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National trends in volume-outcome relationships for extracorporeal membrane oxygenation

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ABSTRACT

Background: The use of extracorporeal membrane oxygenation (ECMO) has emerged as a common therapy for severe cardiopulmonary dysfunction. We aimed to describe the relationship of institutional volume with patient outcomes and examine transfer status to tertiary ECMO centers.

Materials and methods: Using the National Inpatient Sample, we identified adult patients who received ECMO from 2008 to 2014. Individual hospital volume was calculated as tertiles of total institutional discharges for each year independently.

Results: Of the total 18,684 adult patients placed on ECMO, 2548 (13.6%), 5278 (28.2%), and 10,858 (58.1%) patients were admitted to low-, medium-, and high-volume centers, respectively. Unadjusted mortality at low-volume hospitals was less than that of medium- (43.7% *versus* 50.3%, $P = 0.03$) and high-volume hospitals (43.7% *versus* 55.6%, $P < 0.001$). Length of stay and cost were reduced at low-volume hospitals compared to both medium- and large-volume institutions (all $P < 0.001$). In high-volume institutions, transferred patients had greater postpropensity-matched mortality (58.5% *versus* 53.7%, $P = 0.05$) and cost ($190,299 *versus* $168,970, $P = 0.009$) compared to direct admissions. On exclusion of transferred patients from propensity analysis, mortality remained greater in high-volume compared to low-volume centers (50.2% *versus* 42.8%, $P = 0.04$). Predictors of mortality included treatment at high-volume centers, respiratory failure, and cardiogenic shock (all $P < 0.001$).

Conclusions: Our findings show increased in-hospital mortality in high-volume institutions and in patients transferred to tertiary centers. Whether this phenomenon represents selection bias or transfer from another facility deserves further investigation and will aid with the identification of surrogate markers for quality of high-risk interventions.

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Introduction

The relationship between case volume and patient outcomes has been well described in the current literature.[1,2] With superior outcomes after trauma care, cardiac surgery, and several types of cancer operations at institutions with higher patient volume,[3-5] performance of many complex procedures has been delegated to dedicated "centers of excellence".[3] While contributing factors for this association remain ill defined, some have cited greater practitioner experience and streamlined pathways as potential explanations for this finding.[1,6]

Extracorporeal membrane oxygenation (ECMO) represents a highly complex modality that requires sophisticated technical expertise and multidisciplinary competence. ECMO has experienced a dramatic surge over the past decade[7] and is routinely used in selected patients with refractory cardiogenic shock, respiratory failure,[8] and as a bridge to lung and heart transplantation.[9-16] Despite advances in surgical and extracorporeal technology, ECMO continues to have nationally high mortality rates.[17] Specialized ECMO centers have established methods for maintaining quality of care during periods of high volume and increasing demand.[18] However, broader dissemination of ECMO in recent years may adversely impact overall outcomes at less experienced centers.[19]

Currently, there are few comprehensive analyses that describe the relationship between volume and outcomes in patients undergoing ECMO. Because of the complexity and high-risk nature of this advanced care modality, we hypothesized the presence of a positive volume-outcome association for ECMO. The present study was undertaken to characterize the contemporary relationship between institutional discharge volume and patient outcomes at volume-stratified ECMO centers across the United States. Furthermore, we aimed to methodically assess the impact of transfer status as a potential contributor to in-hospital mortality at the receiving institutions.

Materials and methods

All adult patients (age $\geq$ 18) discharged alive from January 2008 to December 2014 in the Healthcare Cost and Utilization Project National Inpatient Sample (HCUP-NIS) were considered for this study. HCUP-NIS is the largest national all-payer inpatient care database that utilizes discharge sample weights from an estimated 20% of hospitalizations.[20,21] Before 2012, the NIS was constructed on 100% of discharge records from 20% of reporting hospitals. At the start of 2012, the NIS was built from 20% of discharges among all reporting hospitals.[22] Despite this discrepancy in sampling across the study period, data from 2012 to 2014 was included to represent hospital-level analyses of institutional volume and outcomes among the contemporary ECMO scene.[23] The requirement for University of California at Los Angeles Institutional Review Board approval was waived given the deidentified nature of the NIS.

Application of ECMO was identified using International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) procedural codes 39.65 (ECMO) and 39.66 (percutaneous ECMO). Hospitals were stratified into low-, medium-, and high-volume tertiles of total annual patient discharges using methodology adopted from existing literature.[24] ECMO case volume was not used to define tertiles due to the severely skewed and inconsistent case distribution among hospitals represented in NIS over the study period. The unique hospital identification number was used to tabulate institutional discharges of each reporting hospital in a given year. Volume cutoffs were then independently determined at the 33rd and 67th percentiles per year yielding low-, medium-, and high-volume centers. Given ECMO is a relatively low-volume procedure with significant mortality burden, a power analysis was performed to determine the number of ECMO cases per hospital needed to double in-hospital mortality rate. Thus, the approach for comparing patient-level outcomes between hospitals grouped by institutional tertiles was substantiated.

We used ICD-9-CM diagnosis and procedure codes to identify ECMO patients with any of the five clinical indications: (1) postcardiotomy; (2) cardiogenic shock; (3) respiratory failure; (4) heart transplantation; and (5) lung transplantation.[25,26] Other patient characteristics included age, gender, race, and the presence of comorbidities, including coronary artery disease, heart failure, hypertension, diabetes, peripheral vascular disease, chronic pulmonary disease, and renal insufficiency. The previously validated Elixhauser Comorbidity Index was used to measure 30 categories of comorbidity based on ICD-9-CM diagnosis codes.[27] Transferred patients from different acute care hospitals were identified using the predefined NIS data element, "TRAN_IN". The primary outcome of interest was the relationship between institutional discharge volume and in-hospital ECMO mortality. To account for patient disease severity beyond the limitations of administrative coding, we conducted a subgroup analysis of the postcardiotomy cohort, a theoretically more homogenous group. Additional subgroup analysis within high-volume hospitals assessed the impact of transfers from outside acute care facilities. We also examined predictors of mortality, temporal trends of ECMO admissions by hospital volume, length of stay, and costs of hospitalization reported with Gross Domestic Product adjustment. Length of stay was reported as median days with the associated interquartile range (IQR).

Patient demographics, hospital characteristics, and outcomes were evaluated using the student's *t*-test for continuous variables, Pearson chi-square test for categorical variables, and chi-square tests for trends. A multivariate logistic regression model adjusting for socioeconomic, demographic, and comorbid factors was constructed to identify independent predictors of in-hospital mortality. Propensity matching was performed to match patients across volume tertiles. Statistical significance was defined as a *P* value less than 0.05. All data extraction and analyses were performed using STATA 14.0 software (StataCorp, College Station, Tx).

Results

Baseline characteristics

A sample of 969 hospitals provided ECMO for an estimated 18,684 patients from January 2008 to December 2014