Journal of Pediatric Surgery 51 (2016) 1650–1654

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

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

Is there a relationship between hospital volume and patient outcomes in gastroschisis repair?

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ARTICLE INFO

Article history:
Received 8 January 2016
Received in revised form 7 March 2016
Accepted 10 April 2016

Keywords:
Volume outcome
Gastroschisis
Newborn surgery
Regionalization

ABSTRACT

Purpose: Given the well-established relationship between surgical volume and outcomes for many surgical procedures, we examined whether the same relationship exists for gastroschisis closure.
Methods: We conducted a retrospective analysis of infants who underwent gastroschisis closure between 1999 and 2007 using a California birth-linked cohort. Hospitals were divided into terciles based on the number of gastroschisis closures performed annually. Using regression techniques, we examined the effects of hospital volume on patient mortality and length of stay while controlling for patient and hospital confounders.
Results: We identified 1537 infants who underwent gastroschisis repair at 55 hospitals, 4 of which were high-volume and 42 of which were low-volume. The overall in-hospital mortality rate was 4.8% and the median length of stay was 46.5 days. After controlling for other factors, patients treated at high-volume hospitals had significantly lower odds of inpatient mortality (OR 0.40; 95% CI 0.21, 0.76). There was a near-significant trend towards shorter hospital length of stay at highvolume hospitals ($p = 0.066$).
Conclusions: Patients who undergo gastroschisis closure at high-volume hospitals in California experience lower odds of in-hospital mortality compared to those treated at low-volume hospitals. These findings offer initial evidence to support policies that limit the number of hospitals providing complex newborn surgical care.

Infants born with congenital defects require complex, coordinated, and interdisciplinary care. The management of infants with gastroschisis, for example, typically requires intensive nursing care and nuanced decision-making regarding nutritional support and abdominal wall closure timing and technique. Ensuring successful outcomes therefore depends on a myriad of interacting factors, including surgeon experience, closure technique, prenatal care, and nursing care. Considering the required coordination, it is plausible that hospitals that care for such patients more frequently, may also deliver higher quality care and have better patient outcomes.

The relationship between surgical volume and patient outcomes has been demonstrated repeatedly [1–3]. This is particularly true for complex surgical procedures that require elaborate, interdisciplinary care, such as esophagectomy [4–6] and pancreatectomy [7–9]. Most neonatal surgical treatments, including those for gastroschisis, meet these criteria, however the relationship between hospital volume and patient outcomes is not well understood for this patient population. In Canada, where care for infants with gastroschisis is regionalized to a few qualifying centers, patients experience similar mortality, length of stay, and days on total parenteral nutrition (TPN) regardless of the modest differences in volume across the centers [10]. In the United States, however, care for infants with congenital surgical conditions remains decentralized, resulting in many hospitals treating only a few number of these patients each year. Therefore, in a system with a broad range of case volumes across hospitals, such as that in the United States, it remains possible that an association exists between higher case volumes and better patient outcomes for patients with gastroschisis.

Using a statewide cohort of patients treated for gastroschisis in California, we sought to determine whether infants treated at high-volume centers experience better outcomes than those treated at low-volume centers. These results would offer valuable data to inform policies that aim to ensure safe and efficacious care of infants with gastroschisis.

1. Methods

1.1. Data source and study population

The study was approved by the Institutional Review Boards at the University of California, Los Angeles and the California Office of Statewide Health Planning and Development (OSHPD). We performed a retrospective analysis using data from a linked maternal-neonatal

Abbreviation: OSHPD, Office of Statewide Health Planning and Development.
Financial disclosures: The authors have no financial relationships relevant to this article to disclose.
Conflicts of interest: None.
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http://dx.doi.org/10.1016/j.jpedsurg.2016.04.009
0022-3468/

database of hospital discharges from 1999 to 2007 in California, as maintained by the California Office of Statewide Health Planning and Development (OSHPD). We identified infants born with gastroschisis using International Classification of Diseases, Ninth Edition (ICD-9) codes. During the study period, one ICD-9 diagnosis code was shared between the abdominal wall defects, gastroschisis and omphalocele. We therefore used this diagnosis code combined with a procedure code specific for gastroschisis closure to identify our study population (diagnostic code 756.73 and procedure code 54.71). This method has previously been used [11] and validated by showing greater than 96% agreement between gastroschisis codes in the cohort file and prenatal ultrasound findings [12].

We assigned patients to a hospital based on the location of the first gastroschisis closure, not the hospital of birth. This first procedure refers to the first time a relevant procedure code appeared in the patient's record. We also recorded whether a patient was transferred between the time of birth and first procedure. Therefore, patients who underwent gastroschisis closure prior to a hospital transfer were excluded from this analysis. Inpatient hospitalization served as our unit of analysis and patients were therefore followed until the time of death or hospital discharge. The administrative data available precluded us from determining whether the closure was staged or definitive, or whether a silo was used.

1.2. Outcomes

We analyzed 2 outcome variables: mortality and length of stay (LOS). Mortality was defined as death of any cause after the first attempt at gastroschisis closure and prior to hospital discharge. LOS was calculated as the time from birth to hospital discharge, including the time spent before or after hospital transfer. We analyzed LOS as a continuous variable to calculate risk-adjusted predictions of LOS and also as a categorical variable in our regression models. For these models, we defined prolonged LOS as greater than the 75th percentile (55 days).

1.3. Covariates

Our main explanatory variable of interest was hospital volume, which we calculated based on the average number of patients in our cohort for each hospital per year. Hospitals were ranked according to mean average volume and divided into terciles based on volume cutoffs that most closely created terciles with similar numbers of patients [13]. The cutoff for the average number of operations performed at low-, medium-, and high-volume hospitals was <5, 5–9, and 9–17, respectively. Of note, each hospital's volume was relatively consistent throughout our study time frame, as noted by the high correlation between annual operative volume and assigned volume tercile (correlation coefficient = 0.83).

To control for the resources available at each hospital, we controlled for the designated neonatal intensive care unit (NICU) level, as defined by the American Academy of Pediatrics [14,15]. Since the vast majority of cases (98.7%) in our sample were from level 3C or 3B NICUs, we categorized NICU level as a binary variable (3C vs. 3B, 3A, or 2B). Most patients (70.5%) treated at hospitals with level 3B NICUs were treated at low volume hospitals and the remainder (29.5%) were treated at medium volume hospitals. We also controlled for patient level factors including gender, gestational age, low birthweight (<2500 g), maternal age, the infant's age on the day of the procedure, and the severity of disease. For the latter concept, we included variables for the presence of necrotizing enterocolitis (ICD-9777.5-777.53), intestinal perforation (ICD-9777.6), and respiratory distress syndrome (ICD-9769), as identified by ICD-9 codes [16]. We also controlled for whether or not the patient was transferred from another facility prior to defect closure. Of note, comparing transferred and non-transferred patients, there was no statistically significant difference in gestational age, maternal age, low birthweight, necrotizing enterocolitis, or intestinal perforation. There was, however, a higher proportion of patients with respiratory distress syndrome among patients who were transferred (3.4%) compared to those who were not transferred (1.3%, p = 0.003 from chi-squared test).

1.4. Statistical analysis

We first determined the distribution of patients across volume tercile. Chi-squared tests and Kruskal–Wallis tests were used to determine differences in demographics by tercile for categorical and continuous variables, respectively.

We then created a hierarchical logistic regression model to predict mortality based on hospital volume using a random intercept for the hospital. This model controlled for patient and maternal demographics, disease severity, and NICU factors using the variables listed in Table 1. To analyze length of stay, we used two separate modeling strategies. First, we categorized length of stay as a binary variable, with prolonged length of stay defined as greater than the 75th percentile (55 days). We then built a hierarchical logistic regression model to predict prolonged length of stay controlling for all covariates. Second, we analyzed length of stay as a continuous variable, using a negative binomial multivariate regression model, again controlling for the previously mentioned covariates and accounting for clustering of cases within hospitals using robust standard errors. Negative binomial regression is used to model count data and is particularly useful when there is over-dispersion as we noted in our data. Using this model, we calculated a risk-adjusted length of stay for each hospital-volume tercile. All statistical analyses were performed using Stata version 13.1 (College Station, Texas).

2. Results

There were 1537 patients who underwent gastroschisis repair at 55 unique hospitals in our sample. The majority of patients were male

Table 1
Patient characteristics at high- and low-volume hospitals for gastroschisis repair.

	Total	Low-volume hospitals	Medium-volume hospitals	High-volume hospitals
Number of patients	1537	516	567	454
Unadjusted mortality (%)	4.8	6.0	4.6	3.5
Unadjusted median length of stay (days)*	46.5	49.0	46.9	43.3
Gender (%)				
Female	48.2	48.6	45.7	50.7
NICU level (%)*				
3B, 3A, 2B	36.8	78.1	28.6	0
3C	63.2	21.9	71.4	100
Gestational age, weeks (%)				
>37	52.1	54.3	49.2	53.3
34–37	36.8	37.6	38.1	34.1
<34	11.1	8.1	12.7	12.6
Maternal age, years (%)				
20–35	64.4	66.7	65.4	60.6
>35	1.4	1.7	1.2	1.1
<20	34.2	31.6	33.3	38.3
Low birthweight, <2500 g (%)	50.4	49.4	51.9	49.6
Complicated gastroschisis (%)				
Necrotizing enterocolitis	3.3	3.3	3.2	3.5
Intestinal perforation	3.8	3.7	3.4	4.4
Respiratory distress syndrome	2.0	2.9	0.9	2.2
Days until initial procedure, mean*	1.4	3.2	0.4	0.5
Transfer from outside hospital (%)*	35.7	17.1	33.5	59.7

* $P < 0.001$; none were significant at an alpha-level between 0.001 and 0.05. p-values calculated using chi-squared test for categorical variables and Kruskal–Wallis test for continuous variables.