Frequency and Variety of Inpatient Pediatric Surgical Procedures in the United States

WHAT'S KNOWN ON THIS SUBJECT: Pediatric surgery is performed in a variety of hospital types. General surgeons as well as fellowship-trained pediatric surgeons and surgical subspecialists perform inpatient operative procedures on infants and children. The distribution of procedures between specialists is not well characterized.

WHAT THIS STUDY ADDS: This study describes the demographics of pediatric surgery: the hospital type, the surgical procedures, and the quantity of inpatient pediatric surgery in the U.S. today. By implication, the data has much to inform health care about hospital and practitioner workforce.

OBJECTIVE: Pediatric surgical procedures are being performed in a variety of hospitals with large differences in surgical volume. We examined the frequency and variety of inpatient pediatric surgical procedures in the United States by hospital type and geographic region using a nationally representative sample.

METHODS: The 2009 Kids’ Inpatient Database for patients <18 years old was used to calculate surgical frequencies by using International Classification of Diseases, Ninth Revision, Clinical Modification, (ICD-9-CM) codes. We performed stratified analysis by hospital type (free-standing children’s hospital, children’s unit within an adult hospital, and general hospital) and geographic region (South, West, Midwest, Northeast) to compare frequencies of surgical procedures.

RESULTS: A total of 216,081 procedures were projected for 2009 with the top 20 procedures accounting for >90% of cases. As many as 40% of all pediatric inpatient surgical procedures are being performed in adult general hospitals. Infrequent complex low-volume neonatal surgical procedures (pulmonary for Hirschsprung disease, surgery for malrotation, esophageal atresia repair; and diaphragmatic hernia repair) were 6.8 to 16 times more likely to occur in a children’s hospital. Significant regional variation in procedure frequency rates occurred for appendectomy and cholecystectomy.

CONCLUSIONS: This report is the first to characterize pediatric surgical inpatient volume in the United States. Such data may influence the distribution of pediatric surgeons, number of trainees, and training curricula for pediatric surgeons, pediatricians, general surgeons and other surgical specialists who might operate on children. In addition, it raises the question of whether complex pediatric surgical procedures should preferably be performed at dedicated high volume children’s hospitals. Pediatrics 2013;132:e1466–e1472

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ABBREVIATIONS: ACGME—Accreditation Council for Graduate Medical Education ICD-9-CM—International Classification of Diseases, Ninth Revision, Clinical Modification KID—Kids’ Inpatient Database NSQIP—National Surgical Quality Improvement Program—Pediatric

Dr Samme planned and conceptualized the study, drafted the initial manuscript, and edited the final manuscript as submitted. Dr Bronsert performed all of the statistical analysis, created of all the tables, drafted the Methods section, and edited the final manuscript as submitted. Dr Morrato participated in the planning of the study, helped with statistical analysis and creation of tables, and edited the final manuscript. Dr Ziegler planned and conceptualized the study, participated in drafting the initial manuscript, and edited the final manuscript as submitted; and all authors approved the final manuscript as submitted.

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Pediatric general and thoracic surgery in the United States is now approaching the century mark since its origin. This historic beginning has generally been attributed to Dr. William Ladd (1880–1967), the first chief of surgery at Boston Children’s Hospital.

The specialty field of pediatric surgery is characterized by overlap with adult general and thoracic surgery as well as by pediatric medicine. The first association of pediatric surgeons subsequently occurred in 1947, with the creation of the Surgical Section of the American Academy of Pediatrics. Around that time, general surgeons or urologists performed most operations on infants and children in both children’s and adult general hospitals, and the operative morbidity and mortality rates were high.

Pediatric surgery has since established itself as an independent subspecialty; it has professional relationships with both pediatric as well as surgical professional associations, it sponsors its own Accreditation Council for Graduate Medical Education (ACGME)-approved training process, it has its own specialty board under the American Board of Surgery, and it has its own journals, multiple specialty-specific textbooks, independent surgical organizations, and research scholarship programs. In collaboration with the American College of Surgeons, it also has developed a National Surgical Quality Improvement Program—Pediatric (NSQIP-P), a risk-adjusted performance improvement program. As the specialty of pediatric surgery has matured, the outcomes for the surgical care of children have benefitted dramatically as a result of improved and more advanced surgical techniques, parenteral nutrition, specialized neonatal and pediatric ICUs, and pediatric anesthesia, to mention a few important advancements.

Continued improvement in contemporary morbidity and mortality after a pediatric surgical procedure has been confirmed by low complication rates seen in the recent NSQIP-P data. In 1975, Touloukian and Cole conducted a survey in Connecticut, which was an initial effort to identify pediatric surgical case volumes performed by pediatric surgeons and general surgeons; their survey suggested that a 50% share of complex neonatal/pediatric index cases were treated by general surgeons without pediatric surgery subspecialty training. This report was supported by an earlier report by Ravitch and Barton. These reports were the first to raise questions as to whether subspecialty training should be a requirement for surgeons who operate on children and if these pediatric surgical conditions should be limited to institutions capable of the highest level of care.

Our study seeks a contemporary answer to these questions and seeks to guide the pending discussions in health care delivery reform, manpower/workforce planning, and the ability to ensure the optimal competency of the surgical workforce, as well as the institutions in which the pediatric surgical patients are cared for. In this report we used the Kids’ Inpatient Database (KID), a nationally representative administrative database, to evaluate the demographics of surgical procedures performed on children in the United States. Others have used this database to assess pediatric postoperative mortality rates. We have used these data to assess the alignment of pediatric surgical resident training experience as it transitions to the practice situation. Ideally, such data will be able to identify surgical management and quality differences between pediatric and nonpediatric hospitals.

Our objectives with this study were as follows:

1. to estimate the scope of the contemporary pediatric surgeon’s practice, specifically identifying the most frequently performed inpatient operations on children;
2. to estimate the quantity and distribution of inpatient pediatric surgical cases in independent children’s hospitals and children’s units versus general hospitals without a children’s-specific unit; and
3. to estimate the pediatric surgical care across geographic regions.

METHODS
Study Type
A retrospective cohort study in children (<18 years of age) undergoing an inpatient surgical procedure was performed by using administrative admissions data obtained from the 2009 KID.

Data Source
The US health care system is made up of numerous hospitals and health care institutions. Combined, these institutions provide health care to the entire population in the United States. The 2009 KID is an 80% sample of pediatric discharges from 4121 community and nonrehabilitation hospitals in 44 states. KID is a component of the Healthcare Cost and Utilization Project. Each patient record in KID contains up to 15 diagnosis and procedure codes for a given hospital admission as defined by the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), along with age at admission, geographic region of the hospital as defined by the US Census Bureau, and hospital type as defined by the National Association of Children’s Hospitals and Related Institutions (see Supplemental Appendix 1). In addition, sampling weights, based on the survey design, were included and allowed for calculation of national estimates of...
operative frequency along with SEs of these estimates. KID does not capture outpatient surgery and patients in observation status admitted for <24 hours.

Operative Case Classification

This study was focused on procedures performed by the general pediatric surgeon in practice. However, we chose as the basis for case definition the pediatric surgical resident CPT code reference file maintained by the ACGME to which resident trainees submit their annual operative experience to a case log registry. Because the training curriculum includes experience in cross-specially pediatric surgical operations, such as pediatric urology, pediatric/adolescent gynecology, and pediatric cardiothoracic surgery, these procedures are included in the database and represent common procedures for pediatric surgeons in practice. However, the performing surgeon cannot be identified by surgical specialty. Surgical cases from KID were then categorized into 86 procedures by using the corresponding ICD-9-CM codes. A combination of procedure code, age at admission, and/or diagnosis codes was used to improve classification resolution; a few procedures were lumped together if this was considered acceptable by the authors (see Supplemental Appendix 1). Finally, endoscopic and trauma procedures (total of 10 procedures) along with 27 other procedures were determined to be unclassifiable using the available ICD-9-CM codes and therefore were not included in the analysis.

Analytic Strategy

Analyses were performed accounting for the complex survey design of the database (SAS 9.3; SAS Institute, Cary, NC), which allowed for 95% confidence intervals to be determined for surgical volume estimates. We performed a stratified analysis by hospital type (children’s hospital and children’s unit versus general hospital) and geographic region (South, West, Midwest, and Northeast) (see Supplemental Appendix 2 for the listing of these regions and their states and the excluded states). To adjust for population differences between regions, US Census population estimates for 2009 were used to estimate surgical volume per 1 000 000 children (<18 years old). In addition, to adjust for differences in surgical volume, procedures for each hospital type were used to estimate procedural volume per 10 000 surgical admissions.

RESULTS

Case Volumes

From >7 000 000 weighted inpatient discharges, 216 081 inpatient admissions involving operative procedures were projected for 2009. The top 20 procedures by quantity (Table 1) accounted for >90% of cases in 2009. Appendectomy is the most frequent procedure, by a good margin, although the data do not allow for stratification of the operation into acute uncomplicated, acute complicated, interval, or incidental appendectomy types. The most frequent neonatal case on the list is closure of an abdominal wall defect (omphalocele/gastroschisis closure), which ranks as number 18 in frequency. Of those remaining in the top 20, several, including patent ductus arteriosus ligation, pyloromyotomy, inguinal hernia repair, antireflux procedure, ostomy creation, and intestinal resection for congenital anomalies, may occur within the first 30 days of life. Most children undergoing inguinal hernia repair are discharged the same day (outpatient surgery) and are not captured by our data. This study reports, almost exclusively, inguinal hernia surgical volume for the neonate/infant population aged <6 months who require admission and monitoring postoperatively.

Case Volumes by Hospital Type

Hospital admissions involving complicated neonatal “index” surgical procedures, such as pull-through for Hirschsprung disease, congenital diaphragmatic hernia repair, esophageal atresia repair, and correction of malrotation, were much more likely to be performed at a children’s institution where pediatric surgical specialty care is readily available (Table 2). These procedures were 6 to 16 times more common in a children’s institution (Table 2). Many common pediatric surgery cases, specialized cases typically performed by a pediatric surgeon or a pediatric surgical subspecialist, were also much more commonly performed in a children’s institution (eg, gastrostomy/jejunostomy [15 times], chest-wall deformity correction [13 times], antireflux procedures [10 times], bladder/ureteral reconstruction [14 times], and pylopleasty [12 times]) (Table 1). Less complicated and more common general surgery procedures, such as appendectomy and cholecystectomy, are just as frequently performed in an adult general hospital as in children’s institutions (Table 1).

Our data reveal that 40% of procedures performed on inpatient pediatric surgery patients were performed in a general hospital in 2009 (Table 1).

Case Volumes by Geographic Region

There was large regional variation in procedure volume frequency rates for appendectomy and cholecystectomy (Table 3); however, no significant differences were found for antireflux procedures, gastroschisis/omphalocele closures, and pyloromyotomies. The regional differences in the frequency of appendectomies and cholecystectomies were notable in that the western
states had the highest operative frequencies for both of these procedures.

### DISCUSSION

This article reports on a comprehensive study into the demography of pediatric surgery in the United States. We have identified the most frequent pediatric surgery operative procedures by hospital type. A striking observation is that although some specific pediatric and even neonatal operative cases are included on this “most frequent” case list, the majority of the top 20 case types performed on children are common general surgery cases. General surgeons without subspecialty training in pediatric surgery may likely perform pediatric cholecystectomies and appendectomies just as well as subspecialty-trained surgeons, although their outcomes may depend on their continued experience, training, and competency as well as the hospital’s pediatric-centric support services. In recognizing that environment-of-care standards are important, the American Pediatric Surgical Association created a document that defines optimal standards for surgeons and institutions that participate in the surgical care of children.15 This document has
since been approved by the American College of Surgeon’s Board of Regents, and a future verification process is planned.

Major pediatric surgery index cases that define the specialty of pediatric surgery (eg, esophageal atresia repair, diaphragmatic hernia repair, intestinal atresia repair, repair of imperforate anus, and surgery for Hirschsprung disease) represent infrequent congenital anomalies typically diagnosed in the newborn period, with a predictable population frequency (1.2000 to 1.15.000). Currently, the United States birth rate remains flat and growth of the 0- to 18-year-old pediatric population continues at a slow 0.65% per year. Therefore, the absolute numbers of such index cases would be expected to increase at a similar slow rate.

Because these diagnoses occur at such a low incidence, they are infrequently seen in the operative case mix for any single surgeon. We have previously reported on this observation and its potential impact on “continued competency” of the pediatric surgeon.

Recently, several articles have been published that suggest a volume-outcome relationship for certain procedures. Individual surgeon case volumes have each been proven to affect surgical outcomes. However, this finding has been disputed in an article that examined the Leapfrog initiative in the state of Washington. Currently, a volume-outcome relationship has not been clearly established for many pediatric surgical procedures, although it has been established for congenital heart surgery and for congenital diaphragmatic hernia. It is anticipated that the NSQIP-P will be able to answer the question of volume-outcome relationships for noncardiac pediatric surgical specialties.

We found that 40% of all pediatric inpatient surgical cases are being performed in an adult general hospital. It is not possible to know from KID if the operation was performed by a sub-specialty-trained pediatric surgeon or a general surgeon without pediatric subspecialty training. Most general hospitals do not have pediatric surgeons on staff; however, if a general hospital has a level 3 NICU, a common status for many regional referral centers, there is a requirement that fellowship-trained pediatric surgeons be on staff to cover surgical emergencies in the NICU, but these surgeons may not cover children outside the NICU. A children’s unit within an adult hospital or a freestanding children’s hospital will almost exclusively be staffed by fellowship-trained and board-certified pediatric surgeons.

Our study has confirmed that, in the United States, a child may undergo an inpatient operative procedure at several different types of institutions. However, our data reveal a large number of inpatient pediatric surgical operative procedures being performed in adult general hospitals (40%; see Table 1). Despite the maturation of our specialty and the considerable growth in the number of pediatric surgeons, this practice pattern is true in the United States today as shown both by our data as well as a recent workforce report by Nakayama et al. In this workforce survey from the membership of the American Pediatric Surgical Association, it was estimated that 21% of surgery on children is performed by general surgical providers. However, it is likely that pediatric surgeons perform the more complex cases.

The trend over the past 2 decades has been toward training surgical subspecialists with a curriculum that limits their general surgery training. Urology, otolaryngology, plastic surgery, and cardiac surgery are specialties that

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**TABLE 3 Selected Procedures by US Census-Defined Region**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Weighted Frequency</th>
<th>Per 1 000 000 Children* (95% CI)</th>
<th>P*</th>
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<tbody>
<tr>
<td>Appendectomy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>27 168</td>
<td>871.7 (829.4–1114.0)</td>
<td>.0001</td>
</tr>
<tr>
<td>West</td>
<td>25 470</td>
<td>1403.8 (1303.4–1604.2)</td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>14 557</td>
<td>907.2 (785.3–1019.1)</td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>14 653</td>
<td>1181.8 (1012.2–1351.4)</td>
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<tr>
<td>Pyloromyotomy</td>
<td></td>
<td></td>
<td>.35</td>
</tr>
<tr>
<td>South</td>
<td>4669</td>
<td>167 (127.7–206.4)</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>2133</td>
<td>117.6 (81.2–153.9)</td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>2583</td>
<td>160.9 (117.6–204.5)</td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>1941</td>
<td>156.5 (99.7–213.3)</td>
<td></td>
</tr>
<tr>
<td>Cholecystectomy</td>
<td></td>
<td></td>
<td>.0001</td>
</tr>
<tr>
<td>South</td>
<td>3028</td>
<td>108.3 (94.3–122.3)</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>2356</td>
<td>128.8 (107.7–149.8)</td>
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<tr>
<td>Midwest</td>
<td>1199</td>
<td>74.7 (62.4–87.0)</td>
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<tr>
<td>Northeast</td>
<td>1116</td>
<td>90 (71.3–108.7)</td>
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<tr>
<td>Antireflux procedure</td>
<td></td>
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<td>.49</td>
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<tr>
<td>South</td>
<td>2474</td>
<td>88.5 (67.0–110.0)</td>
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<tr>
<td>West</td>
<td>1277</td>
<td>70.4 (47.1–93.6)</td>
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<tr>
<td>Midwest</td>
<td>973</td>
<td>90.8 (68.7–116.0)</td>
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<tr>
<td>Northeast</td>
<td>651</td>
<td>50.9 (25.5–76.4)</td>
<td></td>
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<tr>
<td>Gastroschisis/omphalocele</td>
<td></td>
<td></td>
<td>.20</td>
</tr>
<tr>
<td>South</td>
<td>763</td>
<td>27.3 (21.1–33.5)</td>
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<tr>
<td>West</td>
<td>524</td>
<td>28.9 (21.0–38.7)</td>
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<tr>
<td>Midwest</td>
<td>419</td>
<td>26.1 (17.5–34.7)</td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>208</td>
<td>16.8 (9.2–24.4)</td>
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* Procedural volume per 1 000 000 children ≥ 18 years old.
* Rao Scott χ² test for difference in surgical volume rates between regions were adjusted for multiple tests by the Bonferroni method.
medical school. All of these specialties now have fellowships in pediatric subspeciality training. The diffusion of a specialty such as pediatric surgery to alternate care providers further confounds the complex workforce issues in surgery. The pediatric surgery workforce has been closely monitored by American pediatric surgery organizations since 1975.\textsuperscript{15,24–27} The surgical workforce is critically important when contemplating healthcare reform, physician training numbers, centralization of pediatric surgery care, and physician geographic distribution. The concomitant development of several maternal-fetal surgical centers throughout the United States suggests that regionalization to such centers may be necessary to ensure optimal maternal as well as fetal outcomes. For the diagnosis of myelomeningocele, fetal surgery has proven to be beneficial for select patients in highly specialized centers.\textsuperscript{28}

Over the past 25 years, the pediatric surgeon workforce growth rate has been double that of the pediatric population growth. The ACGME can accurately document the number of pediatric surgery trainees. The American Board of Surgery will be able to provide information on board certification. However, the same cannot be said for the assessment of the actual number of practicing pediatric surgeons, where estimates range from as few as 750 to >1100.\textsuperscript{15,24} Even less is known about the surgical case volumes that each surgeon is experiencing and the quality of that volume.

This report surprisingly has also identified regional differences in selected case volumes within 4 geographic regions of the United States (Table 3). Explanations might include regional operative volumes.\textsuperscript{30,31} However, complex procedures in hospitalized inpatients will be captured by KID. KID does not capture patients in observation status (<24-hour admissions).

This study is the first published report, to our knowledge, that uses a national database in the United States to identify the most commonly performed inpatient pediatric surgical procedures. It has answered questions regarding frequency and location of pediatric surgical hospital admissions. Our study also raises several critical discussion points, which include questions regarding the pediatric surgical workforce: How many pediatric surgeons are currently in practice? What is the number and type of cases they perform yearly? What defines an operation that requires a pediatric surgeon, and conversely, which cases can be performed by general surgeons? Finally, should the government mandate regionalization for select pediatric surgical patients with complex conditions?

Our study reveals that there is a high volume of general pediatric surgery being performed every year in the United States. These operations are almost equally divided between specialized pediatric institutions and general hospitals. Complex cases are more commonly taken care of at specialized pediatric institutions where fellowship-trained pediatric surgeons and pediatric subspecialists are available. The impact of this report lies in its influence on the pediatric surgical workforce and how to define competency and clinical excellence. These data suggest a role for surgical care regionalization to ensure the best surgical outcomes for young children and children with complex conditions.

CONCLUSIONS

Our study characterizes the pediatric surgical workforce.

1. KID is an administrative database with results dependent on appropriate case coding; KID is an 80% case sample, and case retrieval is from 44 states in 2009 rather than the entire 50 states. Second, our study is a retrospective cohort study of the complete KID database from 2009, the most recent year data were available at the time of our study. Third, we are assessing only inpatient surgical procedures, which limits the overall case numbers by ~50%, a figure typical for pediatric general and thoracic surgery, to as much as 80% for otolaryngology when the ambulatory surgical volume is contrasted with inpatient
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