ANESTHESIOLOGY

Availability of Inpatient Pediatric Surgery in the United States

Michael L. McManus, M.D., M.P.H.,
Urbano L. França, Ph.D.

ANESTHESIOLOGY 2021; 134:852–61

EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Pediatric hospital care in the United States has been naturally consolidating.
- In 2015, the American College of Surgeons launched its Children's Surgery Verification Quality Improvement Program to promote regionalization and improve the quality of pediatric surgical care.

What This Article Tells Us That Is New

- Before the start of the American College of Surgeons Children's Surgery Verification Quality Improvement Program, pediatric surgical care was highly concentrated, with less than 7% of hospitals responsible for more than 80% of procedures. Nearly half of all pediatric procedures undertaken outside of these centers involved teenagers.

ABSTRACT

Background: In 2015, the American College of Surgeons began its Children's Surgery Verification Quality Improvement Program, promulgating standards intended to promote regionalization and improve pediatric surgical care. It was hypothesized that pediatric surgical care was already highly regionalized and concentrated before implementation of the program. This study aimed to demonstrate this by describing the sites and volume of nonambulatory pediatric surgery.

Methods: A two-part, retrospective, cross-sectional analysis was performed. First, six all-encounter state inpatient data sets (Arkansas, Florida, Kentucky, Maryland, and New York from the Healthcare Cost and Utilization Project and Massachusetts from the Center for Health Information) were used to evaluate all procedures performed within specific hospitals in 2014. Next, a national sample data set (2016 Kids' Inpatient Database) was used to determine the generalizability of the single state results. All acute care hospital admissions for patients less than 18 yr of age were included to describe the nature and location of all surgical procedures therein by patient age, surgical specialty, procedure type, and hospital service breadth.

Results: Within the six study states, there were 713 hospitals, of which 635 (89.1%) admitted patients less than 18 yr old, and 516 (72.4%) reported pediatric procedures. Among these, there were 9 specialty hospitals and 39 hospitals with services comparable to independent children's hospitals. Of 153,587 procedures among 1,065,655 pediatric admissions, 127,869 (83.3%) took place within these 48 centers. This fraction decreased with age (89.9% of patients less than 2 yr old and 68.5% of 15- to 17-yr-olds), varied slightly by specialty, and was similar across states. Outside of specialized centers, teenagers accounted for 47.4% of all procedures. Within the national data sample, the concentration was similar: 8.7% (328 of 3,777) of all hospitals admitting children were responsible for 90.1% (793,905 of 881,049) of all procedures, with little regional variation.

Conclusions: Before the American College of Surgeons Children's Surgery Verification Quality Improvement Program, the vast majority of pediatric nonambulatory surgeries were already confined to a small subset of high-capability and specialty centers.

(ANESTHESIOLOGY 2021; 134:852–61)

In the United States, pediatric hospital care is consolidating, and definitive treatment for many common medical conditions now requires referral to large, specialized referral centers.[1–3] This trend carries important implications for network adequacy, where adult measures are inadequate for children[4]; for emergency management systems, where ambulances must travel further with pediatric patients[5,6]; and for tertiary centers, where crowding results.[7–10]

Pediatric surgical care is also consolidating.[11–13] In general surgery, this is true for the care of both younger and older children.[14,15] In otolaryngology, it is true even of the most frequently performed pediatric procedure, adenotonsillectomy.[16] In orthopedics, it has progressed to bring workforce concerns because common nonoperative conditions are increasingly referred to specialists.[17]

After reviewing the published literature, the American College of Surgeons' (Chicago, Illinois) Task Force for Children's Surgical Care identified neonates, children requiring intensive care, seriously injured children and adolescents, and children with congenital heart disease among those most certainly benefitting from specialized care.[18] Estimating at the time that approximately one third of neonates received surgical care for high-risk conditions outside of pediatric hospitals or units, the task force developed consensus standards of care, and the American College of Surgeons established a Children's Surgery Verification

This article is featured in "This Month in Anesthesiology," page A1. This article is accompanied by an editorial on p. 826. Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org). This article has an audio podcast. This article has a visual abstract available in the online version.

Submitted for publication May 28, 2020. Accepted for publication March 1, 2021. Published online first on April 8, 2021. From Boston Children's Hospital, Department of Anesthesiology, Critical Care and Pain Medicine, Division of Critical Care, Boston, Massachusetts (M.L.M., U.L.F.); and Harvard Medical School, Boston, Massachusetts (M.L.M., U.L.F.).

 Anesthesiology 2021; 134:852–61. DOI: 10.1097/ALN.0000000000003766

Quality Improvement Program to evaluate care within specific hospitals. The pilot phase of this program was launched with six centers in 2015, and the program was officially released in January 2017.[19]

Maintenance of pediatric surgical programs is challenged by many factors, including geographic variation in the distribution of pediatric surgical and anesthesia specialists, the small case volume relative to adults, and the high proportion of Medicaid coverage.[20,21] Because these and other forces drive uncontrolled consolidation, a sufficient number of pediatric surgical sites must be maintained to ensure adequate access to care. We hypothesized that pediatric surgical care across the United States was already highly concentrated within specialized centers before implementation of the American College of Surgeons Children's Surgery Verification Quality Improvement Program. If so, improving care also requires improving the systems that permit children to access these centers. To test our hypothesis, we undertook a two-part study that first uses all-encounter data sets from six representative states to determine where pediatric inpatient surgery takes place and then uses a national sample data set to evaluate the generalizability of that data.

Materials and Methods

Design

This was a two-part, retrospective, cross-sectional analysis focused upon nonambulatory pediatric surgery. We first pursued a detailed analysis of hospital inpatient all-encounter data sets from six representative U.S. states. We then sought to confirm the generalizability of that analysis using national sample data. These studies used no personally identifiable health information. A waiver of informed consent and data use approval was obtained from the Boston Children's Hospital Committee on Clinical Investigation. Subsequent work followed Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

State Selection

For the state selection process, state areas and census information were obtained directly from the U.S. Census Bureau (Washington, D.C.)[22,23] or indirectly from the Kaiser Family Foundation (San Francisco, California).[24] Hospital referral regions and service areas were obtained from the Dartmouth Atlas (Lebanon, New Hampshire).[25]

We ultimately selected Arkansas, Florida, Kentucky, Maryland, Massachusetts, and New York for in-depth analysis. These six states were drawn from five separate U.S. Census Bureau divisions and were chosen for their representative population density, mix of rurality, range of hospital service areas, and presence or absence of freestanding children's hospitals. For example, 2014 pediatric population density (children aged 0 to 18 yr per square mile) in the entire United States ranged from 0.28 children per square mile (Alaska) to 239.68 children per square mile (New Jersey). States included for study here included two high-density states (Massachusetts, 136.17 children per square mile; Maryland, 112.61 children per square mile), two medium-density states (New York, 79.89 children per square mile; Florida, 64.07 children per square mile), and two low-density states (Kentucky, 25.67 children per square mile; Arkansas, 13.84 children per square mile). Rural census among U.S. states ranged from 0 to 82.56% in 2014 and from 16.75 to 71.65% among states here. The role of children's hospitals nationally and in the study states is detailed below. Finally, in 2014, the number of hospital service areas and hospital referral regions within all U.S. states ranged from 1 to 203 (interquartile range, 30 to 91) and 1 to 28 (interquartile range, 4 to 11), respectively, whereas those in the subject states ranged from 30 to 114 (interquartile range, 52 to 102) and 5 to 19 (interquartile range, 6 to 15).

State Data

We began with state Inpatient and Emergency Department[26] data sets from the Healthcare Cost and Utilization Project (Rockville, Maryland) along with Acute Hospital Case Mix data from the Massachusetts Center for Health Information and Analysis (Boston, Massachusetts).[27] Unlike the Kids' Inpatient Database[28] or data from the Pediatric Health Information System,[29] these are comprehensive data sets containing information on all admissions to all hospitals within a given state. For hospital analyses, we considered all admissions to all hospitals during the same year and selected 2014 as the last full year before introduction of the American College of Surgeons Children's Surgery Verification Quality Improvement Program. For consideration of pediatric procedures and care, we included only those admissions of patients less than 18 yr of age and excluded 324 admissions (0.003%) where age was not available.

National Sample Data

Next, for national estimates, we analyzed the 2016 Healthcare Cost and Utilization Project Kids' Inpatient Database.[28] This contains information from 3 million pediatric discharges and is the largest, most recent publicly available pediatric inpatient care database in the United States. The Kids' Inpatient Database samples encounters among patients under 21 yr of age from 4,200 hospitals across all states except Alabama, Idaho, and New Hampshire. Unlike the state inpatient data sets, it does not identify hospitals and lacks the granularity available in all-encounter data sets. As such, it cannot be used to study specific hospitals or states and must be weighted to yield national and regional estimates (see "Statistical Analysis," below). Because only pediatric discharges are sampled, it offers no information concerning hospitals that do not admit children. Finally, as a sample data set, it may not include some specific procedures that are done with low frequency.

Analysis

Procedures. We included all procedure fields within the aforementioned data sets to identify every procedure performed during every inpatient admission. Procedures were specified by International Classification of Diseases, Tenth Revision (ICD-10), within the 2016 Kids' Inpatient Database or International Classification of Diseases, Ninth Revision–Clinical Modification (ICD-9-CM) within state data sets. We also included all procedures specified by American Medical Association (Chicago, Illinois) Current Procedural Terminology coding. We additionally categorized each procedure according to Healthcare Cost and Utilization Project Clinical Classification Software single and multilevel categorization schemes.[30]

For inclusiveness, we began by giving attention to all procedures regardless of the need for or modality of anesthesia. We then excluded minor diagnostic procedures (*e.g.*, "diagnostic spinal tap"), nonoperative procedures (*e.g.*, "cancer chemotherapy" and "nasogastric tube"), percutaneous vascular catheterizations, non–operating room therapeutic procedures, oral/dental services, circumcision, obstetrical codes related to childbirth, dialysis, cardiac catheterization, and "miscellaneous diagnostic and therapeutic procedures." Finally, we removed three common intensive care bedside procedures: laryngoscopy/tracheoscopy (ICD-9-CM 31.42), insertion of intercostal catheter (ICD-9-CM 34.04), and incision of lung (ICD-9-CM 33.1, often applied to needle thoracentesis).

For separate analysis of major infant surgery, we followed Baxter *et al.*[31] selecting children less than 1 yr of age with one of the following five conditions among their first five diagnosis codes: necrotizing enterocolitis (ICD-9-CM 777.5, 777.50, 777.51, 777.52, and 777.53), congenital diaphragmatic hernia (ICD-9-CM 756.6), patent ductus arteriosus (ICD-9-CM 747.0), esophageal atresia/tracheoesophageal fistula (ICD-9-CM 750.3), and gastroschisis/omphalocele (ICD-9-CM 756.79, 756.72, and 756.73)

Hospitals. To understand the sites of surgery within state databases, we identified the hospital wherein each procedure was performed and classified it according to its Hospital Capability Index. This index is designed to capture the range of conditions for which a hospital routinely provides definitive care.[32] As a measure of the breadth and depth of hospitals services, it has been successfully applied in previous studies[2,3,15,32–34] and can be stratified by variables of interest such as age, sex, race, or insurance status. For the Hospital Capability Index calculation, primary admitting diagnosis ICD-9-CM codes are mapped to one of the 266 conditions specified by the Healthcare Cost and Utilization Project Clinical Classification. For every Clinical Classification Software condition, a probability of care completion is then calculated [number admitted/(number admitted + number transferred)], and the probabilities are averaged across all conditions. In this averaging, conditions that are never encountered are assigned an admission probability of zero. As a result, hospitals that encounter, admit, and care for a broad range of conditions with few transfers to other institutions return Hospital Capability Indices near 1. Hospitals with lower Hospital Capability Indices care for a narrower range of conditions and/or more frequently transfer patients for a higher level of care. The Hospital Capability Index carries no quality, capacity, or volume information and, because of rounding, specialty hospitals encountering only one or two conditions may return Hospital Capability Indices of zero.

Pediatric *versus* adult hospital capabilities may be calculated and compared through age stratification.[2,3,34] When stratifying by age, adult Hospital Capability Index denotes calculations based only upon adult encounters, and the pediatric Hospital Capability Index reflects calculations based only upon pediatric (less than 18 yr old) encounters. From this perspective, large general hospitals that care for adults with a broad range of conditions but do not admit children will carry high adult Hospital Capability Indices and low pediatric Hospital Capability Indices. Conversely, large children's hospitals that care for children with a wide range of conditions but admit fewer patients more than 18 yr of age will carry large pediatric Hospital Capability Indices and low adult Hospital Capability Indices. Although the pediatric Hospital Capability Index may vary widely among hospitals, independent children's hospitals studied over multiple years have returned pediatric Hospital Capability Indices of 0.75 or higher.[2,3,15,32,34]

For the state analysis, hospitals were classified as general acute care hospitals, freestanding children's hospitals, specialty hospitals (defined as nongeneral hospitals providing single specialty care in areas such as orthopedics, cancer, otorhinolaryngology, ophthalmology, and burns), and rehabilitation hospitals.

Statistical Analysis

The data analysis and statistical plan were written after the data were accessed. The correlation among the fraction of cases performed in high-capability centers for each type of procedure was assessed using Pearson correlation. Descriptive results on hospital types, admissions, and surgeries are reported as absolute numbers and percentages within cohorts. Interstate variability in the fraction of admissions and surgeries and interhospital variability in the number of procedures are reported as medians and interquartile ranges. Raw procedure counts within the Kids' Inpatient Database were weighted using the DISCWT field values to yield national and regional estimates. All analyses were conducted using open data science tools running Python 3.7 (Python Software Foundation, python.org, accessed March 21, 2021) within Jupyter notebooks (Project Jupyter, jupyter.org, accessed March 21, 2021).[35,36]

Results

Pediatric Surgery within Individual States

Hospitals. In the six study states, there were 713 hospitals, 635 (89.1%) of which admitted patients under 18 yr of age

(Arkansas, 81; Florida, 180; Kentucky, 108; Massachusetts, 62; Maryland, 43; and New York, 161). Of these, 516 (81.3%) reported at least one procedure on a child less than 18 yr old, 416 (65.5%) on a child less than 13 yr old, 368 (57.9%) on a child less than 6 yr old , and 295 (46.5%) on a child less than 1 yr old. Most operating sites were low volume, with only 45.0% (232) reporting more than 25 total pediatric procedures and 21.3% (110) reporting more than 100. Among procedures in lower-volume hospitals, the majority involved teenagers, and those among younger children were primarily limited to appendectomy, tonsillectomy, fracture care, and superficial cutaneous operations.

Adult Hospital Capability Indices ranged from 0.01 (*i.e.*, hospitals primarily caring for children) to 0.98, and pediatric Hospital Capability Indices ranged from 0 (*i.e.*, hospitals never caring for children) to 0.97. Most hospitals admitting at least one child or adolescent (347 of 635, 54.6%) exhibited low pediatric capability (pediatric Hospital Capability Index of 0.25 or lower), many (130 of 635, 20.5%) had intermediate capability (pediatric Hospital Capability Index of higher than 0.25 and lower than 0.74), and a few (39 of 635, 6.1%) exhibited high capability (pediatric Hospital Capability Indices of 0.75 or higher). All six independent children's hospitals carried pediatric Hospital Capability Indices higher than 0.75 (range, 0.78 to 0.90). The nine specialty hospitals in the sample returned lower pediatric Hospital Capability Indices because of the narrower range of treated conditions.

As shown in figure 1, more than three quarters of all pediatric procedures took place within high-capability centers (121,034 of 153,587 cases, 78.8%). The number of such centers in each state ranged from less than 3 to 16. All but four reported more than 1,000 cases in the year. Among intermediate-capability hospitals, a specialized cancer hospital reported 776 cases, a large city hospital reported 679, and the remaining 128 hospitals all reported less than 650. Together, the six freestanding children's hospitals accounted for 27.1% of all pediatric cases (41,577), whereas the nine specialty hospitals accounted for 4.5% (6,835). Overall, high-capability, children's, and specialty hospitals accounted for only 6.7% of all hospitals (48 of 713) but reported 83.3% of all pediatric procedures (127,869 of 153,587). The relative surgical volume by hospital type is graphically presented in figure 2.

Procedures. There were 153,587 procedures among 1,065,655 pediatric admissions. The numbers of procedures by Clinical Classification Software multilevel category are provided in table 1. Overall, the single most common procedure was appendectomy (10,859 cases), followed in frequency by orthopedic procedures, interventional vascular procedures, tonsillectomy, upper endoscopy, and incision/drainage of skin or subcutaneous tissues. Counts of the 50 most common procedures are included in Supplemental Digital Content table 1 (http://links.lww.com/ALN/C580).

The vast majority of all pediatric procedure types were performed within high-capability centers. Apart from specialty hospitals, the fraction of procedures completed in these centers ranged from 96.3% of operations on the cardiovascular system to 65.2% of operations on the male genital organs (table 1). The proportion of all procedures in high-capability centers decreased with age: 89.9% of 0- to 2-yr-olds, 81.2% of 10- to 14-yr-olds, and 68.5% of 15- to 17-yr-olds.

Of the 25,718 pediatric procedures occurring outside of high-capability centers and specialty hospitals, 4,861 (18.9%) were appendectomies, 7,491 (29.1%) were orthopedic, 3,896 (15.1%) were cutaneous procedures (incision and drainage, suture, wound debridement), and 1,826 (7.1%) were otorhinolaryngologic (primarily

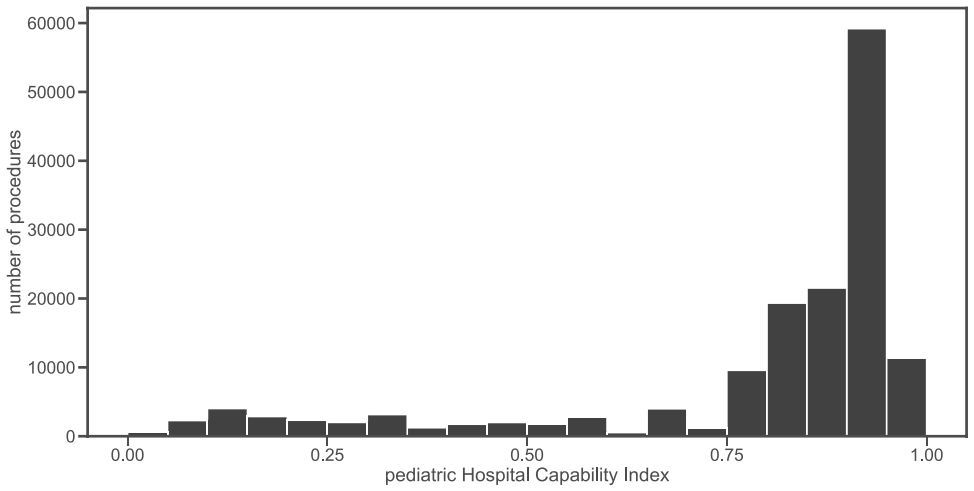

Fig. 1. 2014 distribution of pediatric procedures in Arkansas, Florida, Kentucky, Massachusetts, Maryland, and New York hospitals.

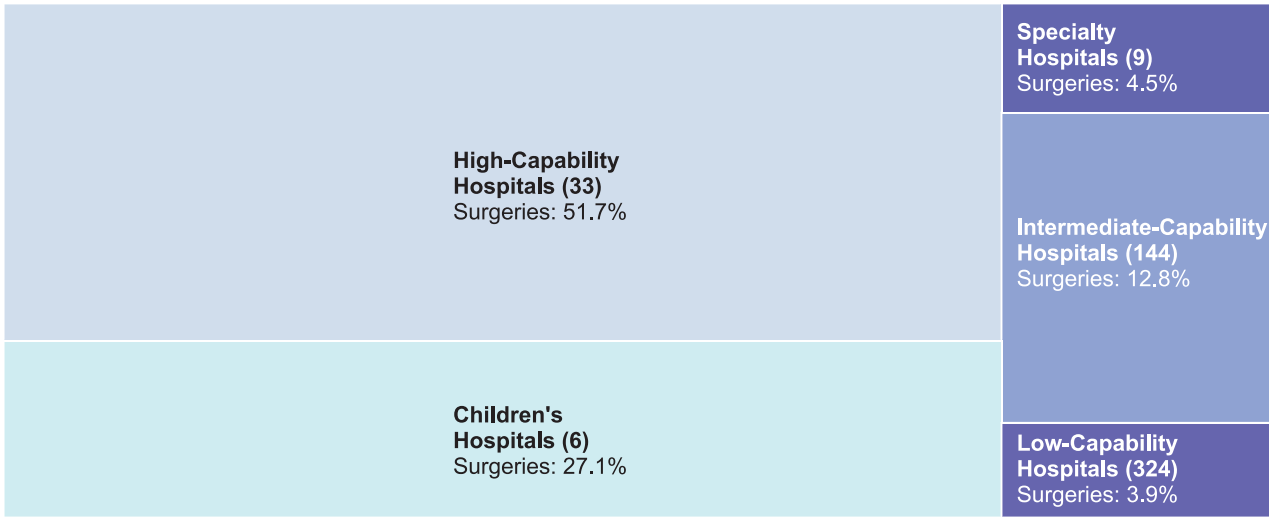

Fig. 2. Relative contribution of hospital types to total inpatient pediatric surgical volume in Arkansas, Florida, Kentucky, Massachusetts, Maryland, and New York in 2014. *Rectangle size* is proportional to the surgical volume in each hospital type. "High," "Intermediate," and "Low" refer to pediatric Hospital Capability Index of 0.75 or higher, 0.25 to 0.74, and less than 0.25, respectively (see text). Children's Hospitals are independent acute care hospitals caring for children, and Specialty Hospitals are independent inpatient facilities with limited practice scope.

tonsillectomy, adenoidectomy, and peritonsillar incision and drainage). Teenagers (ages 13 to 17 yr) accounted for about half of all procedures in these hospitals (47.4%), and only a quarter (26.8%) were among children under 5 yr. The 50 most common procedures reported outside of high-capability hospitals are reported in Supplemental Digital Content table 2 (http://links.lww.com/ALN/C580).

Procedures among Infants under 1 yr of Age

Across all six states, there were 33,150 infant procedures, 30,090 (90.8%) of which were completed in high-capability or specialty hospitals. Among high-capability hospitals, the median volume of infant cases was 616, but with a wide range (interquartile range, 297 to 925) and minimum volume of 50. Of the remaining 3,060 (9.2%) procedures, many were reported from facilities performing only occasional superficial surgeries (*e.g.*, skin incision and drainage or finger amputation), and about half (1,585, 51.8%) were completed in 18 institutions reporting more than 50 infant cases/yr. The most common nonsuperficial procedure reported from hospitals completing fewer than 50 infant cases/yr was pyloromyotomy (144). Infant procedures reported 11 or more times outside of high-capability centers are reported in Supplemental Digital Content table 3 (http://links.lww.com/ALN/C580).

With regard to major neonatal surgical conditions, there were 6,532 associated procedures, 93.8% of which took place in high-capability hospitals. Of the remainder, nearly all were reported from large centers, more than half with pediatric Hospital Capability Indices higher than 0.65.

Procedures among Children 1 to 6 yr of Age

There were 33,202 procedures involving preschool children age 1 to 6 yr, with 27,899 (84.0%) completed in specialty hospitals or high-capability hospitals. Of the remaining 5,303 procedures reported from 270 hospitals, 1,409 were orthopedic, 1,314 involved the skin, and 1,403 were otorhinolaryngologic (including 836 tonsillectomies and 269 myringotomies). Also reported in this group were 411 appendectomies, 134 respiratory procedures (*e.g.*, bronchoscopy), 40 vulvar/peroneal incisions, 16 orchidopexies, and a wide variety of lower-frequency procedures. Eleven hospitals in this group reported more than 100 cases involving children aged 1 to 6, but most reported only occasional procedures (median, 6 procedures; interquartile range, 2 to 17).

Interstate Variability

Across the study states, the fraction of all pediatric hospital admissions to high-capability hospitals varied from 15.5 to 47.4% (median, 29.3%; interquartile range, 20.5 to 38.3%; table 2). The fractions of all surgical cases completed in high-capability hospitals ranged from 65.2 to 87.7% (median, 82.2%; interquartile range, 77.6 to 86.8%). In all states, the fraction of surgeries completed in high-capability centers was highest among younger children. In five of six states, the fraction of cases performed in high-capability

Table 1. Distribution of Procedure Types by Hospital Pediatric Hospital Capability Index and Total Number of Inpatient Surgeries in Six States in 2014

Type of Operation	Pediatric Hospital Capability Index 0.0 to 0.25, %	Pediatric Hospital Capability Index 0.26 to 0.49, %	Pediatric Hospital Capability Index 0.50 to 0.74, %	Pediatric Hospital Capability Index 0.75 to 1.0, %	Surgeries, No.
Musculoskeletal system	5.3	6.8	7.6	80.4	41,761
Digestive system	6.2	7.8	9.2	76.8	33,867
Cardiovascular system	1.8	1.3	0.6	96.3	21,384
Integumentary system	7.7	11.8	11.1	69.4	13,762
Nose, mouth, or pharynx	2.8	6.7	9.5	81.1	10,524
Respiratory system	1.6	2.0	4.7	91.7	8,261
Nervous system	3.8	3.4	3.2	89.5	7,429
Urinary system	2.3	2.2	3.0	92.5	5,217
Ear	2.4	3.8	7.8	86.1	4,265
Eye	3.6	5.4	7.6	83.3	2,022
Female genital organs	7.7	9.9	10.0	72.4	1,821
Male genital organs	9.1	10.3	15.5	65.2	1,434
Hemic and lymphatic system	3.3	3.0	7.3	86.4	1,380
Endocrine system	1.0	2.0	2.2	94.8	460

Table 2. Surgical Locations in Six U.S. States

	Arkansas	Florida	Kentucky	Massachusetts	Maryland	New York
Hospitals						
Admitting children, No, (%)	81 (93.1)	180 (80.3)	108 (100)	62 (96.8)	43 (86.0)	161 (89.4)
Operating on children, No. (%)	47 (54.0)	143 (63.8)	80 (74.1)	61 (95.3)	41 (82.0)	144 (80.0)
High-capability facility, No. (%)	< 3 (< 3.4)	18 (8.0)	3 (2.8)	8 (12.5)	3 (6.0)	15 (8.3)
Admissions						
Admissions, No.	60,929	347,677	82,323	123,172	91,870	359,684
Admissions in high-capability facility, No. (%)	9,458 (15.5)	164,669 (47.4)	16,826 (20.4)	47,366 (38.5)	18,922 (20.6)	136,620 (38.0)
Patients less than 1 yr old						
Inpatient surgeries, No.	800	11,150	1,996	6,129	2,571	10,504
Inpatient surgeries in high-capability facility, No. (%)	631 (78.9)	10,483 (94.0)	1,866 (93.5)	5,913 (96.5)	2,301 (89.5)	8,896 (84.7)
Patients 1 to 5 yr old						
Inpatient surgeries, No.	719	9,660	1,455	11,789	2,468	10,018
Inpatient surgeries in high-capability facility, No. (%)	538 (74.8)	8,899 (92.1)	1,187 (81.6)	10,555 (89.5)	2,284 (92.5)	8,121 (81.1)
Patients 6 to 18 yr old						
Inpatient surgeries, No.	1,971	26,113	4,246	20,168	6,653	25,177
Inpatient surgeries in high-capability facility, No. (%)	1,104 (56.0)	21,722 (83.2)	3,109 (73.2)	16,935 (84.0)	5,286 (79.4)	18,039 (71.6)

"High-capability facility" refers to specialty hospitals or general hospitals with practice scope similar to freestanding children's hospitals (pediatric Hospital Capability Index of 0.75 or higher; see text).

centers was similar across specialties (Pearson correlation coefficients between 0.76 and 0.97), whereas the least populous state reported fewer case types and returned commensurately lower correlations (0.46 to 0.71).

Pediatric Surgery within a National Sample

The 2016 Kids' Inpatient Database contains information concerning 5,459,634 weighted inpatient encounters among children less than 18 yr old reported from 3,777 unique hospitals nationwide. In approximately two thirds of these admissions (3,675,864; 67.3%), the primary diagnosis related to birth ("single liveborn infant," *etc.*). Among all admissions, 3,010 hospitals (79.7%) reported 881,049 procedures, the most common being appendectomy (51,142 procedures). The geographic distribution of hospitals included 1,155 (30.6%) from the Midwest, 476 (12.6%)

from the Northeast, 1,408 (37.3%) from the South, and 738 (19.5%) from the West.

Even within the Kids' Inpatient Database, which excludes hospitals that do not admit children or deliver babies, procedures were extremely concentrated. Nationwide, 8.7% of all Kids' Inpatient Database hospitals (328 of 3,777) accounted for 90.1% of all procedures (793,905 of 881.049; fig. 3). Children's hospitals accounted for 10.6% (580,316) of admissions and 42.9% (377,666) of procedures. Only 169 hospitals (5.6%) reported more than 1,000 procedures. Approximately half of the hospitals reporting any pediatric procedures reported fewer than 15, whereas three quarters reported fewer than 60. Among those reporting few procedures, the vast majority were appendectomies, fracture treatment, minor oral and otolaryngological operations, and simple cutaneous procedures (*e.g.*, "repair scalp skin, external approach"). Slightly more than half of these (51.8%) were among teenagers, and many represented superficial newborn procedures (*e.g.*, "excision of tongue, external approach").

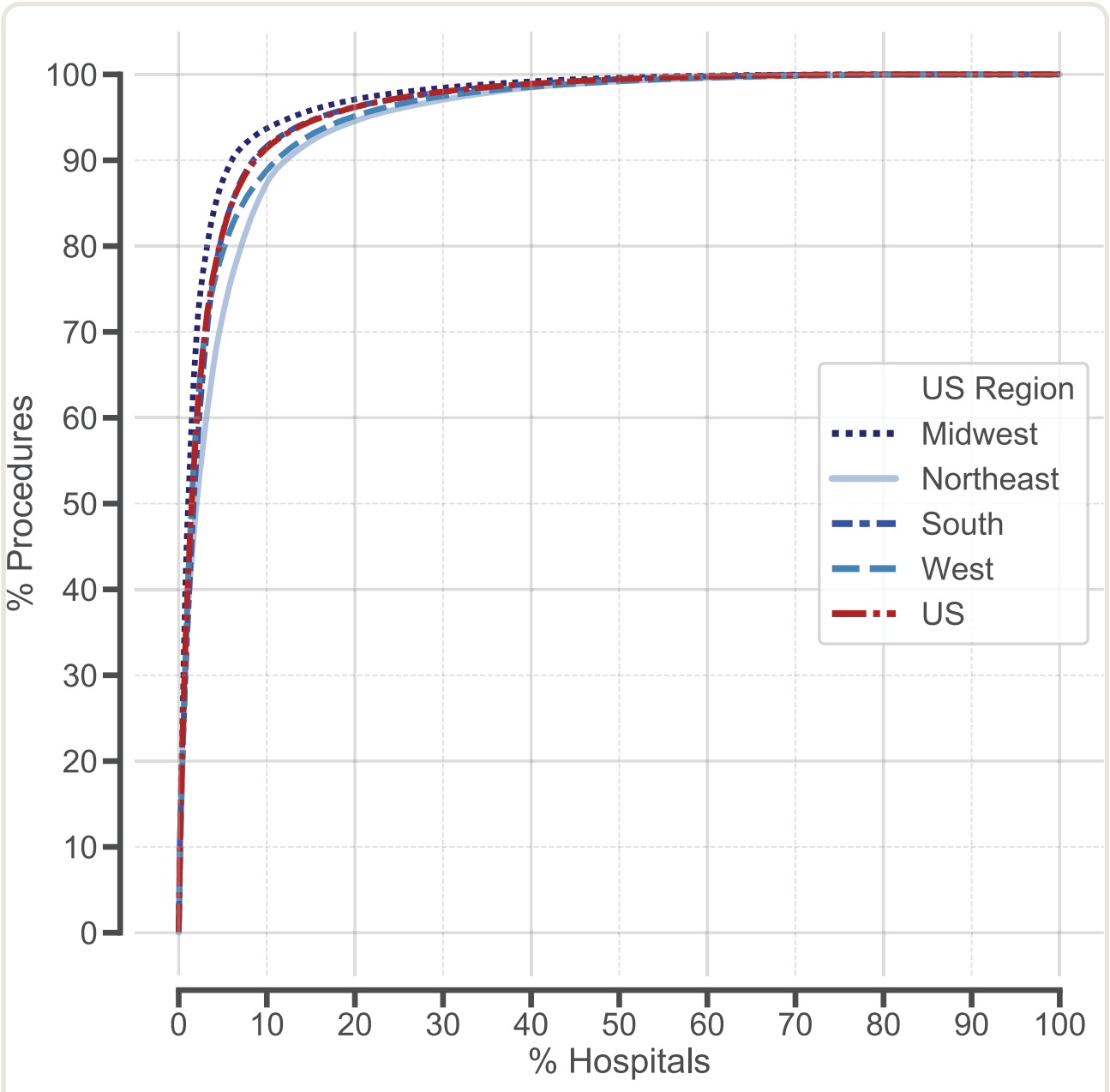

Fig. 3. National and regional concentration of care as measured by the cumulative percentage of pediatric surgical procedures being performed in hospitals within the 2016 Kids' Inpatient Database.

There was little regional variation in hospital case volume, with 50th and 75th percentile counts ranging from 11 to 22 and 36 to 90, respectively. Hospitals reporting more than 1,000 pediatric cases numbered 35 (4.1%) in the Midwest, 33 (7.7%) in the Northeast, 67 (6.1%) in the South, and 34 (5.4%) in the West.

Discussion

Here we present a two-part study of hospital-based pediatric surgery in the United States immediately before implementation of the American College of Surgeons Children's Surgery Verification Quality Improvement Program. Using all-encounter data from six representative states, we observe that the vast majority (more than 83%) of all pediatric procedures were being performed in a small subset (less than 7%) of specialty hospitals, independent children's hospitals, and large general hospitals with capabilities similar to children's hospitals. In the national data, we observed that less than 9% of hospitals reported more than 90% of procedures. These percentages were even higher among younger children, with most procedures undertaken outside of specialty and high-capability centers being relatively minor and superficial. With little variability, this was consistent across specialties, states, and national regions, suggesting that pediatric surgery was largely confined to major centers before the verification program.

Salazar *et al.*[11] used the 2000 to 2009 Kids' Inpatient Database to reveal that pediatric surgical care was shifting toward high-volume centers and that these centers accounted for 76% of admissions for the 500 most commonly performed procedures. Here, we use the 2016 Kids' Inpatient Database sample to show that this dynamic continued and state data to precisely characterize the hospitals involved. To give the most complete picture, we included nearly all therapeutic procedures regardless of frequency, magnitude, or anesthetic requirement. Our summary numbers, therefore, may significantly underestimate the actual concentration of procedures requiring anesthesia.

We classified hospitals according to the depth of their pediatric services and their function within larger hospital systems. Both attributes are compactly captured and quantified in the pediatric Hospital Capability Index, which is straightforwardly calculated from admitting diagnoses and transfer activity.[32] Using New York Statewide Planning and Research Cooperative System (Albany, New York) data from 2000, Kanter and Dexter[37] identified "comprehensive pediatric hospitals" in New York State *via* a combination of educational accreditation, clinical volume, and diversity of treated disorders. Here, without attention to overall volume or educational activity, we identified the same institutions as "high-capability" hospitals. In addition to readily identifying centers that function as children's hospitals, the pediatric Hospital Capability Index permits discrimination among less comprehensive centers and can be automated for calculation from public data sets.

Our findings suggest that fewer children were receiving unspecialized surgical care than was originally estimated by the American College of Surgeons' Task Force for Children's Surgical Care.[18] Our findings are consistent, however, with the increasing transfer rates among children with suspected surgical illness[15] and with emergency department observations that many pediatric transfers are for surgical consultation.[8] Our observation that nearly all high-capability hospitals completed more than 1,000 pediatric cases comports with the American College of Surgeons Children's Surgery Verification Quality Improvement Program definition of a level I center. This cutoff, however, did exclude some institutions that seem to be functioning as referral centers. With regard to high-risk neonatal conditions, Baxter *et al.*[31] estimated that more than one third of complex surgical neonates would need to relocate under the American College of Surgeons Children's Surgery Verification Quality Improvement Program. The data here suggest that this was already occurring before the program began.

Although it is too early to measure the impact of the American College of Surgeons Children's Surgery Verification Quality Improvement Program, it is difficult to imagine that it could significantly increase the degree of surgical regionalization that is occurring naturally. Whereas young children with trauma or neonates with complex conditions clearly benefit from multidisciplinary care within specialized institutions, benefits for children with less serious, more common conditions are unclear. Potentially, overconsolidation of services could produce access barriers and other unintended consequences. In rural areas, these could manifest in delayed diagnoses, long travel distances, and difficult follow-up care.[38] In urban and suburban areas, they may surface in outcome disparities among populations outside of, or unfamiliar with, traditional referral paths. For young surgeons and anesthesiologists aspiring to care for children, care consolidation restricts practice options and, therefore, workforce distribution. For health planners and regulators, it can complicate challenges of network adequacy, cost, surge capacity, and systemic resilience. Fortunately, the American College of Surgeons Children's Surgery Verification Quality Improvement Program provides a tiered framework for hospitals of varying capabilities to work together in optimizing pediatric surgical care.

Limitations

There are several limitations to consider when interpreting this work. First, it carries all of the challenges that routinely accompany administrative data sets (coding errors, *etc.*). We attempted to reduce the impact of these issues on our overall conclusions by using complementary data sets, large numbers, and separate, reinforcing analyses by state, age, and specialty. Second, the generalizability of our findings to unstudied states should be considered with caution. The six study states here comprise approximately

17% of the U.S. pediatric population, were chosen for their representative features, and exhibited general practice patterns similar to those seen in national sample data. However, every state has its own unique characteristics, and specific care patterns may differ.[39] Third, it should be noted that our focus was on nonambulatory surgery and that our findings may not be relevant to outpatient procedures undertaken in freestanding surgical centers or similar facilities.[40] Fourth, despite the clear trends, the data from 2014 and 2016 may not reflect current practice. Finally, we remind readers that our findings are based on administrative data and that no attempt was made to evaluate institutional quality of care.

Conclusions

We determined that the vast majority of all pediatric surgeries were being performed in a small subset of high-capability hospitals before implementation of the American College of Surgeons Children's Surgery Verification Quality Improvement Program. This carries important implications for workforce distribution, network adequacy determination, disaster planning, and general access to pediatric care.

Research Support

Supported by the Boston Children's Hospital Department of Anesthesiology, Critical Care, and Pain Medicine (Boston, Massachusetts) Trailblazer Award and by the Boston Children's Hospital (Boston, Massachusetts) Chair for Critical Care Anesthesia.

Competing Interests

The authors declare no competing interests.

Correspondence

Address correspondence to Dr. McManus: Boston Children's Hospital, Bader 6th Floor, 300 Longwood Avenue, Boston, Massachusetts 02115. michael.mcmanus@childrens.harvard.edu. This article may be accessed for personal use at no charge through the Journal Web site, www.anesthesiology.org.

References

1. Lorch SA, Myers S, Carr B: The regionalization of pediatric health care. Pediatrics 2010; 126:1182–90
2. França UL, McManus ML: Availability of definitive hospital care for children. JAMA Pediatr 2017; 171:e171096
3. França UL, McManus ML: Trends in regionalization of hospital care for common pediatric conditions. Pediatrics 2018; 141:e20171940
4. Colvin JD, Hall M, Thurm C, Bettenhausen JL, Gottlieb L, Shah SS, Fieldston ES, Goldin AB, Melzer SM, Conway PH, Chung PJ: Hypothetical network adequacy schemes for children fail to ensure patients' access to in-network children's hospital. Health Aff (Millwood) 2018; 37:873–80
5. Fishe JN, Psoter KJ, Anders JF: Emergency medical services bypass of the closest facility for pediatric patients. Prehosp Emerg Care 2019; 23:485–90
6. Fishe J, Finlay E, Palmer S, Hendry P: A geospatial analysis of distances to hospitals that admit pediatric asthma patients. Prehosp Emerg Care 2019; 23:882–6
7. Michelson KA, Monuteaux MC, Stack AM, Bachur RG: Pediatric emergency department crowding is associated with a lower likelihood of hospital admission. Acad Emerg Med 2012; 19:816–20
8. Li J, Monuteaux MC, Bachur RG: Interfacility transfers of noncritically ill children to academic pediatric emergency departments. Pediatrics 2012; 130:83–92
9. Gattu RK, Teshome G, Cai L, Wright C, Lichenstein R: Interhospital pediatric patient transfers: Factors influencing rapid disposition after transfer. Pediatr Emerg Care 2014; 30:26–30
10. McManus ML, Long MC, Cooper A, Mandell J, Berwick DM, Pagano M, Litvak E: Variability in surgical caseload and access to intensive care services. Anesthesiology 2003; 98:1491–6
11. Salazar JH, Goldstein SD, Yang J, Gause C, Swarup A, Hsiung GE, Rangel SJ, Goldin AB, Abdullah F: Regionalization of pediatric surgery: Trends already underway. Ann Surg 2016; 263:1062–6
12. Salazar JH, Goldstein SD, Yang J, Douaiher J, Al-Omar K, Michailidou M, Aboagye J, Abdullah F: Regionalization of the surgical care of children: A risk-adjusted comparison of hospital surgical outcomes by geographic areas. Surgery 2014; 156:467–74
13. Short HL, Sarda S, Travers C, Hockenberry JM, McCarthy I, Raval MV: Trends in common surgical procedures at children's and nonchildren's hospitals between 2000 and 2009. J Pediatr Surg 2018; 53:1472–7
14. McAteer JP, LaRiviere CA, Oldham KT, Goldin AB: Shifts towards pediatric specialists in the treatment of appendicitis and pyloric stenosis: Trends and outcomes. J Pediatr Surg 2014; 49:123–8
15. França UL, McManus ML: Outcomes of hospital transfers for pediatric abdominal pain and appendicitis. JAMA Netw Open 2018; 1:e183249
16. Shay S, Shapiro NL, Bhattacharyya N: Patterns of hospital use and regionalization of inpatient pediatric adenotonsillectomy. JAMA Otolaryngol Head Neck Surg 2016; 142:122–6
17. Hsu EY, Schwend RM, Julia L: How many referrals to a pediatric orthopaedic hospital specialty clinic are primary care problems? J Pediatr Orthop 2012; 32:732–6
18. Task Force for Children's Surgical Care: Optimal resources for children's surgical care in the United States. J Am Coll Surg 2014; 218:479–87.e1–4

19. American College of Surgeons: About Children's Surgery Verification. Available at: http://facs.org/quality-programs/childrens-surgery/childrens-surgery-verification/about. Accessed November 1, 2020.
20. Mayer ML, Beil HA, von Allmen D: Distance to care and relative supply among pediatric surgical subspecialties. J Pediatr Surg 2009; 44:483–95
21. Muffly MK, Medeiros D, Muffly TM, Singleton MA, Honkanen A: The geographic distribution of pediatric anesthesiologists relative to the US pediatric population. Anesth Analg 2017; 125:261–7.
22. United States Census Bureau: American FactFinder. Available at: data.census.gov. Accessed March 17, 2021.
23. United States Census Bureau: New Census Data Show Differences between Urban and Rural Populations, 2016. Available at: https://www.census.gov/newsroom/press-releases/2016/cb16-210.html. Accessed January 13, 2020.
24. Kaiser Family Foundation: Population Distribution by Age. Available at: https://www.kff.org/other/state-indicator/distribution-by-age/. Accessed December 15, 2019.
25. Dartmouth Atlas of Health Care: Research Methods: Files Used in the Atlas, 2015. Available at: http://archive.dartmouthatlas.org/downloads/methods/research_methods.pdf. Accessed February 20, 2019.
26. Agency for Healthcare Research and Quality: HCUP State Inpatient (SID) and Emergency Department (SEDD) Databases. Available at: https://www.hcup-us.ahrq.gov/databases.jsp. Accessed January 13, 2020.
27. Massachusetts Center for Health Information and Analysis: CHIA Case Mix Data. Available at: http://www.chiamass.gov/case-mix-data/. Accessed January 13, 2020.
28. Agency for Healthcare Research and Quality: HCUP Kids' Inpatient Database (KID). Available at: https://www.hcup-us.ahrq.gov/kidoverview.jsp. Accessed January 13, 2020.
29. Children's Hospital Association: Pediatric Health Information System (PHIS). Available at: https://www.childrenshospitals.org/Programs-and-Services/Data-Analytics-and-Research/Pediatric-Analytic-Solutions/Pediatric-Health-Information-System. Accessed January 13, 2020.
30. Agency for Healthcare Research and Quality: HCUP Clinical Classifications Software (CCS) for ICD-9-CM, 2006–2009, 2013. Available at: https://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp. Accessed January 13, 2020.
31. Baxter KJ, Gale BF, Travers CD, Heiss KF, Raval MV: Ramifications of the Children's Surgery Verification Program for patients and hospitals. J Am Coll Surg 2018; 226:917–924.e1
32. França UL, McManus ML: Transfer frequency as a measure of hospital capability and regionalization. Health Serv Res 2017; 52:2237–55
33. Michelson KA, Hudgins JD, Lyons TW, Monuteaux MC, Bachur RG, Finkelstein JA: Trends in capability of hospitals to provide definitive acute care for children: 2008 to 2016. Pediatrics 2020; 145:e20192203
34. França UL, McManus ML: Assessment of acute hospital use and transfers for management of pediatric seizures. JAMA Netw Open 2020; 3:e203148
35. Perez F, Granger BE: IPython: A system for interactive scientific computing. Comput Sci Eng 2007; 9:21–9
36. McKinney W: Python for Data Analysis, 2nd edition. Sebastopol, California, O'Reilly Media, Inc., 2016
37. Kanter RK, Dexter F: Criteria for identification of comprehensive pediatric hospitals and referral regions. J Pediatr 2005; 146:26–9
38. Chien AT, Pandey A, Lu S, Bucholz EM, Toomey SL, Cutler DM, Beaulieu ND: Pediatric hospital services within a one-hour drive: A national study. Pediatrics 2020; 146:e20201724
39. McManus ML, França UL: Visualizing patterns in pediatric and adult hospital care. Hosp Pediatr 2019; 9:398–401
40. Dexter F, Epstein RH, Rodriguez LI: Decline of pediatric ambulatory surgery cases performed at Florida general hospitals between 2010 and 2018: An historical cohort study. Anesth Analg 2020; 131:1557–65