Resource use trends in extracorporeal membrane oxygenation in adults: An analysis of the Nationwide Inpatient Sample 1998-2009

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Objective: The study objective was to determine whether significant trends over time have occurred in resource use associated with the use of extracorporeal membrane oxygenation in critically ill adults.

Methods: All adult admissions involving extracorporeal membrane oxygenation were examined by using the Nationwide Inpatient Sample database (years 1998-2009). Trends in volume, outcome, and resource use (including hospital charges, length of stay, and charges per day) were analyzed.

Results: An estimated total of 8753 admissions involved extracorporeal membrane oxygenation over the study period. Overall length of stay was 18.3 ± 1.3 days. Total hospital charges averaged $344,009 ± $30,707 per admission, with average charges per day of $40,588 ± $3099. Cumulative national charges for extracorporeal membrane oxygenation admissions increased significantly from $109.0 million in 1998 to $764.7 million in 2009 ($P = .0016$). Charges per patient and length of stay also increased significantly ($P = .0032$ and .0321, respectively). The increasing trend in the number of extracorporeal membrane oxygenation admissions during the study period was not statistically significant ($P = .19$). The post-cardiotomy group had more favorable outcomes and lower resource use. A shift was observed in the relative case-mix of extracorporeal membrane oxygenation admissions over the study period, with a relative decrease in the post-cardiotomy group and increases in the cardiogenic shock, respiratory failure, and lung transplant groups.

Conclusions: These results suggest that dramatic increases in resource use associated with extracorporeal membrane oxygenation are not solely the result of increased volume, but in part are due to a shift toward extracorporeal membrane oxygenation use in patient groups (other than in the post-cardiotomy setting) with greater resource use and worse outcomes. (J Thorac Cardiovasc Surg 2014;148:416-21)

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Supplemental material is available online.

Extracorporeal membrane oxygenation (ECMO) is a well-established but complex and resource-intensive life-support intervention for critically ill patients with cardiac or respiratory failure.[1] ECMO therapy in adults was first used in 1972 in a case of acute post-traumatic respiratory failure.[2] Since that time, ECMO expanded to a wide-range of life-support indications. Although adult patients represent a minority (12.5%) of all ECMO records in the international Extracorporeal Life Support Organization registry, they are a rapidly growing group.[3]

Single institution reports and those including only the neonatal population have described the costs[4,5] and cost-benefit or cost-effectiveness analyses[6,7] of ECMO, but multi-institutional studies on the use of ECMO in adults are lacking.[8] More focused economic analyses[9,10] have not provided information on trends over time in the resource use associated with ECMO use in adults.

We used an established, nationally representative administrative database to examine trends in resource use measures and in-hospital mortality in adults undergoing ECMO from 1998 to 2009, to test the hypothesis that changes in the numbers and makeup of this population have caused significant shifts in ECMO-associated resource use.

MATERIALS AND METHODS

The Stanford University Institutional Review Board granted an exemption from review because this research uses de-identified data. Administrative records were extracted from discharge datasets for the years 1998 to 2009 from the Nationwide Inpatient Sample (NIS), Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality. The NIS is the largest publicly available all-payer database for inpatient care in the United States. Each dataset year includes records on 7 to 8 million admissions from approximately 1000 hospitals in 44 states, which reflect

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Abbreviations and Acronyms

CPI = Consumer Price Index
ECMO = extracorporeal membrane oxygenation
ICD-9-CM = International Classification of Diseases, 9th Revision, Clinical Modification
NIS = Nationwide Inpatient Sample

a 20% stratified sample of all US nonfederal, nonrehabilitation hospitals.[11] It contains discharge sample weights to facilitate nationally representative estimates based on the sampling design. Although it contains limited, administrative data on each inpatient encounter, its size and sampling frame facilitates the analysis of comparatively rare clinical events at a national level.

Healthcare Cost and Utilization Project–supplied Clinical Classifications Software for the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) was used to generate diagnostic, comorbidity, and procedural classification codes. ECMO use was established using ICD-9-CM Volume 3 procedure codes 39.65 (extracorporeal membrane oxygenation) and 39.66 (percutaneous extracorporeal membrane oxygenation). These codes are explicitly exclusive of codes for cardiopulmonary bypass (used in the operating room for cardiac surgery) and hemodialysis. All adult (age $\geq$18 years) admission records with an ECMO procedure code recorded were identified and sorted into 1 of 7 predefined groups, based on prior internal reviews and existing literature documenting categories of indications for ECMO use in adults: post-cardiotomy circulatory or respiratory failure (not including heart or lung transplant),[12,13] pre- or post-heart transplant,[14] pre- or post-lung transplant,[15-18] cardiogenic shock/circulatory failure (outside of the context of cardiac surgery), respiratory failure and severe lung disease (not including lung transplantation),[19-21] trauma/hypothermia/drowning,[22] and miscellaneous. The classification process was done using a hierarchical system of diagnosis and procedure code criteria (Appendix Table E1) to create mutually exclusive groups. After initial examination, 2 groups were excluded from further analysis. The trauma/hypothermia/drowning group had an insufficient volume of admission records (no year with >7 admissions nationwide) to be analytically useful. The miscellaneous group (those who had a recorded ECMO procedure code but none of the related diagnosis or procedure codes that would help identify the indication for ECMO) was reviewed in detail. The primary diagnosis and procedure codes present in these records revealed no plausible indication for ECMO. The mortality rates and length of hospital stay recorded in these records was not consistent with ECMO use. Therefore, it was thought that this group likely represented the fraction of records in which an ECMO procedure code was entered erroneously. This process left 5 remaining groups for analysis, hereafter referred to by the following abbreviated labels: post-cardiotomy, heart transplant, lung transplant, cardiogenic shock, and respiratory failure.

Discharge weights were used to create national estimates for the use of ECMO within the NIS stratified sampling frame, and ECMO use was analyzed by group and year. Primary outcome measures included inpatient length of stay (variable LOS), total inpatient hospital charges (variable TOTCHG), calculated mean hospital charges per day, and in-hospital mortality (variable DIED). Discharge disposition (for patients discharged alive) was defined using the variable DISPUNIFORM as discharge to home, transfer to another acute-care hospital, or discharge to rehabilitation (including skilled nursing facility, long-term subacute care hospital, or home-based nursing care), and then summarized as discharge to home or nonhome.

Hospital charges and charges per day were indexed to inflation by adjusting all values to 2009 dollars using the Bureau of Labor Statistics Consumer Price Index (CPI). The CPI subindex specific to inpatient hospital services was used with a baseline of December 1996 taken as 100, and yearly CPI values were used to generate a conversion factor to 2009 dollars.[23] For example, the CPI for inpatient hospital services in 2000 is 113.8; in 2009, it is 203.54. Therefore, the conversion from 2000 dollars to 2009 dollars involves multiplying by (203.564 $\div$ 113.8), or 1.78879.

Statistical Analysis

Because the stratified sampling frame of the NIS requires the use of advanced techniques (facilitated by PROC SURVEYMEANS in SAS; SAS Institute Inc, Cary, NC) to estimate variance, continuous variables are presented as mean $\pm$ standard error. Multi-group comparisons were carried out using a 1-way analysis of variance for continuous variables and Pearson's chi-square test for categoric variables. Trends over time were examined using a Mann–Kendall test for trend[24] (a nonparametric test to determine the presence and direction of a trend over time). A predetermined alpha of 0.05 was used as the threshold of statistical significance. Analyses were performed using SAS 9.3.

RESULTS

Overall, a total of 9243 admissions included ECMO intervention during the study period. After exclusion of the trauma/drowning (n = 132) and miscellaneous (n = 357) groups, 8753 admissions remained for analysis.

Figure 1 shows the temporal trend in cumulative national hospital charges for ECMO admissions, which increased significantly from $109.0 million in 1998 to $764.7 million in 2009 (test for trend $P = .0016$). Figure 2 shows the trend in number of ECMO admissions, which demonstrated a nonsignificant increase over the study period (test for trend, $P = .19$) from 742 in 1998 to 1621 in 2009.

In the entire study group, average length of stay was 18.3 $\pm$ 1.3 days. Mean total charges were $344,009 $\pm$ $30,707, with average charges per day of $40,588 $\pm$ $3099. Figure 3 shows the temporal trends in mean total hospital charges and mean length of stay, both of which increased significantly over the study period (test for trend $P = .0032$ and .0321, respectively). In-hospital mortality increased over the study period from 33.1% in 1998 to 52.9% in 2009, but this trend did not reach statistical significance ($P = .19$).

Table 1 displays the size, baseline characteristics, and outcome variables of each group. Of note, the post-cardiotomy group was older, with a greater male predominance, and included the greatest proportion of admissions from a nonteaching hospital. This group had the shortest length of stay and lowest total charges. Compared with the post-cardiotomy group, the cardiogenic shock, respiratory failure, and lung transplant groups had longer lengths of stay, higher total charges, higher rates of in-hospital mortality, and higher proportions of patients with a nonhome discharge disposition.

Figure 4 shows the temporal trends in relative frequency of ECMO use by group over the study period. Over the study period, a shift in case mix was observed, with a relative decrease in the post-cardiotomy group and increases in