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Perioperative support, not volume, is necessary to optimize outcomes in surgical management of necrotizing enterocolitis

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ABSTRACT

Background: This study examines the relationship between hospital volume of surgical cases for necrotizing enterocolitis (NEC) and patient outcomes.
Methods: A retrospective cross-sectional review was performed using the HCUP SID for California from 2007 to 2011. Patients with NEC who underwent surgery were identified using ICD-9CM codes. Risk-adjusted models were constructed with mixed-effects logistic regression using patient and demographic covariates.
Results: 23 hospitals with 618 patients undergoing NEC-related surgical intervention were included. Overall mortality rate was 22.5%. There were no significant differences in the number of NICU beds ($p = 0.135$) or NICU intensivists ($p = 0.469$) between high and low volume hospitals. Following risk adjustment, no difference in mortality rate was observed between high and low volume hospitals respectively (24.0% vs. 20.3%, $p = 0.555$).
Conclusions: Our observation that neonates with NEC treated at low-volume centers have no increased risk of mortality may be explained by similar availability of NICU and intensivists resources across hospitals.

1. Introduction

Necrotizing enterocolitis (NEC) is a devastating intestinal illness in neonates, with many patients requiring surgical intervention. NEC is the most common gastrointestinal surgical emergency among neonates,[1] affecting approximately 7–8% of extremely low birth weight infants. Greater than 30% of low birth weight infants with necrotizing enterocolitis require surgical treatment.[2] Though the etiology remains unclear; the disease is characterized clinically by feeding intolerance, abdominal distention, hemodynamic instability, and potential multiple organ failure.[3] Risk factors include preterm birth and low birth weight. The estimated mortality for NEC ranges between 20 and 50%, with highest rates among infants that require surgery.[2,3] Although infants with mild NEC can often be managed non-operatively with bowel decompression, bowel rest, broad-spectrum intravenous antibiotics and hyperalimentation, surgical intervention remains the mainstay for more advanced disease.[2]

Necrotizing enterocolitis remains an important area of research, as it has been difficult to eradicate despite advances in neonatal intensive care. Affected patients incur high health care costs and often endure lasting neurodevelopmental morbidities.[4] Due to the complex nature of perioperative care required for these patients, many are transferred to tertiary centers. Previous studies[5,6] have shown that hospitals with high surgical volume have lower mortality rates than those at hospitals that are less experienced (low surgical volume centers, LSVC). High surgical volume centers (HSVC) are more likely to have specialists, technology, and better staffing of intensive care units.[5,6] Surgical volume is increasingly used as a surrogate for the quality of surgical care; however this relationship has not been well studied in the pediatric population. This study examines the relationship between hospital volume of necrotizing enterocolitis cases requiring surgical intervention and

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patient outcomes with the objective of determining whether surgery at a high surgical volume center (HSVC) improved overall mortality (death prior to discharge from the hospital) as compared to surgery at a low surgical volume center (LSVC). A secondary aim was to determine if hospital characteristics interacted with the relationship between hospital volume and outcomes.

2. Methods

2.1. Data sources

We obtained patient level data from the Healthcare Cost and Utilization Project (HCUP) State Inpatient Database (SID) for California for the years 2007–2011 to perform a retrospective cross-sectional review. The SID is an administrative, all-payer data set aggregated by the Agency for Healthcare Research and Quality (AHRQ) to inform health related decisions.[7] The Institutional Review Board at our institution deemed the study exempt from review as the data are de-identified, protected and publically available.

Hospital characteristics were assessed using the American Hospital Association (AHA) Annual Survey Database from 2011. This nationwide database contains information categorizing an institution's organizational structure, facility and service lines, operation expenses, and staffing.[8] We linked the patient level data from HCUP SID to the AHA annual survey for hospital data.

2.2. Patient and hospital characteristics

Patients included for study were between birth and 1 year of age, carried a diagnosis of necrotizing enterocolitis, and underwent a surgical intervention. The diagnosis and procedures were identified by *International Classification of Diseases, 9*th *Revision, Clinical Modification*, (ICD9) codes for necrotizing enterocolitis (777.51–3) and various surgical interventions, including exploratory laparotomy (54.11), small bowel resection (45.01–2, 45.10, 45.29, 45.31–32, 45.60–63, 45.33–4, 45.50–52), large bowel resection (45.03, 45.26, 45.41–43, 45.49, 45.72–76, 45.76, 45.79, 45.8, 46.99), stoma creation (46.01–4, 46.10–11, 46.13–14, 46.20–24, 46.31–32, 46.39–43, 46.50–52, 46.60–64, 47.91), primary anastomosis (45.91, 45.93–95, 46.73–76, 46.79, 46.93–94), and lysis of adhesions (46.79, 46.81, 47.99, 54.11, 54.51, 54.59, 54.95). We extracted demographic data from HCUP including sex, race (Caucasian, African-American, Hispanic, other), insurance status (Medicaid, Private, Self-Pay), number of diagnoses and whether the patient was born in the hospital where they had surgery (Table 1).

For hospital level analysis, we first determined annual volume of surgical NEC cases from HCUP data. Each hospital was placed into one of five quintiles based on procedure volume per year. The procedure volume cutoffs that are used most closely result in an equal distribution of patients throughout the quintiles. Hospitals were then further separated into high surgical volume centers (HSVC) (highest quintile, 11–15 cases per year) and low surgical volume centers (LVSC) (lowest four quintiles, 1–9 cases per year). Hospital level explanatory variables contained within the AHA Annual Survey database included number of pediatric beds, number of NICU beds, number of neonatal intensivists, and NICU intensivist to NICU bed ratio.

2.3. Statistical methods

The primary outcome of interest was risk adjusted mortality, defined as patients who died prior to discharge from the hospital. Descriptive statistics of the study population were calculated using arithmetic means with standard deviations for continuous variables and proportions for categorical variables. Population unadjusted mortality was obtained using a simple proportion of number of inpatient mortalities by the total population. For determining hospital mortality, a weighted mean as a function of individual hospital volume was used. Risk adjusted mortality was calculated using a mixed-effects logistic regression model with fixed effects for patient sex, race, insurance status, number of concurrent diagnoses, and location of birth (same vs. different hospital). Model fit was assessed using the Akaike Information Criterion and C-statistic. All statistical analyses were performed using STATA version 13 (StataCorp LP, College Station, TX).

Table 1
Baseline characteristics of study population and hospitals.

Characteristic	Frequency (%), mean (SD)
Patient characteristics (N = 618)	
Gender	
Female	243 (39.3%)
Male	375 (60.7%)
Race	
White	132 (21.4%)
Black	76 (12.3%)
Hispanic	310 (50.2%)
Asian	30 (4.9%)
Other	70 (11.3%)
Insurance type	
Medicaid	337 (54.5%)
Private	197 (31.9%)
Self-Pay/Other	84 (13.6%)
Family income, by zip code (quartile)	
1st	263 (42.6%)
2nd	153 (24.8%)
3rd	129 (20.9%)
4th	73 (11.8%)
Hospital birth (in hospital of surgery)	
Yes	173 (28.0%)
No	445 (72.0%)
Number of diagnoses	18.7 (6.5)
Hospital characteristics (N = 23)	
Annual Volume (cases per year)	5.4 (4.0)
NICU Beds	47.0 (24.3)
NICU Intensivists	8.0 (5.3)
NICU Intensivist/NICU Beds	0.21 (0.16)
Pediatric Beds	66.5 (61.0)

NICU- Neonatal Intensive Care Unit.

3. Results

The study sample included 618 patients with surgical necrotizing enterocolitis at 23 hospitals. The study population was 61% male, 50% Hispanic, 55% had Medicaid as the primary payer, and 28% of patients were born in the hospital in which they underwent surgery (i.e. inborn) (Table 1). The overall unadjusted mortality rate for all hospitals was 22.5% (Fig. 1). Following risk adjustment for sex, race, insurance status, and inborn status, no difference in mortality rate was observed between hospitals in the highest quintile (11–15 cases per year) and the lower four quintiles in aggregate (1–9 cases per year) (24.0% vs 20.3%, $p = 0.555$).

Of the 23 hospitals included, 4 (17%) were high surgical volume centers (HSVC) and 19 (83%) were considered low surgical volume centers (LSVC). The average annual volume for surgical NEC cases across all hospitals was 5 cases per year. Of the four HSVC, the average volume of patients with NEC that were operated on was 62 ± 9.5 patients, while the average volume at LSVC was 19.5 ± 11.5. The mean number of pediatric beds, NICU beds, and NICU intensivists were 67, 47, and 8 respectively (Table 1). In comparing hospital characteristics, HSVC had a significantly greater number of pediatric beds (152.8 vs 47.4 beds, $p < 0.001$). However, the number