Journal of Pediatric Surgery 52 (2017) 1681–1687

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Utilization patterns of extracorporeal membrane oxygenation in neonates in the United States 1997–2012

Ashley Y. Song [a,b], Hsuan-Hsiu Annie Chen [a], Rachel Chapman [a], Ameish Govindarajan [a], Jeffrey S. Upperman [c], Rita V. Burke [c], James Stein [c], Philippe S. Friedlich [a], Ashwini Lakshmanan [a,b,d,]*

[a] Fetal and Neonatal Institute, Division of Neonatology, Children's Hospital Los Angeles, Department of Pediatrics, Keck School of Medicine, University of Southern California, Los Angeles, CA, United States

[b] Department of Preventive Medicine, Keck School of Medicine, University of Southern California, Los Angeles, CA, United States

[c] Department of Pediatric Surgery, Children's Hospital Los Angeles, University of Southern California

[d] Leonard D. Schaeffer Center for Health Policy and Economics, University of Southern California, Los Angeles, CA, United States

ARTICLE INFO

Article history:
Received 13 December 2016
Received in revised form 17 April 2017
Accepted 28 May 2017

Key words:
ECMO
Utilization patterns
Length of stay
Charges
Costs
Neonates
Outcomes

ABSTRACT

Background: Extracorporeal membrane oxygenation (ECMO) remains one of the most intensive therapies for newborns in the United States. However, there is limited information on resource utilization for neonates receiving ECMO.

Methods: We conducted a retrospective data analysis of the Kids' Inpatient Database from 1997 to 2012. Bivariate and multivariate analysis was completed to identify predictors of LOS, hospital costs and mortality. Cardiac and non-cardiac diagnoses of neonates receiving ECMO were also included in the bivariate and multivariable analysis.

Results: Of the 5151 ECMO cases, survival to discharge was 62%. 22% had a principal cardiac diagnosis. After adjusting for covariates, increased mortality was associated with treatment in the midwest compared to the northeast region (aOR = 2.0, $p < 0.01$) and decreased among neonates with a non-cardiac diagnosis (aOR = 0.4, $p < 0.01$). Living in midwest was associated with longer LOS by 13 days and increased hospital costs by 63,000 dollars ($p < 0.01$). When stratified by non-cardiac diagnoses, infants with a diagnosis of congenital diaphragmatic hernia was associated with increased mortality (2.3, $p < 0.01$) and longer LOS (25, $p < 0.01$) and increased costs (11,100, $p < 0.01$).

Conclusion: Neonates who received ECMO in certain regions of the United States were associated with poorer survival outcomes as well as increased LOS and hospital costs.

Type of study: Retrospective study.

Level of evidence: Level III.

Extracorporeal membrane oxygenation (ECMO) is a specialized resuscitation technique that enhances neonatal survival during acute, but potentially reversible, cardiac and/or respiratory failure [1–4]. Despite a 12% increase in the number of active Extracorporeal Life Support Organization (ELSO) centers in the United States from 2002 to 2011 and neonates making up the largest patient population in the registry, there are currently no universally accepted criteria for neonatal ECMO support [5–7]. Common diagnoses in neonates receiving ECMO support include congenital heart disease and non-cardiac diagnoses include congenital diaphragmatic hernia (CDH), meconium aspiration with respiratory symptoms (MAS), and persistent pulmonary hypertension of the newborn (PPHN) [6,8].

In the United States, the incidences of CDH, MAS, and PPHN are estimated to be 19.3 per 100,000, 1800 per 100,000, and 190 per 100,000, respectively [9–12]. Previous studies have demonstrated a 73% reduction in mortality associated with ECMO implementation [13]. While CDH is the most common non-cardiac diagnosis identified in neonates receiving ECMO support, neonates with a diagnosis of MAS have the highest survival rate [6,14]. Similarly, the advent of ECMO is associated with significantly improved survival in PPHN [15,16]. However, with its advances in capabilities and applications, ECMO has become one of the most cost- and resource-intense therapies in the United States [8,17].

As United States healthcare spending continues to increase, it is essential for providers to judiciously implement cost-effective use and care of patients receiving ECMO therapy. Past studies have shown that patient demographics, clinical characteristics, and institutional factors all significantly impact ECMO survival outcomes [18–21]. A recent study assessed predictors of in-hospital survival and determinants of resource utilization of ECMO support in all pediatric patients from 1997 to 2009 [22]. Our study provides comprehensive and up to date analyses of outcomes and resource utilization patterns of ECMO support in only

* Corresponding author at: Children's Hospital Los Angeles, Newborn and Infant Critical Care Unit, 4650 Sunset Boulevard, MS #31, Los Angeles, CA 90027. Tel.: +1 323 361 6393.
E-mail address: alakshmanan@chla.usc.edu (A. Lakshmanan).

http://dx.doi.org/10.1016/j.jpedsurg.2017.05.026
0022-3468/

neonates in the United States from 1997 to 2012. The objectives of this study are: 1) to determine the differences in resource utilization between survivors and non-survivors in neonates that received ECMO therapy, 2) to identify the predictors of mortality in neonates receiving ECMO support, and 3) to identify the determinants of length of stay (LOS) and total hospital costs in neonates receiving ECMO support. We hypothesized that there were specific predictors of survival, mortality, length of stay and cost.

1. Methods

We utilized Agency for Healthcare Research and Quality-sponsored Healthcare Cost and Utilization Project (HCUP) Kids' Inpatient Database (KID) of years 1997, 2000, 2003, 2006, 2009, and 2012 for this study [23]. The KID is a pediatric inpatient administrative database released every 3 years since 1997 and reports 2 to 3 million records per year. The KID uses nationwide sampling of patient discharges aged 20 years or younger from all community, and non-rehabilitation hospitals in states participating in HCUP. Systematic random sampling is used to select 10% of uncomplicated in-hospital births and 80% of complicated in-hospital births and other cases from each hospital to generate the sampling frame. Discharge weights are provided within the database that, when applied, allows for calculation of national estimates. As of 2012, 44 states provided pediatric discharge information to the KID and a total of 6,675,222 discharges were recorded [23]. The KID contains data on patient demographics, clinical information, payment information,

Table 1
Characteristics of Neonates Receiving Extracorporeal Membrane Oxygenation (ECMO) Therapy.

	Total sample (N = 5151)	Survivors (N = 3196)	Non-survivors (N = 1955)	
	N	N (% of sample)	N (% of sample)	p-value
Patient demographics				
Gender				
Male	3066	1940 (61)	1126 (58)	0.03
Female	2085	1256 (39)	829 (42)	
Race/Ethnicity				
White non-Hispanic	1903	1129 (48)	774 (53)	0.0006
Black non-Hispanic	646	443 (19)	203 (14)	
Hispanic	684	428 (18)	256 (18)	
Asian/Pacific Islander	182	105 (4)	77 (5)	
Native American	22	13 (1)	9 (1)	
Other	368	243 (10)	125 (9)	
Payer type				
Government issued insurance	2504	1549 (49)	955 (49)	0.04
Private insurance	2219	1387 (44)	832 (43)	
Self-pay	73	34 (1)	39 (2)	
Other	331	208 (6)	123 (6)	
Hospital characteristics				
Hospital region				
Northeast	788	548 (17)	240 (12)	<0.001
Midwest	1298	743 (23)	555 (28)	
South	1533	990 (31)	543 (28)	
West	1531	915 (29)	616 (32)	
Hospital bed size				
Small	773	487 (16)	286 (15)	0.72
Medium	1439	908 (29)	531 (28)	
Large	2800	1734 (55)	1066 (57)	
Hospital location/teaching status[a]				
Rural	2	2 (0)	0 (0)	0.007
Urban non-teaching	200	145 (5)	55 (3)	
Urban teaching	4810	2982 (95)	1828 (97)	
Clinical characteristics				
In-hospital birth	845	411 (87)	434 (78)	<0.001
Common principal diagnoses[b]				
Congenital diaphragmatic hernia	608	324 (10)	284 (15)	<0.001
Fetal and newborn aspiration	461	427 (13)	34 (2)	<0.001
Persistent pulmonary hypertension	351	277(9)	74 (4)	<0.001
Meconium aspiration syndrome	268	253 (8)	15 (1)	<0.001
Hypoplastic left heart syndrome	295	136 (4)	159 (8)	<0.001
Sepsis	110	54 (2)	56 (3)	<0.001
Cardiac-related principal diagnoses[b]				
Yes	1143	541 (17)	602 (31)	<0.001
No	4008	2655 (83)	1353 (69)	
Length of stay; median (IQR)	3058	32 (20–57)	18 (9–36)	<0.001
Days from admission to principal procedure; median (IQR)	3067	3 (0–5)	1 (0–8)	<0.001
Cardiac principal diagnoses	1143	5 (2–9)	5 (2–11)	0.19
Non-cardiac principal diagnoses	4008	1 (0–3)	1 (0–7)	<0.001
Days from admission to principal procedure: ECMO; median (IQR)	3780	1 (0–3)	2 (0–7)	<0.001
Total charges; median (IQR)	2886	358,309 (211,378–663,010)	430,663 (219,789–797,898)	0.001
Total costs; median (IQR)[c]	2129	174,609 (111,918–300,584)	191,388 (108,796–319,409)	0.04

Characteristics of neonates by survival are shown as numbers with percentage of the sample unless otherwise noted. Discharge weights were applied for calculation of national estimates. Missing values were not included. Total numbers for length of stay, total charges, and total costs were not weighted. p-values for categorical characteristics derived using chi-square test (for 2 sample comparison) and ANOVA test (for multi-group comparison) unless otherwise noted; p-values for continuous characteristics derived using Wilcoxon Rank Sum test (for 2 sample comparison) and Kruskal–Wallis test (for multi-group comparison).

[a] p-values derived from Fisher's exact test.

[b] Diagnoses were identified based on ICD-9 code (Appendix).

[c] Hospital costs were only available for 2003–2012 and adjusted for inflation relative to 2012 dollars.