Management of Surge in Extracorporeal Membrane Oxygenation Transport

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Background. **Transporting patients receiving extracorporeal membrane oxygenation (ECMO) support is safe and reliable with a dedicated program and established management protocols. As our program has grown, our teams have had to adapt to manage surges in transport volume while maintaining patient safety. We assessed the outcomes at peak use of our ECMO transport services during surges.**

Methods. **We conducted a single-center retrospective review of all patients transported to our institution while supported with ECMO from September 2008 to September 2016. Survival to discharge was the primary outcome. Surge patients were defined as those transported during months with at least 8 transports or patients transported within 24 hours of another patient in nonsurge months.**

Results. **From 2008 to 2016, 222 patients were transported to our institution while supported with ECMO. Baseline characteristics and indices of disease severity were comparable between surge and nonsurge patients. Of the 84 patients transported during surges, 59 surge patients (70%) survived to hospital discharge vs 86 (63%) of nonsurge patients ($p = 0.31$). Multivariable logistic regression showed that age and APACHE II (Acute Physiology and Chronic Health Evaluation) severity index score were predictors of in-hospital death ($p < 0.05$), but transportation during a surge was not (odds ratio, 0.91; 95% confidence interval, 0.46 to 1.80; $p = 0.79$).**

Conclusions. **Patient safety and clinical outcomes can be maintained during surges in ECMO transport volume if the ECMO program has developed plans for handling transient increases in volume and considers staff fatigue and burnout. Standardizing interhospital communication, patient selection, and management protocols are critical to maintaining quality of care.**

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Patients with refractory cardiac or respiratory failure may be stabilized with extracorporeal membrane oxygenation (ECMO) and subsequently transported to tertiary centers for advanced care or transplantation. Although ECMO use is limited to specialized centers, interfacility transport of patients receiving ECMO is becoming more common. At the time of this publication, however, only 4 centers have reported a total of more than 100 transports [1–4].

We previously published our experience with 100 patients transported while supported with ECMO [2], and as our program has grown, we have had to adapt to periods of exceptionally high volume while ensuring patient safety and excellent outcomes. Although institutional resource allocation and interfacility communication are vital to a successful ECMO transport program, in these instances, patient triage, interfacility and intrafacility communication, and strategic resource allocation become paramount. This study evaluates whether surges in ECMO transport volume affected patient outcomes and describes the lessons our institution has learned to safely manage these periods of high volume.

Patients and Methods

The Columbia University Institutional Review Board approved this study, and patient consent was waived due to its retrospective nature. Data were collected retrospectively from our institution's electronic medical record. From January 2008 to September 2016, 222 adult patients were transported to our institution while receiving venovenous (VV) or venoarterial (VA) ECMO. Both types were examined because of their relevance to referring hospitals and consistency with prior literature. There were 84 patients transported during surges, defined as patients transported during months in which

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there were at least 8 such patient transports (equating to 2 SDs above the mean number of transported patients per month), or patients transported within 24 hours of another patient in a nonsurge month. We made an a priori decision to limit our analysis to transport patients alone, rather than including all institutional ECMO patients, owing to differences in acuity between the populations. Most patients cannulated at our institution are awaiting lung transplantation.

Intake Protocol

Patients are referred for ECMO from other institutions through an institution-wide transfer center. The transfer center nurse connects the referring physician with one of the designated ECMO nurse practitioners in the intensive care unit (ICU), who completes a standardized intake form. This is then reviewed with the on-call ECMO intensivist, surgeon, and the ICU attending to determine whether a patient meets criteria for ECMO transport. Patients who in arrest or are in cardiogenic shock must demonstrate at least partial recovery of neurologic function, clinically, before transport acceptance. If accepted, the transfer center nurse will obtain emergency privileges for the ECMO surgeon (several surgeons also have licenses in nearby states), fax an ECMO checklist to the referring hospital, secure an ECMO-capable ambulance, and request an appropriate bed for the incoming patient. Before leaving for the other hospital, the transport team completes predeparture checklists.

Patient Selection

Patients are evaluated case-by-case, and selection criteria have evolved with time. Initially, only patients aged younger than 65 years were considered for transport. However, we have safely transported older patients with reversible disease processes, and chronologic age alone is no longer an exclusion criterion. Our program also does not consider obesity to be a contraindication to transfer and has safely transported a patient with a body mass index of 79 kg/m^2. Relative contraindications to ECMO transport currently include respiratory or cardiac failure that is not potentially reversible as determined by the information available to the team at the time of decision making. The inability to tolerate anticoagulation is a relative (not absolute) contraindication. Similarly, patients with multiorgan failure must be carefully assessed to determine the probability of reversal of organ failure and reasonable recovery. Patients with end-stage lung disease, without the possibility of lung transplantation, are considered to have an absolute contraindication.

Transport Team

Our transport team consists of 1 surgeon, 1 ECMO fellow, 2 perfusionists, and 2 critical care paramedics. The ECMO fellow is responsible for cannulating and transporting all patients under the direct supervision of the attending surgeon. Our institution maintains several ECMO attendings—intensivists and thoracic surgeons—who rotate weekly, round on all ECMO patients, and are on call at home in the evenings should there be an emergency ECMO transfer. The increased number of surgeons and ECMO attendings reduces staff burnout and fatigue and ensures patient safety during cannulation, transportation, and care after arrival. Moreover, with increasing experience, nurse practitioners in the medical ICU have become adept at caring for ECMO patients. Upon arrival to our institution, transport patients are cared for in a similar fashion to in-house ECMO patients and are managed by the ICU team with consultation from the ECMO team. After decannulation, an extended team, consisting of a critical care attending, social worker, and clinical coordinator, monitors these patients.

ECMO Circuit

The details of our ECMO circuit configuration and transport procedures have been previously described [2]. Our team currently uses dual-site cannulation for VV ECMO for most of the patient transports because it obviates the need for fluoroscopy, unless patient indicators dictate single-site cannulation. Venous drainage cannulas are generally Bio-Medicus (Medtronic, Brooklyn Park, MN) and reinfusion cannulas are Elongated One Piece Arterial (Medtronic) cannulas. The transport circuit consists of a Quadrox iD oxygenator (Maquet, Wayne, NJ) and a Rotaflow (Maquet) or Cardiohelp (Maquet) centrifugal pump.

Before departure from the referring hospital after ECMO is initiated, ventilator settings are adjusted to achieve an initial degree of lung protection: tidal volumes are reduced to maintain peak airway pressures at less than 35 mm Hg, the respiratory rate is decreased to less than 20 breaths/min, with concurrent adjustments in sweep gas flow rate, to maintain a pH between 7.35 and 7.45, unless the patient's metabolic acidosis is severe. Adjustments in positive end-expiratory pressure are generally not made at this stage to avoid rapid derecruitment before transport.

Upon arrival to our ICU, the ECMO circuit is transitioned to our conventional circuit consisting of pre-/postoxygenator pressure monitors, a variable input patient electronic record clinical interfacing module (Spectrum Medical, Fort Mill, SC), gas blender, heat exchanger, and a Sprinter Cart XL (Maquet) scaffold. Currently, our institution has 15 Cardiohelp centrifugal pumps with the capability of creating more circuits with Rotaflow pumps and Quadrox oxygenators.

Statistical Methods

Descriptive statistics for categoric variables are reported as frequency and percentage, and continuous variables are reported as mean and SD or median and interquartile range (IQR) depending on the normality of distribution with the Shapiro-Wilk test. Baseline categoric variables between surge and nonsurge patients were compared with the χ^2 test, and continuous variables were compared with the Student t or Mann-Whitney U tests, where