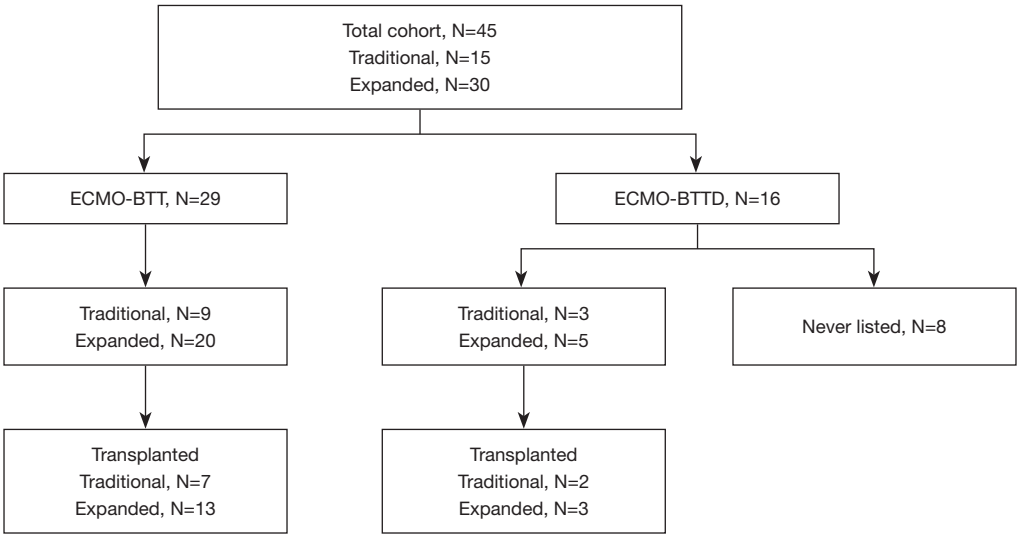

Figure 1 Flow chart of included patients. ECMO, extracorporeal membrane oxygenation; BTT, bridge to transplant; BTTD, bridge to transplant decision.

Our primary outcomes were: the odds of one-year post-transplant survival amongst those who received a transplant and one-year post-ECMO survival. Secondary outcomes included receiving transplantation, delisting or death on the waitlist, ECMO-related complications, hospital length of stay, and one-year post-transplant 6MWD.

Statistical analysis

Categorical baseline characteristics were compared between groups (traditional vs expanded selection criteria cohorts) using Fisher's Exact Test. Binary outcome variables were compared using Pearson's Chi-squared tests with odds ratios and 95% confidence intervals presented. Continuous variables were compared using Wilcoxon rank sum test. P values of <0.05 were considered statistically significant. BlueSky Statistics software v7.2 (BlueSky Statistics LLC, Chicago, IL, USA) was used for all statistical analysis.

Results

The initial search resulted in the identification of 392 unique patients. A total of 45 adult patients (64% male) were placed on ECMO as bridge therapy from January 2009 to July 2021. Out of those 29 patients (64%) received ECMO as bridge to transplant and 16 patients (36%) as bridge to transplant decision. Traditional criteria cohort consisted of 15 (33%) patients and the expanded criteria cohort consisted of 30 (67%) patients (*Figure 1*). Total number of patients who received ECMO as bridge therapy increased during the study period. During the first half of the study both groups had almost same number of patients. However, in the second half the expanded group had more than twice the number of patients as compared to the traditional group (*Figures 2,3*).

Baseline characteristics are summarized in *Table 2*. The expanded criteria cohort was older [53.0 years (IQR: 33, 61) *vs.* 40.0 (IQR: 45, 60.0), P=0.02] and underlying fibrotic lung diseases were more common [19 (63%) *vs.* 4 (27%), P<0.05] compared to the traditional criteria cohort. The groups were otherwise similar.

In the traditional criteria cohort, 9 out of 15 (60%) patients were transplanted compared to 16 out of 30 (53%) patients in the expanded criteria cohort (OR: 1.31, CI: 0.37–4.62, P=0.67). No difference in surviving to 1-year post-transplant (OR: 0.53, CI: 0.03–9.71, P=0.67) or 1-year post-ECMO (OR: 0.77, CI: 0.23–2.56, P=0.67) was observed between the two groups. In those surviving to one-year post-transplant, no difference in one-year post-transplant 6MWD was observed between the groups (*Table 3*). One patient from each group died following the transplant: the patient from the traditional criteria group died on post-transplant day 36 due to necrotizing pancreatitis complicated with multiorgan failure, and the patient from the expanded criteria group died on post-transplant day 20

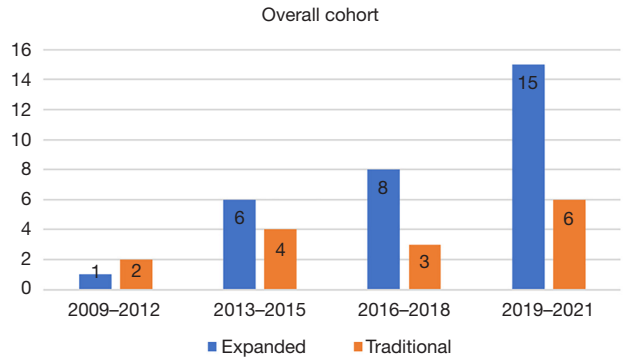

Figure 2 Trends of ECMO as bridge therapy during the study period. ECMO, extracorporeal membrane oxygenation.

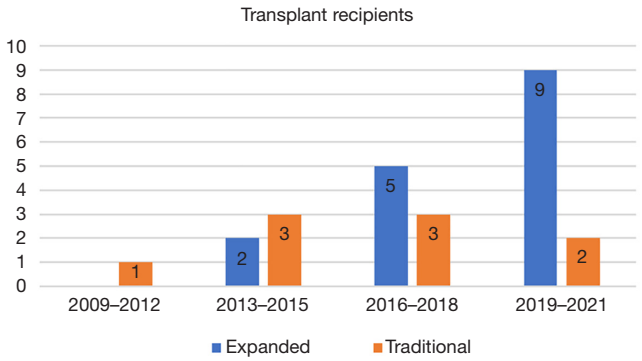

Figure 3 Trends of successful ECMO-bridge to transplant during study period. ECMO, extracorporeal membrane oxygenation.

Table 2 Baseline characteristics of included patients

Demographics	Overall cohort (N=45)	Met traditional candidate selection criteria (N=15)	Met expanded candidate selection criteria (N=30)	P
Age, years	50 [40, 56]	40 [45, 60]	53 [33, 61]	0.02*
HLA sensitization				0.88
None	7 (15.6)	2 (13.3)	5 (16.7)	
Low (cPRA 1–30%)	8 (17.8)	3 (20.0)	5 (16.7)	
Moderate (cPRA 31–65%)	11 (24.4)	3 (20.0)	8 (26.7)	
Highly (cPRA >65%)	14 (31.1)	6 (40.0)	8 (26.7)	
Unknown	5	1 (6.7)	4 (13.3)	
Male	29 (64.4)	10 (66.7)	19 (63.3)	1.00
BMI (kg/m^2)	25 [23, 30]	26 [24, 30]	25 [23, 31]	1.00
Underlying lung disease[†]				
Fibrotic lung disease	23 (51.1)	4 (26.7)	19 (63.3)	0.03*
CF or bronchiectasis	3 (6.7)	1 (6.7)	2 (6.7)	1.00
COPD/emphysema	5 (11.1)	2 (13.3)	3 (10.0)	1.00
Pulmonary hypertension	13 (28.9)	4 (26.7)	9 (30.0)	1.00
ARDS	5 (11.1)	2 (13.3)	3 (10.0)	1.00
Other	18 (40.0)	7 (46.7)	11 (36.7)	0.54
Co-morbidities				
CKD Stage 1-3	1 (2.2)	0	1 (3.3)	1.00
CKD > Stage 3	0	0	0	0.65
Obstructive coronary artery disease	5 (11.1)	1 (6.7)	4 (13.3)	1.00
Diabetes mellitus	5 (11.1)	2 (13.3)	3 (10.0)	1.00
Hypertension	9 (20.0)	3 (20.0)	6 (20.0)	1.00
Prior stroke	1 (2.2)	0	1 (3.3)	1.00
Secondary pulmonary hypertension[‡]	4/32 (12.5)	2/11 (18.2)	2/21 (9.5)	0.59

Table 2 (*continued*)

Table 2 (*continued*)

Demographics	Overall cohort (N=45)	Met traditional candidate selection criteria (N=15)	Met expanded candidate selection criteria (N=30)	P
Pre-Hospital Functional Status				0.18
Independent with ADL	39 (86.7)	15 (100.0)	24 (80.0)	
Dependent with ADL	6 (13.3)	0 (0.0)	6 (20.0)	
6MWD (meters)[§]	203 [29, 326]	265 [61, 346]	190 [40, 294]	0.40
Initial ECMO configuration				1.00
VV-ECMO	35 (77.8)	12 (80.0)	23 (76.7)	
Peripheral VA-ECMO	4 (8.9)	1 (6.7)	3 (10.0)	
Central VA-ECMO	6 (13.3)	2 (13.3)	4 (13.3)	
Had change in ECMO configuration	16 (35.6)	2 (13.3)	14 (46.7)	0.05*
Extubated while on ECMO	7 (15.6)	2 (13.3)	5 (16.7)	1.00
Listed for transplant	37 (82.2)			1.00
Prior to ECMO initiation	29 (64.4)	9 (60.0)	20 (67.7)	0.75
Following ECMO initiation	8 (17.8)	3 (20.0)	5 (16.7)	1.00
Never	8 (17.8)	3 (20.0)	5 (16.7)	0.75
Grafts listed	N=37	N=12	N=25	0.10
Lung alone	29 (78.4)	7 (58.3)	22 (88.0)	
Heart and lung	7 (18.9)	4 (33.3)	3 (12.0)	
Other multi-organ	1 (2.7)	1 (8.3)	0	
Graft received	N=25	N=9	N=16	0.57
Bilateral lung	19 (76.0)	6 (66.7)	13 (81.3)	
Combined heart-lung	5 (20.0)	2 (22.2)	3 (18.8)	
Other multi-organ	1 (4.0)	1 (11.1)	0	
Intra-operative transplant support	N=25	N=9	N=16	0.59
Cardiopulmonary bypass	17 (68.0)	6 (66.7)	11 (68.8)	
VA-ECMO	7 (28.0)	2 (22.2)	5 (31.3)	
VV-ECMO	1 (4.0)	1 (11.1)	0	
Post-operative support	N=25	N=9	N=16	0.01*
VV-ECMO	6 (24.0)	2 (22.2)	4 (25.0)	
VA-ECMO	8 (32.0)	0	8 (50.0)	
None	11 (44.0)	7 (77.8)	4 (25.0)	

Data are presented as n (%), median [IQR], unless otherwise indicated. *, denotes statistical significance. [†], 22 patients had more than 1 underlying lung disease; all patients with COPD/emphysema had more than 1 underlying lung disease. [‡], 4/32 (12.5%) primary pulmonary hypertension was not counted in denominator. [§], 6MWD at time of transplant listing. HLA, human leukocyte antigen; cPRA, calculated panel reactive antibodies; ADL, activities of daily living; ARDS, acute respiratory distress syndrome; BMI, body mass index; CF, cystic fibrosis; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; ECMO, extracorporeal membrane oxygenation; VV, venovenous; VA, venoarterial; 6MWD, 6-minute walk distance.

Table 3 Outcomes and survival of transplant recipients

Outcomes	Overall cohort (N=45)	Met Traditional Candidate selection criteria (N=15)	Met expanded candidate selection criteria (N=30)	P or OR (95% CI) and P, where applicable*
Received transplant	25 (55.6)	9 (60.0)	16 (53.3)	OR: 1.31 (0.37–4.62), P=0.67
Time from ECMO cannulation to transplant (days)	15 [5, 33]	15 [5, 33]	14 [6, 27]	0.91
1-year post transplant survival	23 (92.0)	8 (88.8)	15 (93.7)	OR: 0.53 (0.03–9.71), P=0.67
12-month 6MWD (m)	407 [267, 532]	410 [243, 453]	388 [276, 534]	0.68

Data are presented as n (%), median [IQR], unless otherwise indicated. *, the OR in this table are interpreted as "meeting traditional selection criteria increased/decreased the odds of outcome. OR, odds ratio; CI, confidence interval; ECMO, extracorporeal membrane oxygenation; 6MWD, 6-minute walk distance in meters.

due to septic shock.

The odds of requiring renal replacement therapy were significantly lower (OR: 0.15, CI: 0.02–1.28, P=0.05) in the traditional criteria cohort. There was no significant difference in being delisted or dying on the waitlist (OR: 0.58, CI: 0.13–2.58, P=0.47), hospital length of stay, or vascular and ECMO site complications between the two groups (*Table 4*). Extracranial bleeding of any severity was the most common complication. Intracranial bleeding occurred in 3 patients (7%) all from the expanded group and was fatal in one patient who was also the only patient to suffer from cerebral infarction (*Table 3*). Among the other two patients with intracranial bleeding, one had subdural hematoma without neurologic deficit, and one was with subarachnoid hemorrhage that was reported as small and resolved on follow up imaging in a week.

Among the expanded criteria cohort, 12 (40%) patients had >1 deviation from traditional criteria. Most common reasons for deviation were age >55 years [12 (40%)] and prehospitalization 6MWD <200 meters [12 (40%)], BMI >30 kg/m^2 [9 (30%)], and prednisone >10 mg/day [8 (27%)]. While this did not reach statistical significance possibly due to small sample size, patients who had >1 reason for deviation from traditional selection criteria appeared to be less likely to receive a transplant (OR: 0.46, CI: 0.12–1.78, P=0.26), had higher odds of being delisted or dying while on waitlist (OR: 2.65, CI: 0.64–10.97, P=0.17), and had higher odds of receiving renal replacement therapy (OR: 3.61, CI: 0.82–15.90, P=0.08).

Table 5 shows the outcomes of the 20 patients who were not transplanted, 4 patients died (1 patient had right ventricular dysfunction, 1 suffered from stroke and 2 patients developed hemorrhagic shock) while on the waitlist, and 8 patients were delisted. Most common reason for delisting was multiorgan failure 5 (62%) followed by human leukocyte antigen sensitization in 2 patients (25%) and 1 patient (13%) developed biventricular failure. Among the 8 patients who were never listed, 4 patients (3 with pulmonary fibrosis and 1 with hypersensitivity pneumonitis) died due to multiorgan failure prior to being listed. Remaining 4 patients were weaned off ECMO, 1 had underlying pulmonary hypertension and the three were with acute respiratory distress syndrome.

Discussion

In our two-center cohort, we found no difference in the odds of 1-year post-transplant survival, ECMO related complications, or hospital and ICU length of stay between those patients meeting traditional ECMO-BTT candidate selection criteria compared to those not. In our cohort, 36% of the patient population was not listed for transplant prior to ECMO cannulation, which is a strict ECMO-BTT exclusion criteria at some transplant centers (8,9).

Columbia Medical Center reported a 59% ECMO-BTT success rate with 88% one-year post transplant survival (9). ECMO-BTT was limited to patients who were already on transplant list and were able to participate in physical therapy. These patients were younger than our cohort with a median age of 44 (IQR 30–58 years), and non-obese with a median BMI of 22 kg/m^2 (IQR 17–27). Similarly, Hoetzenecker *et al.* reported a 1-year post ECMO-BTT survival of 70 %. ECMO was limited to patients who were already on the transplant list. This population was also younger with a lower BMI compared to our cohort (10). Benazzo *et al.* reported their 20-year (1998–2017) experience of ECMO-BTT with improved 1-year post

Table 4 Outcomes and clinical course

Outcomes	Overall cohort (N=45)	Met traditional candidate selection criteria (N=15)	Met expanded candidate selection criteria (N=30)	P or OR (95% CI) and P where applicable*
ECMO related complications†				
Renal replacement therapy	11 (24.4)	1 (6.7)	10 (33.3)	OR: 0.15 (0.02–1.28), P=0.05‡
CVA	1 (2.2)	0	1 (3.3)	N/A
Vascular complications	29 (64.4)	9 (60.0)	20 (67.7)	OR: 0.75 (0.20–2.70), P=0.66
Intracranial hemorrhage	3 (6.7)	0	3 (10.0)	
Extracranial hemorrhage	26 (57.8)	9 (60.0)	17 (56.7)	
Limb ischemia	0	0	0	
DVT	5 (11.1)	2 (13.3)	3 (10.0)	
PE	1 (2.2)	0	1 (3.3)	
ECMO site complications	18 (40.0)	9 (60.0)	9 (30.0)	OR: 3.48 (0.96–12.78), P =0.09
Bleeding	12 (26.7)	5 (33.3)	7 (23.3)	
Thrombosis	8 (17.8)	5 (33.3)	3 (10.0)	
Pseudoaneurysm	1 (2.2)	0	1 (3.3)	
Infection	3 (6.7)	0	3 (10.0)	
Reduction in EF to <45%	6 (13.3)	0	6 (20.0)	N/A
ICU length of stay in days	46 [20, 100]	62 [23.0, 92.0]	36.5 [15.5, 93]	0.46
Died in the ICU	18 (40.0)	5 (33.3)	13 (43.3)	OR: 0.65, P=0.52
Hospital length of stay in days	62 [32, 133]	82 [38.5, 300.5]	57 [29.5, 135.2]	0.59
Died in hospital	18 (40.0)	5 (33.3)	13 (43.3)	OR: 0.65, P=0.52
1-year post ECMO survival	27 (60.0)	10 (66.7)	17 (56.7)	OR: 0.77 (0.23–2.56), P=0.67

Data are presented as n (%), median [IQR], unless otherwise indicated. *, the OR in this table are interpreted as "meeting traditional selection criteria increased/decreased the odds of outcome; †, complications were recorded from ECMO-cannulation to ECMO-withdrawal. This does not include intraoperative complications; ‡, denotes statistical significance. OR, odds ratio; CI, confidence interval; ECMO, extracorporeal membrane oxygenation; CVA, cerebrovascular accident; DVT, deep venous thrombosis; PE, pulmonary embolism; EF, ejection fraction; ICU, intensive care unit.

transplant survival rate from 40% to 70%. But patients were younger with a median age varying from 31–36, and ECMO-BTT was not offered if patients were on mechanical ventilation for >7 days or had a BMI >30 kg/m^2 or severe frailty (11).

Our study results of ECMO-BTT rate of 56% (25 out of 45 patients) and 1-year post-transplant survival of 92% are encouraging and emphasize the importance of an individualized approach to patient selection for ECMO as a bridge therapy for those with end-stage lung diseases. Moreover, our study results corroborate the findings of Gan *et al.*: very sick patients can be bridged to transplant with ECMO (or mechanical ventilation) and have positive long-term outcomes (12).

Not all candidate selection criteria have a similar impact, and their effect on the outcomes may be cumulative. Our study did show that patients who had >1 reason for deviation from traditional criteria for ECMO-BTT or bridge to transplant decision had higher odds of being delisted or dying on the waitlist and were less likely to receive a transplant. However, our study was not powered to detect all clinically meaningful differences and the significance of one selection criteria compared to others could not be determined. Larger studies are needed to determine if any one criteria is a determinant of outcomes. Additionally, our results suggest that receiving a transplant or not may be the

Table 5 Outcomes of patients who did not receive transplant

Outcomes	Overall cohort (N=45)	Met traditional candidate selection criteria (N=15)	Met expanded candidate selection criteria (N=30)	P or OR (CI) and P where applicable*
Removed from the waitlist	8 (17.8)	1 (6.6)	7 (23.3)	OR: 0.58 (0.13–2.58), P=0.47[§]
Died prior to transplant	4 (8.9)	2 (13.3)	2 (6.6)	
Never listed	8 (17.8)	3 (20.0)	5 (16.7)	OR: 1.25 (0.26–6.12), P=0.78

Data are presented as n (%), unless otherwise indicated. *, the OR in this table are interpreted as "meeting traditional selection criteria increased/decreased the odds of outcome; [§], composite outcome of died on waitlist or delisted. OR, odds ratio; CI, confidence interval.

most important factor in determining the outcome. Deaths among those transplanted were rare events.

Despite significant progress in ECMO techniques and devices, patients receiving ECMO as a bridge therapy are at higher risk of complications due to their underlying diagnosis, pretransplant mechanical ventilation and ability to participate in physical therapy while on ECMO (13,14). Previous reports of complications in ECMO-BTT patients have varied from center to center and how the complications were reported. In our study we reported ECMO related complications during the bridging period and post-transplant for those patients who needed ECMO post operatively. Biscotti *et al.* and Tipograf *et al.* from Columbia medical center reported higher complication rates in patients who did not receive the transplant despite following strict selection criteria and delisting a high percentage of patients, suggestive of increased risk of complications in sicker patients (6,9). Hoetzenecker *et al.* reported an overall cerebrovascular rate of 4.2% and bleeding complications in 35% of ECMO-BTT patients (10). Benazzo *et al.* reported very few complications during the bridging period. However, majority of their patients remained on ECMO after receiving the transplant and had higher rates of complications including ECMO site complications (11). In our study complications occurred more in the expanded group as compared to traditional group that might be because those patients were older and sicker. Offering bridge therapy to such a sick patient population does come with the risk of complications but it brings the possibility of getting transplant without which death is certain for them. Emerging data do suggest that previously considered sick patients could be potential transplant recipients with use of ECMO as a bridge therapy (12,15,16) .

Due to the paucity of data and the advancing nature of ECMO-BTT, there is significant variability in the selection process and criteria to assess the eligibility of patients for ECMO-BTT or bridge to transplant decision (17). The strategy to apply strict selection criteria to offer ECMO may lead to better post-transplant survival (9,11). However, for those with end-stage cardiopulmonary disease who are excluded to receive ECMO based on certain criteria, death is certain. Issues related to the availability of resources, distribution of donor organs, and ethical concerns need broader discussion (17,18).

The limitations of our study include the inherent bias of a two-center, retrospective data collection, and analysis. The small cohort size limited some of the statistical comparisons; underpowered to detect differences between number of deviations. Outcomes may be limited by selection bias by who was selected to proceed to ECMO as a bridge to transplant versus recovery. Our study did not evaluate and report the details of transplant donors. Consideration for ECMO as bridge therapy is likely impacted by the availability of donors, but this is beyond the scope of the current study. Also, our study did not evaluate detailed descriptions of different ECMO modalities. Results of our study may not apply to other transplant centers due to different patient selection processes, availability of ECMO and donor organs, and individual center's transplant and ECMO experience. Also, the outcomes may be affected by local immunosuppression protocol, surgical and ECMO techniques.

This two-center study suggests that stringent selection criteria may limit the transplant opportunity for patients who may otherwise have favorable outcomes with ECMO-BTT. Future multicenter, prospective studies are needed to evaluate the impact of individual selection criteria, develop better prediction tools, and prove non-inferiority with expanded selection criteria.

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Footnote

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-13/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-13/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Mayo Clinic Institutional Review Board (IRB No. 21-010789). All included patients, or their legally authorized representatives had provided a prior research authorization consenting to their already existing medical records to be used for research purposes.

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