



# Influence of hospital-level practice patterns on variation in the application of minimally invasive surgery in United States pediatric patients ☆☆☆



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## ABSTRACT

**Background:** Although disparities in access to minimally invasive surgery are thought to exist in pediatric surgical patients in the United States, hospital-level practice patterns have not been evaluated as a possible contributing factor. **Methods:** Retrospective cohort study using the Kids' Inpatient Database, 2012. Odds ratios of undergoing a minimally invasive compared to open operation were calculated for six typical pediatric surgical operations after adjustment for multiple patient demographic and hospital-level variables. Further adjustment to the regression model was made by incorporating hospital practice patterns, defined as operation-specific minimally invasive frequency and volume.

**Results:** Age was the most significant patient demographic factor affecting application of minimally invasive surgery for all procedures. For several procedures, adjusting for individual hospital practice patterns removed race- and income-based disparities seen in performance of minimally invasive operations. Disparities related to insurance status were not affected by the same adjustment.

**Conclusion:** Variation in the application of minimally invasive surgery in pediatric surgical patients is primarily influenced by patient age and the type of procedure performed. Perceived disparities in access related to some socioeconomic factors are decreased but not eliminated by accounting for individual hospital practice patterns, suggesting that complex underlying factors influence application of advanced surgical techniques.

**Level of evidence:** II.

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Minimally invasive surgical techniques were first introduced more than twenty years ago to pediatric surgeons in the United States [1]. Over time, these techniques have become more widely adopted as training programs have begun teaching advanced laparoscopic skills, and new technology and smaller instruments have become available [2,3]. These advances have made minimally invasive surgery (MIS) possible in even the smallest of babies [4]. Minimally invasive surgery is generally thought to confer the same advantages over open surgery in the pediatric population as in adults, i.e. fewer complications, shorter length of stay (LOS), and improved quality of life [5–7].

Adult studies have shown disparities in access to MIS that appear to correlate with hospital factors such as location, teaching status, and private versus government funding [8]. Discrepancies in access have also been evaluated in relation to patient factors such as age, comorbidities, insurance, county of residence, and other demographics [9,10]. A few studies in the pediatric surgical literature have found similar themes,

but none has accounted for hospital-level frequency of MIS application as a possible factor [11,12].

This study examines the influence of patient- and hospital-level factors on the application of MIS in pediatric patients. In addition, we incorporate hospital-level practice patterns (operation-specific minimally invasive frequency and volume) to provide further standardization of comparisons.

## 1. Methods

The study protocol and use of the Healthcare Cost and Utilization Project's Kids' Inpatient Database (KID) were reviewed by the Institutional Review Board of the University of Buffalo and need for informed consent was waived (UB FAID: FWA00008824).

### 1.1. Study design

A retrospective cohort study was performed using the Healthcare Cost and Utilization Project's Kids' Inpatient Database (KID). The KID contains data from approximately 3 million pediatric discharges per year, making it the largest publicly available all payer pediatric inpatient database in the United States [13]. For the present study, we utilized the

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2012 database, which includes a sample of pediatric discharges from more than 4000 community hospitals in 44 states across the U.S. All patients less than 19 years of age were included. We chose six common pediatric surgical procedures that carry Current Procedural Terminology (CPT) codes for open and minimally invasive approaches: appendectomy, fundoplication, partial and total abdominal colectomy, lung lobectomy and enterolysis.

### 1.2. Exposures and outcomes

Exposures of interest included both hospital and patient factors. Hospital factors were children's vs nonchildren's hospital, urban vs rural location and teaching vs nonteaching designation. Patient factors included age, ethnicity, private vs government insurance, and zip code income quartile. In addition, individual hospital frequency and volume of minimally invasive operations were included as a variable of interest. The primary outcome of interest was utilization of minimally invasive surgery.

### 1.3. Statistical analysis

Univariate analysis using Pearson's chi-square test (or Fisher's exact test for calculations involving less than five patients) was used to compare patient and hospital demographics for patients undergoing MIS [14]. Exposures were incorporated into a logistic regression for multivariable analysis. Odds ratios of undergoing a minimally invasive compared to open operation were calculated after adjustment for multiple patient demographic and hospital-level variables. All statistical analyses were performed using STATA version 12.1 (StataCorp, College Station, Tex.) For the multivariable modeling, 2-sided  $p$  values  $<0.05$  were considered statistically significant.

## 2. Results

An estimated total of nearly 100,000 pediatric surgical procedures comprising the six of interest were identified in the year 2012 (appendectomy, 76,905; partial colectomy, 3199; total abdominal colectomy, 494; enterolysis, 7458; fundoplication, 6017, and lung lobectomy, 996). Table 1 summarizes the hospital and patient demographics for patients who underwent open and minimally invasive procedures. Overall, there was a larger proportion of males in the cohort than females. A greater proportion of patients undergoing minimally invasive appendectomies (71.3%,  $p < 0.001$ ), partial colectomies (80.8%,  $p < 0.001$ ), total abdominal colectomies (89.1%,  $p < 0.001$ ) and enterolysis (66.2%,  $p < 0.001$ ) was in the oldest subgroup (10–18 years old), while a greater proportion of patients undergoing minimally invasive fundoplication (53.5%,  $p < 0.001$ ) and lung lobectomy (49.2%,  $p < 0.001$ ) was in the youngest subgroup ( $<1$  year of age).

Non-Hispanic white patients comprised a significantly greater proportion of those undergoing minimally invasive appendectomy (52.4%,  $p < 0.001$ ) and partial colectomy (65.2%,  $p < 0.001$ ). A higher proportion of patients undergoing minimally invasive partial colectomy (66.1%,  $p < 0.001$ ), total abdominal colectomy (67.3%,  $p < 0.001$ ) and enterolysis (51.9%,  $p < 0.001$ ) had private insurance. A greater proportion of patients who received minimally invasive appendectomy (26.1%,  $p < 0.001$ ), enterolysis (27.6%,  $p < 0.001$ ) and fundoplication (30.2%,  $p < 0.001$ ) was in the highest income quartile.

In terms of hospital characteristics, overall the majority of MIS is performed in nonfreestanding children's hospitals (78.4%,  $p < 0.001$ ). Likewise, the majority of MIS is also performed in teaching hospitals (63.2%,  $p = 0.001$ ) and hospitals in an urban location (93.0%,  $p < 0.001$ ).

### 2.1. Multivariable analysis, patient and hospital factors

Adjusted odds ratios for undergoing a minimally invasive procedure based on patient demographic and hospital factors are listed in Table 2. This did not account for frequencies with which hospitals performed

minimally invasive surgery or overall hospital volumes. Females were significantly more likely to undergo laparoscopic appendectomy (OR 1.12 95% CI 1.07–1.17,  $p < 0.001$ ) and partial colectomy (OR 1.47, 95% CI 1.18–1.82,  $p < 0.05$ ) than males. Older patients were significantly more likely to undergo all types of minimally invasive surgery with the exception of lung lobectomy. Pediatric patients who underwent enterolysis, partial colectomy or total colectomy were significantly more likely to receive minimally invasive surgery when operated on at a freestanding children's hospital. Patients operated on at a freestanding children's hospital were also more than four times as likely to have minimally invasive appendectomy (OR 4.35, 95% CI 3.98–4.74,  $p < 0.001$ ) as those who underwent procedures at a nonfreestanding children's hospital. There was a significantly higher likelihood that patients operated on at urban teaching hospitals would receive minimally invasive appendectomy (OR 2.68, 95% CI 2.49–2.89,  $p < 0.001$ ) and enterolysis (OR 1.93, 95% CI 1.09–3.42,  $p < 0.05$ ) than those operated on at rural nonteaching hospitals. Living in the highest zip code income quartile increased the odds of receiving minimally invasive appendectomy (OR 1.39, 95% CI 1.29–1.49,  $p < 0.001$ ), partial colectomy (OR 2.73, 95% CI 1.96–3.81,  $p < 0.001$ ) and total abdominal colectomy (OR 3.25, 95% CI 1.50–7.02,  $p < 0.05$ ).

### 2.2. Adjustment for hospital practice patterns

In order to evaluate the influence of hospital practice patterns on MIS application variability, hospitals were categorized into quartiles according to their utilization frequency and volume of MIS for particular operations. Fig. 1 shows the frequency with which hospitals performed MIS operations. The highest hospital performers (p75) did less than half of their partial colectomies and enterolysis using MIS, but did almost no open total abdominal colectomies or appendectomies. The lowest performing hospitals (p25) did no minimally invasive partial colectomies or lung lobectomies. They did nearly 75% of their appendectomies using MIS. The greatest variation in performance of minimally invasive procedures between the highest and lowest performers was seen with lung lobectomy and total abdominal colectomy; the least variation was seen with lysis of adhesions and appendectomy. Hospital MIS frequency categories were then incorporated into the multivariable logistic regression model examining odds ratios for undergoing minimally invasive surgery for each of the six operations examined.

Fig. 2 illustrates what percentage of each procedure (of all those performed in the U.S.) is performed by hospitals in each quartile grouping of MIS utilization. The highest MIS utilization group (p75) received overall the largest share of each procedure, and hospitals in that group reached a maximum of receiving nearly 2% of all lung lobectomies done nationally. The lowest share of a procedure for hospitals in the 75th percentile was for appendectomy, receiving only 0.25% of all appendectomies performed. Hospitals in the 25th percentile of MIS utilization (p25) received overall the lowest share of all procedures. The greatest difference in shares of a procedure between the highest and lowest performing groups was for lung lobectomy; hospitals in the highest performing group did nearly 2% of all those done nationally, while hospitals in the lowest performing group did approximately 0.35%. The smallest difference was noted for appendectomy, with hospitals in all groups doing 0.25% or less.

### 2.3. Modified multivariable analysis, incorporating hospital practice patterns

Odds ratios for undergoing minimally invasive surgery after adjustment for the frequency with which hospitals perform each procedure and their case volume are shown in Table 3. Females remained significantly more likely to receive laparoscopic appendectomy (OR 1.15 95% CI 1.09–1.22,  $p < 0.001$ ) and partial colectomy (OR 1.48, 95% CI 1.14–1.93,  $p < 0.05$ ), and older patients were still more likely to receive all types of MIS except for lung lobectomy. Non-Hispanic white patients were no

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