A decade of interfacility extracorporeal membrane oxygenation transport

Yuliya Tipograf, MD, a Peter Liou, MD, b Roy Oommen, MD, b Cara Agerstrand, MD, c Darryl Abrams, MD, c Daniel Brodie, MD, c and Matthew Bacchetta, MD, MBA a

ABSTRACT

Objective: Extracorporeal membrane oxygenation (ECMO) is used to provide support for patients with cardiopulmonary failure. Best available medical management often fails in these patients and referring hospitals have no further recourse for escalating care apart from transfer to a tertiary facility. In severely unstable patients, the only option might be to use ECMO to facilitate safe transport. This study aimed to examine the characteristics and outcomes of patients transported while receiving ECMO.

Methods: Statistical analysis was performed on data gathered retrospectively from the electronic medical records of adult patients transported while receiving ECMO to Columbia University Medical Center between January 1, 2008, and December 31, 2017.

Results: Two hundred sixty five adult patients were safely transported while receiving ECMO with no transport-related complications that adversely affected outcomes. Transport distance ranged from 0.2 to 7084 miles with a median distance of 16.9 miles. One hundred eighty-three (69%) received on veno-venous, 72 (27%) veno-arterial, and 10 (3.8%) veno-venous arterial or veno-arterial venous configurations. Two hundred ten (79%) cannulations were performed at our institution at the referring hospital. Sixty-four percent of patients transported while receiving ECMO survived to hospital discharge.

Conclusions: Interfacility transport during ECMO was shown to be safe and effective with minimal complications and favorable outcomes when performed at an experienced referral center using stringent protocols. (J Thorac Cardiovasc Surg 2019;157:1696-706)

The use of extracorporeal membrane oxygenation (ECMO) is increasing in patients with refractory cardiac or pulmonary failure for whom optimal medical management fails.1-3 High-volume ECMO centers are typically best equipped to provide resources critical to the initiation, transport, and management of patients requiring mechanical support.4 In certain cases, when referring facilities have no further recourse for escalation of care in an unstable patient, apart from transfer to a tertiary facility,
the only option might be to use ECMO to facilitate a safe transfer. Over the past decade, our institution has evolved to become an active referral center with a robust transport program because of advances in mobile mechanical support devices as well as a consolidation of dedicated resources to our ECMO units. This study aimed to examine the characteristics and outcomes of patients transported by our institution while receiving ECMO over the past decade.

**METHODS**

**Program Evolution**

Columbia University Medical Center (CUMC) program’s structured intake process has been a vital component in its role as a high-volume referral center. Critical to the program’s development has been a dedicated closed intensive care unit with a multidisciplinary team consisting of surgical and critical care medicine physicians, critical care nurses, acute care nurse practitioners, perfusionists, physical therapists, respiratory therapists, occupational therapists, speech therapists, and pharmacists experienced in managing patients with cardiopulmonary failure, from acute respiratory distress syndrome to end-stage cardiac and lung disease.

The ECMO referral and transport process has been well described by Biscotti and colleagues in 2015. Selection criteria for ECMO transport candidates have evolved significantly since our institution’s first published experience in 2011 (Table 1). Criteria are continually revisited with the acquisition of experience in this process. The referral decision process remains dynamic and includes constant reassessment of the patient’s clinical status. The same criteria are applied if the patient is cannulated at the referring institution.

With respect to extremes of age, the adult ECMO team transported patients older than 14 years while maintaining an upper limit of 77 years of age. There were some exceptions to patients who required prolonged mechanical ventilation >7 days. These patients were younger and healthier at baseline with minimal ventilator settings earlier in their course. There were a handful of people with malignancies who were accepted for transport primarily on the basis of favorable prognoses as assessed by the referring physicians and our team. Patients with cardiomyopathy or cardiogenic shock were considered for temporary left ventricular assist devices, destination therapy left ventricular assist devices, and heart transplantation. There were no ECMO transports for lung transplantation patients unless the patient was already listed at CUMC. Hemodialysis is not an exclusion criterion. There were no patients who had been receiving ECMO before and weaned off by referring institutions.

Since the expansion of the selection criteria, the team has accepted and transported patients with body mass index (BMI) >50, patients older than 65 years of age, patients with traumatic brain injury and intracranial pathology, post-transplant patients with significant immunosuppression, and patients whose religious beliefs precluded them from receiving blood products, with acceptable morbidity and mortality in the overall cohort.

**Table 1. Criteria for ECMO transport and cannulation**

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
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</thead>
<tbody>
<tr>
<td>Reversible hypoxemic respiratory failure with PaO2/FiO2 &lt; 100 and Pplat &gt; 30 cm H2O</td>
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</tr>
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<td>Reversible hypercapnic respiratory failure with pH &lt; 7.15 despite failed conventional management</td>
<td>Advanced age &gt; 70 years old</td>
</tr>
<tr>
<td>Bridge to lung transplantation listed at our center</td>
<td>Documented irreversible brain injury</td>
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<td>Irreversible multisystem organ failure</td>
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<td>Limited vascular access because of skeletal deformities</td>
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**Mobile ECMO Team**

When a patient has been accepted for transfer with ECMO, the mobile ECMO team is deployed. The referring hospital must grant the cannulating surgeon temporary emergency privileges and consent from the patient or their surrogate. The ground transport team consists of 2 critical care paramedics, a cardiothoracic surgeon, a surgical ECMO fellow, and a perfusionist. ECMO personnel are expected to direct all aspects of the patient’s care during transport. These highly trained teams must be prepared for any issues involved in the transfer of a critically ill patient receiving ECMO. Upon arrival, the referring facility is responsible for providing a bedside ultrasound and a surgical tray. A mobile enterprise point-of-care Blood Analysis System (Siemens USA, Washington, DC) is used to obtain blood gases and biochemical analyses on all transports.

CUMC has limited its use of single-site cannulation for veno-venous (VV) ECMO because of unreliable access to imaging modalities including fluoroscopy and transesophageal echocardiography at referral facilities. Our preferred approach is percutaneous dual-site cannulation of the right femoral vein and right internal jugular vein using the Biomedicus (Medtronic, Brooklyn Park, Minn) venous drainage cannula and Elongated One-Piece Arterial (Medtronic) reinfusion cannula, respectively. For veno-arterial cannulation, the Biomedicus venous drainage (Medtronic) and arterial reinfusion cannulas are placed in the femoral vessels. Central to our simplified ECMO circuit is the highly mobile Cardiohelp (Maquet, Rastatt, Germany) support system, which has been used in transport and in-hospital ECMO cannulation since 2014. Changes to the circuit are performed as needed to provide more appropriate physiologic support for the patient. This usually consisted of the addition of an arterial limb to convert from VV to veno-arterial venous configuration. Procedures on patients were performed almost exclusively at CUMC with the exception of emergencies necessitating immediate intervention.

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**Abbreviations and Acronyms**

- APACHE = Acute Physiology and Chronic Health Evaluation
- BMI = body mass index
- CUMC = Columbia University Medical Center
- ECMO = extracorporeal membrane oxygenation
- IQR = interquartile range
- VV = veno-venous

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**Acute Physiology and Chronic Health Evaluation**

- PaO2:FiO2 = Partial pressure of arterial oxygen to fraction of inspired oxygen ratio
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Statistical Methods

Data were collected retrospectively from the electronic medical record of adult patients who were transported by our institution while receiving ECMO from January 2008 to December 2017. The study population was divided into cohorts on the basis of timing of transport (era A and era B) and etiology of organ failure (respiratory failure and cardiogenic shock). The era A cohort consists of the first 100 patients transported by our institution from September 2008 to January 2014 as described by Biscotti and colleagues. Era B is comprised of the subsequent 165 patients transported from February 2014 to December 2017. Categorical variables were reported as frequency and percentage. Continuous variables were presented as mean and standard deviation or median and interquartile range (IQR) depending on the normality of distribution using the Shapiro–Wilk test. Univariate analysis for categorical variables was performed using the Pearson $\chi^2$ test and continuous variables were analyzed using independent samples $t$ test or Mann–Whitney $U$ tests where appropriate. Tests were 2-sided with statistical significance defined as a $P$ value $< .05$. Survival analysis was compared across cohorts using the Kaplan–Meier method and log rank test. Statistical analysis was performed using SPSS version 24.0 (IBM Corp, Armonk, NY). This study was approved by the Columbia University institutional review board.

RESULTS

Patient Characteristics

Two hundred sixty-five patients were transported while receiving ECMO by our institution from January 2008 to December 2017. The median age was 42.2 (IQR, 28-56) years and 61.1% were male. Two hundred one (76%) of the patients referred for ECMO had respiratory failure as their primary etiology and 64 (24%) were referred for ECMO because of cardiogenic shock (Table 2). Baseline patient characteristics of patients in era A (n = 100) and era B (n = 165) cohorts are shown in Table 2. Era B cohort patients had a greater BMI compared with era A (28.8 [IQR, 24.4-34.6] vs 27.2 [IQR, 23.0-32.6]; $P = .02$) but lower APACHE II scores (25.3 ± 8.5 vs 29.2 ± 6; $P < .01$). Characteristics of respiratory failure patients stratified by era are described in Table 3. An ECMO referral database was established in 2015 to monitor referrals and track referrals to ECMO.
outcomes. From June 2015 to Dec 2017, 474 ECMO referrals were received, 76 (16%) were accepted for transport with ECMO, 48 (10%) accepted for transport without ECMO, and 350 (76%) were rejected. Monthly referral outcomes are shown in Figure 1.

Cannulation

Two hundred ten (79%) patients were cannulated at the bedside by the CUMC ECMO team at the referring facility, whereas the remaining 55 (21%) were cannulated at the referral center. All patients were successfully cannulated at the referring facility and received mechanical ventilation for a mean duration of 2.2 days before transport by our team. There was a significant reduction in precannulation ventilator duration from era A to era B (IQR, 0-5 vs 0-3 days; \( P = .02 \)). One hundred eighty-three (69%) patients had a VV configuration, 72 (27%) had a veno-arterial configuration, and 10 (3.8%) had a VV arterial or veno-arterial venous ECMO with no significant difference in configurations used between era A and B (\( P = .09 \)). Duration of ECMO support was 8 (IQR, 5-14) days and there was a significant increase in days of ECMO from era A to era B (7 [IQR, 4-12] vs 9 [IQR, 5-15]; \( P = .01 \); Table 2).

Transport

Ambulance was the primary mode of transport in 259 (98%) cases, whereas 6 transports used fixed-wing aircraft. Median distance traveled was 16.9 (IQR, 8.3-32.6) miles. There was no statistically significant difference in transport distance between cohorts. There were 2 complications during transport of 265 patients receiving ECMO. During ground transport, a pump console failure event required hand cranking until power was restored. An episode of oxygenator decoupling occurred when unsecured medical equipment was dislodged and activated the system’s oxygenator release latch. This was quickly corrected by reinserting the oxygenator into its housing with minimal

### Table 3. Characteristics and outcomes of respiratory failure patients transported on ECMO to CUMC stratified according to era

<table>
<thead>
<tr>
<th>Era A (n = 82)</th>
<th>Era B (n = 119)</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>35 (26-48)</td>
<td>39 (27-51)</td>
</tr>
<tr>
<td>Male sex</td>
<td>44 (54)</td>
<td>74 (62)</td>
</tr>
<tr>
<td>BMI</td>
<td>27.1 (22.2-32.1)</td>
<td>28.6 (24.3-34.7)</td>
</tr>
<tr>
<td>APACHE II score</td>
<td>29.2 ± 6.0</td>
<td>23.5 ± 8.9</td>
</tr>
<tr>
<td>Mechanical ventilation to ECMO (d)</td>
<td>2 (1-6)</td>
<td>1 (0-3)</td>
</tr>
<tr>
<td>Duration of ECMO run (d)</td>
<td>8 (5-12)</td>
<td>10 (6-17)</td>
</tr>
<tr>
<td>Cannulated by CUMC</td>
<td>77 (94)</td>
<td>113 (95)</td>
</tr>
<tr>
<td>Transport distance (miles)</td>
<td>16.4 (8.0-38.3)</td>
<td>15.4 (7.9-31.9)</td>
</tr>
<tr>
<td>Survival to decannulation (%)</td>
<td>83</td>
<td>82</td>
</tr>
<tr>
<td>Survival to hospital discharge (%)</td>
<td>68</td>
<td>72</td>
</tr>
</tbody>
</table>

Pre-ECMO

| PaO2:FiO2 | 56.1 ± 14.1 | 69.2 ± 48.9 | .33 |
| pH         | 7.27 ± 0.15 | 7.20 ± 0.16 | .02 |
| pCO2       | 59.7 ± 32.1 | 62.7 ± 30.0 | .52 |

On-ECMO*

| pH | 7.39 ± 0.12 | 7.49 ± 0.10 | .62 |
| PaO2 | 136.0 ± 103.4 | 144.5 ± 94 | .55 |
| pCO2 | 36.8 ± 8.5 | 35.5 ± 10.2 | .33 |

Values are n (%), mean (± standard deviation) or median (interquartile range). BMI, Body mass index; APACHE, Acute Physiology and Chronic Health Evaluation; ECMO, extracorporeal membrane oxygenation; CUMC, Columbia University Medical Center; PaO2:FIO2, partial pressure of arterial oxygen to fraction of inspired oxygen ratio; pCO2, partial pressure of carbon dioxide; PaO2, partial pressure of arterial oxygen. *First arterial blood gas after ECMO initiation.
interruption in support. Throughout the 265 transports, there was no transport-related morbidity or mortality.

Survival
All patients survived transportation while receiving ECMO from the referring hospitals to CUMC intensive care units. Overall survival to decannulation was 77%, and 64% of patients survived to hospital discharge. Rates of survival to discharge remained stable as the annual frequency of transports increased (Figure 2). There was no statistically significant difference in the rate of survival to discharge rates between era A and B cohorts (P = .48; Table 2). Additionally, Kaplan–Meier survival curves did not show a significant difference in in-hospital length of stay (log rank test P = .10; Figure 3). Patients who were cannulated at CUMC had higher rates of survival to discharge (72%) than those cannulated by the referring facility (44%; P < .01); however, patients cannulated at the referring institution had higher mean APACHE II scores (30.4 ± 4.6 vs 25.9 ± 8.2; P < .01; Table 2). Cannulating institution had a significant effect on the rate of survival after stratifying according to primary etiology. When cannulated by the CUMC team, patients in the cardiogenic shock cohort had survival to discharge rates of 65% (vs outside hospital 39%; P = .05) and the respiratory failure cohort had a survival to discharge rate of 73% (vs outside hospital 45%; P = .05).

Cardiogenic Shock Versus Respiratory Failure
Patients with respiratory failure continued to receive ECMO for a period of 10 (IQR, 5-14) days versus 5 (IQR 3-12) days for cardiogenic shock patients (P < .01; Table 4). Compared with patients with respiratory failure, patients with cardiogenic shock were significantly older (55 years vs 37 years; P < .01), had higher APACHE II scores (29.8 vs 25.8; P < .01), had fewer ventilator days before cannulation (0 days vs 1 day; P < .01), were less likely to be cannulated at our institution (31% vs 94%; P < .01), and had worse outcomes (survival to decannulation, 64% vs 81%; P < .01, and survival to discharge, 47% vs 72%; P < .01, respectively). Kaplan–Meier estimates showed a significant difference in survival between patients with respiratory and cardiac etiologies (log rank test P = .01; Figure 4). Median hospital length of stay for patients with respiratory failure was 88 days, versus 45 days for those with cardiogenic shock. There was no significant difference in pre-ECMO blood gas measurements between patients with respiratory failure and those with cardiogenic shock (Table 4).

DISCUSSION
Experience at CUMC has shown that a tertiary care referral center can develop an interfacility ECMO transport system that is safe and efficient with favorable outcomes. Recent studies have shown that patients cannulated and transported by mobile ECMO teams have outcomes comparable to those of patients cannulated at the referral center.9,10 Centers with >30 adult ECMO cases per year have produced lower mortality rates than centers with less ECMO volume, potentially making them appropriate candidates for the development of interfacility ECMO transport.4,10 Survival outcomes of patients transported by our facility are comparable with other high-volume university-affiliated tertiary care mobile ECMO programs and surpass those from the international registry of the Extracorporeal Life Support Organization.3,9,11-13 The current Extracorporeal Life Support Organization registry encompasses 15,686 adult respiratory cases and 15,201 adult cardiac cases with rates of survival to discharge of 59% and 41%, respectively, in contrast to our rates of 72% and 47%, although comparable risk stratification is not available.3
From its inception in 2008, the CUMC mobile ECMO transport program has seen an annual increase in transports with a peak of 45 patients in 2016 (Figure 5). Salna and colleagues highlight that our center’s infrastructure has allowed for survival outcomes to be maintained in periods of high-volume transport surges, particularly during flu season.14 Our transport trends have also shown a steady increase in patients’ BMI (Figure 5). A recent study from our institution of 97 patients with BMI >30 has shown that morbidly obese patients can be safely transported while receiving ECMO.15,16

Interfacility ECMO transports were defined as “primary transports” when the mobile ECMO team performed cannulation at the referring facility and then transported the patient to the home institution. “Secondary transports” consisted of patients who required transport to another facility but were already receiving ECMO support, thus not requiring cannulation by the mobile ECMO team. All 265 patients in this study were cannulated at the referring hospital and transferred during ECMO. Seventy-nine percent of patients in this study were primary transports, and cannulated by our team. In contrast, only 30% of patients were transported while receiving ECMO in a report of 133 patients by Ranney and colleagues, of which 53% were cannulated by physicians at the referring facility.11 No APACHE or Sequential Organ Failure Assessment Score data were included in their report so it is difficult to draw comparisons according to severity of illness. Bryner and colleagues evaluated 220 patients who were receiving ECMO who were transported by their team. Fourteen percent (n = 31) of patients were cannulated by outside physicians with no significant difference in survival between patients cannulated by the mobile ECMO team and those cannulated by the referring hospital.13 The mobile ECMO team from Karolinska University Hospital performed 82% of primary transports in a study population

### TABLE 4. Characteristics and outcomes of patients transported on ECMO to CUMC stratified according to etiology

<table>
<thead>
<tr>
<th></th>
<th>Respiratory failure (n = 201)</th>
<th>Cardiogenic shock (n = 64)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>37 (27-50)</td>
<td>55 (44-61)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Male sex</td>
<td>118 (59)</td>
<td>44 (68)</td>
<td>.15</td>
</tr>
<tr>
<td>BMI</td>
<td>28.0 (23.3-33.8)</td>
<td>29.5 (25.1-34.3)</td>
<td>.20</td>
</tr>
<tr>
<td>APACHE II score</td>
<td>25.8 ± 8.3</td>
<td>29.8 ± 5.1</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Mechanical ventilation to ECMO (d)</td>
<td>1 (0-4)</td>
<td>0 (0-1)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Duration of ECMO run (d)</td>
<td>10 (5-14)</td>
<td>5 (3-12)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Cannulated by CUMC</td>
<td>190 (94.5)</td>
<td>20 (31.3)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Transport distance (miles)</td>
<td>16.1 (8.0-32.4)</td>
<td>23.1 (15.4-46.1)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Survival to decannulation (%)</td>
<td>81</td>
<td>64</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Survival to hospital discharge (%)</td>
<td>72</td>
<td>47</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Pre-ECMO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PaO2:FiO2</td>
<td>64 ± 39.4</td>
<td>69.6 ± 35.6</td>
<td>.67</td>
</tr>
<tr>
<td>pH</td>
<td>7.22 ± 0.15</td>
<td>7.12 ± 0.13</td>
<td>.06</td>
</tr>
<tr>
<td>pCO2</td>
<td>61.6 ± 30.7</td>
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<td></td>
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<td>On-ECMO*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>7.39 ± 0.11</td>
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</tr>
<tr>
<td>PaO2</td>
<td>140.9 ± 97.8</td>
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<td></td>
</tr>
<tr>
<td>pCO2</td>
<td>36.0 ± 9.5</td>
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![Figure 4](image-url)  
**FIGURE 4.** Kaplan–Meier estimate of patient survival transported on ECMO with cardiogenic versus respiratory etiology.
consisting of 343 pediatric and adult patients. A unique feature of the Karolinska program is the particularly long distance covered by their transport team for each transfer. Unlike our institution that relies heavily on designated critical care ambulances, most of their transports used fixed wing aircraft (59%) with an additional 5% transported by helicopter and only 36% by ground transport,7 which likely reflects geographical differences.

Patients referred for ECMO with cardiogenic shock had significantly poorer outcomes than those with respiratory failure (Figures 4 and 6, Table 4). Similar findings were noted by Beurtheret and colleagues in patients transported while receiving ECMO for cardiogenic shock. However, their ECMO transport survival rates were comparable with those of patients cannulated within their hospital for similar indications.17 Most of our cardiogenic shock patients were secondary transports, which is partially attributed to the large number of postcardiotomy patients who were cannulated perioperatively. Patients in cardiogenic shock were found to have higher APACHE II scores, which might explain why these patients were more likely to be cannulated at the referring facility rather than delaying ECMO until team arrival.

Adverse events during transport emphasize the need for highly trained professionals who can maintain adequate mechanical support and patient safety in resource-poor settings. Complications encountered during our transport series, which were extremely rare, had no effect on patient outcomes. Each incident was reviewed, analyzed, and safeguards were implemented to prevent their recurrence.

FIGURE 5. Trends in interfacility ECMO transport at Columbia University Medical Center 2008 to 2017. APACHE, Acute Physiology and Chronic Health Evaluation; BMI, body mass index.

FIGURE 6. Interfacility transport on extracorporeal membrane oxygenation is safe and effective with minimal complications when performed at an experienced referral center using stringent protocols. VA, Veno-arterial; VAV, veno-arterial venous; VV, veno-venous; ELSO, Extracorporeal Life Support Organization; CUMC, Columbia University Medical Center.
Experience from other major ECMO centers report similar issues during transport including failure of various circuit components, oxygenator thrombosis, unreliable access to electricity or insufficient battery duration, and inadvertent decannulation. It is important to note that these complications can also occur at the ECMO center independent of ECMO transport but can be minimized with proper training and awareness. Certain conditions are inextricably linked to the mode of patient transport and remain difficult to control. Ground transports are limited by the amount of oxygen and electrical power that can be supplied whereas traffic places the team at risk of motor vehicle accidents and might increase total transport time. In aeromedical evacuations, hemodynamics, barometric pressure, humidity, temperature, and oxygenation can change quickly with altitude. Despite these challenges, mortality during transport remains a rare occurrence and most adverse events remain inconsequential to patient outcome. Only 2 deaths are reported in a series of 452 ECMO transports from 8 studies. Both of these fatalities resulted from unexpected cardiac failure and were not attributed to events in transport.

Limitation
This observational, retrospective study has methodological limitations that are inherent to post hoc data collection and analysis. Patients who died before mobile ECMO team arrival were not included in the study. This can be attributed to varying thresholds of referring facilities to contact an ECMO center for prompt evaluation that suggests the need for the implementation of guidelines for referrals to regional centers. Survival analysis beyond hospital discharge was limited because most patients sought to follow-up at facilities closer to their original referring centers. Outcomes reported in this study were from a single center with established protocols and a high volume of intrainstitutional ECMO. These findings might not be applicable to new programs with low ECMO volume and a limited referral base. Although trends in survival appear favorable, these results come from retrospective single-institution studies. Multicenter, prospective randomized controlled trials might be better suited to evaluate the role of ECMO in interfacility transport.

CONCLUSIONS
The process of evaluating, transporting, and managing patients requiring ECMO entails a considerable allocation of resources. Being respectful of the resource demands and potential efficacy of ECMO transport, as well as the criteria for initiating ECMO, we only accepted 16% of ECMO referrals at our center for cannulation and transfer. Because of the high acuity and cost of ECMO as a life-saving measure, future consideration should be given to the development of standardized thresholds and guidelines for referral to regional high-volume ECMO centers and cost analysis for optimal resource allocation. CUMC’s experience as an ECMO referral center has required the development of a prompt and rigorous selection process to identify patients who will most likely benefit from a timely and safe transfer. As such, this study encompasses the largest cohort of adult ECMO transports to date and provides the basis for future analysis. The transport infrastructure implemented by our facility has shown that ECMO transport is safe and effective with outcomes comparable with other high-volume institutions and for patients who receive ECMO within our own institution.

Conflict of Interest Statement
Dr Brodie is currently the co-chair of the Trial Steering Committee for the Extracorporeal Carbon Dioxide Removal with the Hemolung Respiratory Assist System for Mechanical Ventilation Avoidance During Acute Exacerbation of COPD (VENT-AVOID) trial sponsored by ALung Technologies; he was previously on the medical advisory board of ALung Technologies and Kadence. All compensation for these activities is paid to Columbia...
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References

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Discussion

Dr Christopher Sciortino (Pittsburgh, Pa). Thank you for an excellent presentation on this important topic. This is a phenomenal report, and a nice addition to what your group has been reporting for several years. The first question is, have you a 16% ECMO transport rate and about a 10% non-ECMO transport rate. What is the incidence of declining ECMO or transport once your team arrives at an outside hospital?

Dr Yuliya Tipograf (New York, NY). From reviewing the data, it has only been a handful of times, less than five. Dr Sciortino. So that speaks to how good your process of evaluation is over the phone. I assume that most of these places are coming from non-Columbia–based hospitals?

Dr Tipograf. Ninety-eight percent of our referrals are from non-NYP facilities.

Dr Sciortino. Have you mapped the distribution of referring centers over time to see if you are getting increased referrals from a core number of centers versus referrals from new centers because you offer this type of service?

Dr Tipograf. If I were to make one of those maps, it would be difficult to fit in all of our referrals because we have had so many transports from different locations, but the majority of our transports come from the tri-state area, and the majority are ground transports within 3 to 4 hours’ driving distance. However, we have had a lot of transports that we have also done by air.

We have developed relationships with certain facilities that are frequent referrers, and I believe that’s because we have a system that helps not only provide an ECMO consult but also a critical care consult.

Dr Sciortino. I think that’s an important point.

The next question is, have you done anything to educate your referring centers and other centers as to when to call? You are getting patients a little bit earlier it seems in the era B. Is that because of success or are you actively educating the region who refers when to call, because obviously it’s better to go on ECMO before you are totally in extremis and educating probably helps with success.
Dr Tipograf. We have tried to educate centers when we have turned down referrals, we always give them a reason why. It seems that the following time they call back, it’s more of an appropriate consult. Clearly, we have been able to incorporate an educational component into the referral process.

Dr Sciortino. Absolutely. Sometimes you have to say no, which can result in better education and more appropriate consultations.

Once the patients are decannulated from ECMO, do they stay with you or do you ever transport them back to the referring hospital, for example, once they are out of the ICU or safe to be back in the level of care from which they came?

Dr Tipograf. It happens very infrequently. In the past year we have only had 1 patient, this was a peripartum patient, who wanted to return to the outside facility to be closer to their child.

Dr Sciortino. Have you found any particular challenges in getting emergency privileges, especially new centers in the middle of the night? We sometimes have issues with this in terms of cannulating at a non-network hospital; particularly obtaining timely emergency privileges.

Dr Tipograf. We have a very good administrator who is able to coordinate obtaining emergency hospital privileges. So, no, it really hasn’t been a major issue. The critical care team at the referring hospitals is usually very good about getting us privileges as well.

Dr Sciortino. Have you run into issues with obtaining insurance authorization to bring patients to your hospital?

Dr Tipograf. There have been certain episodes with patients who were already cannulated, where there have been reimbursement issues. In general, if they are in the New York region, we have been able to manage that process.

Dr Sciortino. Do you think that the patients for whom you go out to put on ECMO are at the same level of illness as those patients cannulated at your own institution, or do you think because you are transporting them you might be putting patients on earlier?

Dr Tipograf. That’s a possibility. In our hospital we don’t put on as many patients, especially for respiratory failures, because we have a team that has a lot of additional resources; for example, nitric oxide and proning beds.

Dr Sciortino. We don’t have information on what percentage of the respiratory failures were prone, on nitric, et cetera, from the outside places. What we see is that there are outside institutions that do not have the resources for such treatments, and so it’s easier to put them on ECMO and either transport them or transport them early and put them on if they need it.

Dr Tipograf. We have some analysis of the rescue treatments, it is recored in our referral database. It seems that most of the facilities that refer to us have employed some aspect of ARDS management protocols.

Dr Sciortino. Yes, that’s exactly right, all the more important for you and your team to have this system. Congratulations.

Dr Shaf Keshavjee (Toronto, Ontario, Canada). That was a very good discussion, because you clearly put your finger on a lot of the issues right now that we can do ECMO better. Some of the more important challenges are these sort of things, like how do you turn someone down. And the question you asked about how often do you turn someone down once you get to the site, I think that’s an important thing to learn, because you do your best to screen them over the phone, but sometimes when you arrive I think you also have to have the idea that, you know what, this wasn’t as advertised and we’re not going to do it. And oftentimes the team we send out basically goes out to go cannulate and bring back and they don’t really make a further assessment. So we have started working on that as well.

I had one question. What do you do about patients who have been put on ECMO and have been on for a while somewhere else and then they call you and say, well, you know, our perfusionists are running out and can you take this patient? Do you still take patients?

Dr Tipograf. We will accept very selective cases but generally we are reluctant to take patients who have been on ECMO for an extended period time from an outside facility.

Dr Keshavjee. But you do accept them?

Dr Tipograf. We do. They are not as likely to get accepted, but we still do.

Dr Keshavjee. It’s a challenge.

Dr Zachary N. Kon (New York, NY). Could you touch a little bit more on your algorithm or some kind of granular thought process of who you actually put on when you go out? And I actually would ask the question the opposite of how Chris asked it. Do you find that the patients you go out and see are actually sicker?

Dr Tipograf. Yes.

Dr Kon. And the reason I ask that is because your survival to decannulation was about 10 to 15 points higher than your survival discharge, which usually demonstrates that the patients die of something other than their pulmonary process and usually is, as Dr Keshavjee said, a function of you were kind of told one story and then find out, oh, by the way, they have terminal cancer.

Dr Tipograf. The case is almost always that the patients are significantly sicker. Sometimes it just depends
who is calling our center and sometimes facilities are overwhelmed by the extent of severity of illness. Once the transfer center is activated, they reach out to one of the nurse practitioners in our respiratory failure unit. We have a highly protocolized algorithm for our intake process, and other optimization strategies are offered at that time. It’s a very dynamic process and we check in constantly unless we feel the patient needs to be cannulated and transferred immediately, and in that case we can mobilize within 30 minutes depending on how far away the facility is. The process is very structured. The Biscotti paper provides a lot of those details.

There have been a handful of cases where we have gone and the patient is actually doing much better than we thought. Once we see the patient we can re-evaluate him or her, and we have had to say no and that we won’t put this patient on ECMO. Usually in that case we transfer the patient to our hospital, just not on ECMO.