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The impact of children's hospital designation on outcomes in children with malrotation☆,☆☆,★

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ABSTRACT

Background: The benefit of Ladd's procedure for malrotation at a Children's Hospital (CH) has not previously been established. Our aim was to characterize the potential variations in management and outcomes between CH and Non-Children's Hospitals (NCH) in the treatment of malrotation with Ladd's procedure.
Methods: There were 2827 children identified with malrotation and complete information from the Kids' Inpatient Database (2003, 2006, 2009). Outcomes were compared between CH and NCH and evaluated with logistic and linear regressions. Additional propensity score matching was used to balance covariates between CH and NCH.
Results: There were 2261 (80.0%) children with malrotation undergoing Ladd's procedures treated at CH; 566 (20.0%) were treated at NCH. In multivariate analysis, CH was associated with a 39% lower odds of resection ($p = 0.004$), with no differences observed for mortality, morbidity and LOS. Comparison of a propensity score matched cohort confirmed these findings, as well as demonstrated no significant differences in associated costs.
Conclusions: The majority of pediatric intestinal malrotation is managed at CH. While measured outcomes of mortality, morbidity, LOS, and costs were not different at NCH, CH was less likely to perform intestinal resection during Ladd's procedure.

Malrotation is a congenital anomaly resulting from the embryologic failure of normal rotation and fixation of the intestine. The importance of expedited management of children presenting with malrotation with volvulus cannot be overstated as the intestine is potentially compromised by the ensuing vascular insufficiency leading to bowel ischemia, and may necessitate surgical resection when frank necrosis is encountered. The potential consequences are substantial and include short-gut syndrome, sepsis, and death [1–4]. In equivocal cases of bowel viability, experienced specialists may be more comfortable with avoiding intestinal resection and its potential sequelae including the risk of anastomotic leak or intestinal insufficiency [5].

A growing body of literature has established benefits in the management of diseases or injury in children in specialized centers such as pediatric trauma centers (PTC) or Children's Hospitals (CH) [5–14]. Whether outcomes following Ladd's procedure for malrotation are improved at CH relative to other hospitals has not previously been established. The majority of studies addressing malrotation are based on single-institution experiences [1–3,15–18]. Using a large national administrative pediatric database, we sought to characterize the potential variations in management and outcomes between CH and NCH in the treatment of malrotation with Ladd's procedure.

1. Patients and methods

1.1. Data

Data were obtained from the Kids' Inpatient Database (KID) (2003, 2006, and 2009) of the Healthcare Cost Utilization Project (HCUP). The KID is a hospital administrative dataset designed specifically to assess the use of hospital services by newborns, children and adolescents [19]. It includes data from approximately 2–3 million patients and represents a nationwide sample of all-payer inpatient pediatric discharges [19]. In its most recent year, the KID captured data from 44 states and 4000 hospitals including various hospital types (i.e. rural, urban, teaching) from all geographic areas of the country. As part of HCUP, the data were designed to be nationally representative, and intended to help inform decision-making at the national, state and community levels [19]. Data are de-identified and publically available every three years.

Children undergoing Ladd's procedure for malrotation were identified from the KID utilizing a previously described methodology for population level analysis [4]. To summarize, patients under the age

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of 18 in the KID with a discharge diagnosis of intestinal malrotation were identified using an International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis code of 751.4 (anomaly of intestinal fixation). Since there is no specific ICD-9-CM procedure code for Ladd's procedure, patients were included for analysis if their discharge record included a procedure code for a key component of the operation (ICD-9-CM: 46.80, 46.81, 46.82, 54.4, 54.51, 54.9, 54.95) [4]. Similarly, we also included patients with a principal discharge diagnosis of malrotation or intestinal vascular compromise (volvulus [560.2] or acute vascular insufficiency of the intestine [557.0, 557.9]) and had a procedure code for intestinal resection, while excluding patients with a diagnosis of small bowel obstruction to avoid capturing patients operated upon for that indication with only a history of a Ladd's procedure [4].

As not all states collect or report race data, and admission data were incomplete for some patients, those entries with incomplete or missing race and admission data were retained and included in the analyses as a "missing" category. Additionally, as cost was an intended primary outcome, those with missing cost data ($n = 366$) were excluded. Patients were stratified by hospital designation (CH or NCH) according to the National Association of Children's Hospitals and Related Institutions (NACHRI). Children's Hospitals included both Children's Hospitals within General Hospitals and Free-Standing Children's Hospitals. Patients with a missing NACHRI designation were excluded from analysis ($n = 284$). Comorbidities were defined using the Deyo adaptation of the Charlson Comorbidity Index (CCI), which uses ICD-9-CM diagnosis codes and assigns different weights to various patient comorbidities [20–22]. This study was assessed by the Penn State Hershey Medical Center Institutional Review Board and found to be exempt from formal review.

1.2. Outcomes

There were five primary outcomes of interest: 1) mortality, 2) morbidity, 3) intestinal resection, 4) length of stay (LOS), and 5) costs. Morbidity was defined by the presence of in-hospital complications during index hospitalizations and was obtained utilizing previously described methods based on ICD-9-CM diagnoses [23,24]. Intestinal resection was established based on ICD-9-CM procedure codes (45.6, 45.61, 45.62, 45.63). LOS was based on the duration of index operative admission. A hospital perspective was adopted as the basis for cost analysis. Total inpatient hospital costs were calculated using the hospital-specific cost-to-charge ratios (CCR) and were adjusted for inflation to 2009 US dollars according to the medical care component of the consumer price index [25]. In addition to unadjusted costs, adjusted costs are reported using two different methods (generalized linear regression and propensity score matching) as described below.

1.3. Statistical analysis

The purpose of our statistical analysis was to determine whether patients with malrotation treated with Ladd's procedure at designated CH had different outcomes than patients treated at NCH. Univariate statistical tests were used to compare baseline characteristics of patients between CH and NCH, using chi-square, Student's t and Mann–Whitney U tests, as appropriate. Mortality, in-hospital complications and intestinal resection were modeled using logistic regression. LOS and costs were modeled using a generalized linear regression model to account for severe skewness in the data. The models assumed a gamma family of distributions and an identity link function.

A propensity score analysis was used to balance the distribution of covariates between both CH and NCH, which might otherwise confound the impact of CH designation on the outcomes of interest, and to confirm the validity of the regression models. Patients treated at CH were matched 1:1 without replacement to patients treated at NCH using a nearest neighbor approach with a caliper restriction. After matching, the distributions of patient characteristics were not significantly different. Our primary metric for the propensity score was the average effect of treatment on the treated (ATT). The ATT estimates the difference between the outcome for patients treated at CH and the outcome had CH patients been treated at a NCH, allowing one to estimate differences in the outcomes of interest in comparable or similarly matched patients. To assess the sampling variability in the propensity score model and to account for variation induced by the matching procedure, we used a bootstrapping algorithm with 1000 replicates to compute 95% confidence intervals. All analyses were performed using STATA (version 10/MP; Stata Corp., College Station, TX) and the PSMATCH2 routines [26]. p Values less than 0.05 were considered statistically significant.

2. Results

A total of 2827 pediatric patients with malrotation were identified in the KID (2003, 2006, and 2009), who underwent a Ladd's procedure. Of these patients, 80.0% ($n = 2261$) were treated at a CH. Patient characteristics are presented in Table 1, stratified by hospital type. Patients had similar age distributions between both hospital types. When considering all patients, 37.7% of patients undergoing Ladd's procedure for malrotation were less than one month of age, 34.2% were 1–11 months of age, and 28.1% of patients were 12 months or older. Patients were more likely to require non-elective surgery at NCH (68.0% vs. 57.5%, $p < 0.001$), while admission type was missing more frequently in CH (15.5% vs. 12.7%, $p < 0.001$).

Table 1
Summary statistics for children undergoing Ladd's procedure for malrotation, stratified by hospital designation.

Variable	Non-Children's Hospital ($n = 566$)	Children's Hospital ($n = 2261$)	p Value
Age			0.11
<1 month	40.6%	37.0%	
1–11 months	30.6%	35.1%	
≥ 2 months	28.8%	27.9%	
Sex (male)	57.5%	56.1%	0.54
Race			<0.001
White	48.8%	40.8%	
Black	10.2%	10.7%	
Hispanic	15.9%	13.4%	
Other	7.8%	7.5%	
Missing	17.3%	27.6%	
Charlson Comorbidity Index			0.15
0	94.7%	92.3%	
1	4.6%	6.6%	
2+	0.7%	1.1%	
Admission type			<0.001
Elective	19.3%	27.0%	
Nonelective	68.0%	57.5%	
Missing	12.7%	15.5%	
Operative details			
Volvulus	6.9%	7.8%	0.47
Hospital type			
Teaching	70.3%	96.3%	<0.001
Median household income for ZIP[a] code			<0.001
0–25th percentile	24.2%	24.1%	
26th–50th percentile	25.0%	25.7%	
51st–75th percentile	25.5%	24.9%	
76th–100th percentile	25.3%	25.2%	
Payer status			0.96
Medicaid	43.4%	44.5%	
Commercial	51.2%	49.9%	
Other	5.5%	5.6%	

[a] ZIP—Zone Improvement Plan.