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Health Outcomes and the Healthcare and Societal Cost of Optimizing Pediatric Surgical Care in the United States

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1.1 Introduction

The American College of Surgeons (ACS) and the Task Force for Children's Surgical Care recently partnered to create the Children's Surgery Verification (CSV) Program.[1] The purpose of this program is to optimize clinical outcomes for pediatric surgical patients by ensuring that each patient is cared for in an environment that has resources commensurate with the patient's needs. The impetus for the program is based in part on studies of neonates, infants, and children who are high risk given their comorbidities or the complexity of their planned procedure. These studies suggest that high-risk children are likely to benefit from receiving care in a specialized healthcare environment with access to sub-specialty-trained pediatric anesthesiologists, advanced level neonatal intensive care units (NICU) and pediatric intensive care units (PICU), and care from other providers with pediatric specialty training.[2–7]

In the U.S., however, more than 40% of children's surgical procedures are conducted in hospitals that may not be designed specifically for the care of children.[8] In certain common conditions including cholecystitis, burns, and uncomplicated appendicitis in school-aged children, care may appropriately be provided by surgeons with limited pediatric expertise.[8,9] However, in the setting of more complex procedures such as pyloromyotomy, [10] inguinal hernia repair,[11] and appendectomy in young children,[10] providers with sub-specialty training in pediatric surgery have been shown to have improved outcomes. Hospital characteristics appear to influence outcomes as well, particularly in children younger than five years of age.[10,12]

The CSV guidelines recommend that children who require complex pediatric surgeries or have high-risk comorbidities be treated at institutions with the resources appropriate to the complexity of each child's case. The primary objective of this study is to assess the potential impact of the CSV care model, as compared to the status quo, on healthcare outcomes, healthcare costs, and societal costs in a multi-state sample.

1.2 Methods

1.2.1 Data Sources

The 2011 state-specific Healthcare Cost and Utilization Project (HCUP) family of databases for Florida, Iowa, Nebraska, New York, Utah, and Vermont was used to identify all children less than 18 years of age who had complex inpatient surgical procedures.[13,14] These six states were chosen to estimate the potential impact of this optimization effort on varied geographic and demographic regions in the U.S. The 2011 data were the most recent source for inpatient and emergency department (ED) readmissions from the State Inpatient Database (SID) and the State Emergency Department Database (SEDD), and had the variables needed for analysis including age by year and home zip code, as well as the linkage variable allowing analysis of index hospitalization, readmissions, and subsequent ED visits. The American Hospital Association (AHA) survey file data[15] was linked to the SID/SEDD database to provide hospital-specific data.

1.2.2 Surgery Center Classification

All hospitals were classified into one of three groups (i.e., Level I (the highest resource level), Level II, and Level III) using the ACS standards upon which verification is based.[1] We classified hospitals in a stepwise fashion (Figure 1) utilizing a combination of AHA data, survey data, and expert opinion. The survey obtained information from hospitals in the study to determine whether they provided the critical components for Level I classification under the CSV guidelines. It mirrored aspects of the Centers for Disease Control and Prevention Levels of Care Assessment Tool (CDC LOCATe).[16] Further details regarding data sources and surgery center classification can be found in the online supplemental material (Appendix A and Appendix B).

1.2.3 Study Population

The study population was selected to include patients expected to require the highest level of pediatric resources (i.e. a Level I center) based on the ACS standards contained in "Optimal Resources for Children's Surgical Care 2015." [1] In six children's surgical fields (General and Thoracic Surgery, Urology, Orthopedic Surgery, Otolaryngology, Neurosurgery and Plastic Surgery), experts were consulted for identification of complex surgical procedures that could be expected to require the highest level of resources. The patient population was then further defined by cross-referencing diagnosis, procedure(s), age at admission, timing of operation relative to admission, and length of stay to confirm procedures that required the highest level of care. Only children with an index admission that included a diagnosis or surgical procedure recommended for a Level I facility were included for analysis. Outcomes were attributed to the initial hospital where the primary treatment occurred. If a patient was transferred or readmitted, complications were assigned to the primary treating hospital. For example, in order to capture the primary treating hospital for gastroschisis, we defined our patient population as infants diagnosed with gastroschisis, admitted within 48 hours of birth, and had a length of stay of greater than 48 hours. This was to ensure that patients born at a referring institution and quickly transferred to a higher level of care for their primary treatment had their outcomes attributed to the institution where that treatment took place. Specific patient population definitions can be found in Appendix C.

1.2.4 Healthcare Outcomes

Outcomes were identified and defined using International Classification of Diseases 9th revision (ICD-9) codes provided in the HCUP databases. The primary outcome of interest was any post-operative complication, defined by ICD-9 codes 996–999, which included central line-associated bloodstream infection (CLABSI), catheter-associated urinary tract infection (CAUTI), ventilator associated pneumonia (VAP), surgical site infection (SSI), cardiac arrest, and death.[17] Given the limited granularity of these administrative data sources, procedure specific complications were not captured, nor could re-operations be reliably classified. Secondary outcomes included inpatient readmissions and emergency department visits to any participating hospital in the state during the 30 days following discharge from the index admission. Unplanned readmissions were identified using methods developed by Berry et al., based on ICD-9 codes determined likely to represent a planned readmission.[18]

Demographic factors included age, race, gender, household income in the census tract, insurance status (public, private, or self-pay), residence in a metropolitan statistical area, and presence of comorbidities. Comorbidities for these patients included central nervous system anomalies (ICD-9 740.0–742.9), cardiovascular anomalies (745.0–747.4, 747.6, 747.8, 747.9), respiratory anomalies (748.0–748.9), cleft lip and palate (749.0–749.2), major gastrointestinal anomalies (750.3, 751.1–751.9), renal anomalies (753.0–753.9), congenital musculoskeletal anomalies (756.0–756.9), abdominal wall anomalies (756.7–756.79), chromosomal anomalies (758.0–758.9), other congenital anomalies (759.7–759.9), necrotizing enterocolitis (777.5–777.53), and major inborn errors of metabolism (270.0–272.9, 277.0–277.9).[10]

1.2.5 Cost Data

Healthcare charges were converted to costs using the HCUP Cost-to-Charge ratio files.[19] Societal cost data included the cost of travel to a higher-level facility and productivity losses associated with missed work time due to inpatient length of stay.[20] Transportation distance was defined as the distance between the patient's home zip code (available in HCUP) and the base case hospital zip code (available in the AHA Survey File). The distance between these two end points was calculated using the *mapdist* function in the *ggmap* package in R (version 3.3.2). Transportation mileage costs were estimated using the U.S. General Services Administration (GSA) Privately Owned Vehicle Mileage Reimbursement Rate.[21] Only one round trip was included to favor conservative estimates. Parent time costs were valued at the U.S. average adult hourly wage plus fringe (\$29.22 in 2011). Parent lost productivity time was estimated using length of stay data for the index admission and any associated readmissions. Total costs were calculated for the index admission, the sum of hospital care costs, and the parent-incurred costs. All costs were inflated to common 2015 dollars using the Personal Health Care Expenditure deflator.[22]

1.2.6 Statistical Analysis

Univariate analyses were performed using chi-squared and Student's t-tests for categorical and continuous variables, respectively. Multivariable analyses for healthcare outcomes were performed to adjust for age, race, gender, income, insurance, home zip code, metropolitan statistical area, and comorbidities, and were adjusted for clustering by state. A micro-costing approach was used to estimate total societal costs; this entailed multiplying a unit cost for each resource by an estimation of utilization for each resource.[20] Poisson regression was used for healthcare outcomes analyses and a generalized linear model was used for costs analyses.[23] These analyses compared two scenarios: 1) the *base case scenario*, in which outcomes and costs were examined for the surgical center where care was actually received, and 2) the *optimized scenario*, in which the outcomes and costs associated with shifting the procedure to the closest within-state Level I center were simulated with recycled predictions. [24] Recycled predictions allow for the estimation of a marginal difference in an outcome for a subgroup compared to a reference group. Hence, results estimate differences in the outcomes and costs between the *base case scenario*, where children received care variously at Level I, II, and III centers, and the *optimized scenario*, where all children were assumed to be treated at Level I centers, with 95% confidence intervals. Due to concern that the

heterogeneity of procedures may confound the findings, a sensitivity analysis excluding common conditions (i.e., pyloric stenosis and appendicitis) was conducted. The study was approved by the Seattle Children's Institutional Review Board.

1.3 Results

1.3.1 Provision of Care

There were 8,006 children treated for selected conditions judged to require the resources of an ACS Level I center. Among those children, 54.6% received their care outside of a Level I center: 2,391 (30%) received care at a Level II center and 2,005 (24.6%) at a Level III center (Table 1). Nearly half ($n = 3820$, 47.7%) of all children treated were less than one year of age, and 55.3% ($n = 2093$) of these infants were treated outside of a Level I center. Children treated at Level I centers were more frequently white and a greater proportion had private insurance compared to those treated at Level II and III centers (Table 1). Children treated at Level I centers were more likely to have complex chronic conditions than the children treated at Level II and III centers (47% Level I, 40% Level II, 33% Level III). When examined by specialty, the distribution of operations by hospital level was not equal. For example, about two-thirds of orthopedic procedures were performed at Level II/III centers (Table 2). In the calendar year evaluated, volumes for the surgical conditions included in the analysis were higher at Level I centers compared to Level II and III centers. In fact, 9 of the 13 Level I centers each treated over 250 children with these conditions. In contrast, among the Level II and III centers, 73% treated fewer than 15 of these selected high-risk children in the entire calendar year.

1.3.2 Healthcare Outcomes and Readmissions

Overall complications were infrequently reported, with only four total cases of central line-associated blood stream infection (Table 3). Adjusted for covariates, there was no significant difference in composite morbidity event rates or mortality between Level II or III centers and Level I centers (Table 4). Adjusted for covariates, children treated at Level II centers had a 1.61 (95% CI 1.11, 2.34) higher incidence rate of readmission within 30 days compared to children treated at Level I centers (Table 4). This translates into 23.5 (95% CI 6.48, 40.4) excess readmissions per 1,000 children each year associated with treatment at a Level II, instead of Level I, center (Table 4). There was no statistically significant difference in readmissions between Level III and Level I centers. Additionally, there was no difference between groups in ED visits within 30 days of discharge from the index hospitalization (Table 4). In contrast to the base case analysis, the sensitivity analysis found significantly lower mortality in Level II vs. Level I centers (incidence rate ratio 0.61, 95% CI: (0.46, 0.81)). Otherwise all base case analysis results were robust to the exclusion of common procedures (Appendix D).

1.3.3 Healthcare and Societal Costs

Length of stay and healthcare costs were not statistically different between the base case and the optimized scenario (Table 4). Based on home and hospital zip codes, Level II centers were 15.3 miles closer to families than Level I (95% CI 10.7, 19.9) centers. Accordingly, travel costs were 33% less when children were treated at Level II compared to Level I

centers (0.67, 95% CI 0.55, 0.82), corresponding to \$40.9 (95% CI \$19.1, \$62.7) in additional travel costs per child for treatment in the optimized scenario. There was not a statistically significant increase in travel distance or costs for children treated at Level III versus Level I centers (Table 4). Overall, societal costs, including both travel costs and lost productivity costs, were not significantly different across sites in multivariable analyses (Table 4).

1.4 Discussion

This study offers a unique medical and social perspective on the potential impact of the ACS-CSV verification program on healthcare outcomes and the cost of children's surgical care in the United States. Our findings suggest that half of surgically complex children with needs meriting care at a Level I center are currently treated at Level II or III centers. Our data further suggest that treating children in this cohort in the optimized scenario at Level I centers would not significantly increase total costs, but would decrease readmissions. The impact of optimization would likely vary by specialty, with the greatest change observed in specialties with a higher proportion of children currently being treated at level II and III centers, such as orthopedics.

One of the most striking findings of the study is the large number of young children with complex surgical diseases who are being treated at centers with a limited pediatric surgical case volume (<15 complex cases/year). Among the 235 hospitals included in the study population, 69% (163) performed fewer than 15 high-risk operations in 2011. This finding is consistent with previous work by Berry et al evaluating the prevalence of common pediatric surgical operations for children less than 18 years of age at 3,438 hospitals across 36 states. [25] Examining ventricular septal defect surgery, tracheotomy, ventricular peritoneal shunt placement, and posterior spinal fusion, Berry and colleagues found that half of all hospitals completed four or fewer of these procedures per year.[25] Taken in context with previous work, our data suggests that high-risk surgery in low-volume centers is a prevalent phenomenon. This is potentially concerning, given that annual case totals may fall below the safety threshold for volume-outcome relationships in some circumstances.

Most of the available data suggests a positive association between institutional case-volume and outcomes. However, this relationship is complex, mediated by the institution's patient population (children only vs. mixed), sub-specialty area, and the case volume of the affiliated individual surgeons. In multiple pediatric subspecialties, including cardiac surgery[26,27] and transplant surgery[28], there is a relatively strong volume to outcome relationship at the center level. For example, Spiegelhalter et al found that hospitals doing 120 open cardiac operations per year for children less than 1 year of age had, on average, a mortality 34% lower than hospitals carrying out 40 operations when adjusting for heterogeneity in case load.[26] In other areas, including spinal surgery[29] and general surgery[30], that relationship has not always been demonstrable. A complicating factor in meaningful synthesis of available data is variability in definitions of "low volume center" which have varied by patient population and procedure from less than a dozen to 500 cases annually.[31]

While center volume is undoubtedly a factor shaping outcomes, it is one of many that are likely salient. In the regression models by Spiegelhalter et al, they estimated that only 12–17% of the excess mortality in low volume centers was due to lower volume, suggesting this outcome is multifactorial.[26] This finding aligns with research suggesting additional factors that mediate patient outcomes including designation as a “free-standing” children’s hospital and the case volume of individual surgeons. With regards to center designation, a study by McAteer et al using the KID inpatient database found reduced odds of any post-operative complication for patients undergoing appendectomy (OR= 0.40, 95% C.I. 0.35–0.46) and pyloromyotomy (OR = 0.31, 95% C.I. 0.17–0.58) at urban freestanding children’s hospitals compared to rural non-children’s hospitals.[10]

With regards to available data on the practice patterns of individual surgeons, several studies have found that high-volume surgeons have reduced rates of complication following pyloromyotomy as compared to their low and moderate-volume counterparts.[32,33] At the individual level, pediatric specialty training may also be relevant, with one study of 780 pyloromyotomies performed in North Carolina demonstrating a lower incidence of mucosal perforation, lower total hospital charges and shorter length of stay when the surgeries were performed by pediatric surgeons as compared to those without specialty training.[34]

Taken in aggregate, available evidence suggests that institutional case volume, designation as a “free-standing” children’s hospital, sub-specialty area, and case volume of affiliated individual surgeons may each influence patient outcomes. As regionalization trends in pediatric surgery continue to evolve and expand, further evaluation of case volume will be warranted, particularly how volume is reflected in, or affected by, verification status. At present, only Level I centers have a volume requirement and it is relatively low and not procedure specific (1000 cases annually in patients < 18 year of age). If certain case volumes and composition are required for Level I verification, it may lead to improved outcomes. However, such requirements may inhibit advancement of Level II or III centers: if they are discouraged from performing certain operations because they don’t have the volume, then they will never have the necessary volume to qualify for higher status. The volume-outcome relationship, and what role it may play in the CSV progress, will require further investigation in the ongoing efforts to optimize children’s surgical care.

Over 40 years ago, a similar resource standards verification process for trauma care was initiated with the same underlying premise – that patients sustaining higher severity injuries would have better outcomes when cared for in centers with appropriate resources. Trauma systems and trauma center designation were first proposed by the ACS in 1976, but national implementation was slow, with only 5 states developing a trauma system by 1990.[35] Improvement in motor vehicle crash mortality was not observed for another decade. Nathens et al. suggested this was due to many factors consistent with the implementation and maturation of both hospital and system factors (e.g. trauma resuscitation protocols, increased physician and nursing experience, inter-hospital transfer agreements, organization and infrastructure, ongoing quality assurance) as well as societal factors (e.g. improved EMT and field resuscitation, seat-belt legislation).[35] Three decades after the initiation of trauma systems, the National Study on the Costs and Outcomes of Trauma found that in-hospital and 1-year mortality were both significantly lower at trauma centers than at non-trauma

centers.[36,37] The difference in mortality was most notable in trauma patients with severe injuries.[36] It is reasonable to assume that some correlations may be made to ACS-CSV efforts in that a) outcome differences may take a decade or more to appreciate as hospitals and systems mature, and b) differences may be most pronounced in the sickest children with the most complex conditions. The national experience with trauma center designation highlights the need to identify further explore and iteratively define the populations of children who will potentially benefit most from systematic organization of children's surgical centers.

In the current healthcare climate, evaluations of the value of care are critical and it is essential to include healthcare utilization and cost metrics. Although our univariate analysis demonstrated fewer readmissions and ED visits within 30 days of the index hospitalization for Level I centers compared to both Level II and III centers, these differences were only maintained in the multivariable model when Level I centers were compared to Level II. These mixed results are in contrast to previous studies examining the association between healthcare utilization outcomes and free-standing children's hospitals (which are the majority of the Level I centers in this analysis) which found a more consistent association, particularly for certain common pediatric operations such as pyloromyotomy and appendectomy. For example, Raval et al used the Kids' Inpatient Database to identify 10,969 pediatric patients who underwent pyloromyotomy. The study found that children treated at a free-standing children's hospital had a significantly shorter length of stay than those treated at a children's unit in a general hospital or at a general hospital.[38] Other studies examining the association between care at free-standing children's hospitals compared to general hospitals have also shown a shorter length of stay and a lower rate of readmissions. [33,38,39] The lack of difference in our study may be related to the heterogeneity of patients and procedures evaluated. Though capturing this heterogeneity may have obscured some differences with regards to readmission, it was an essential component of study design given our stated goal of informing CSV efforts, which focus broadly on all pediatric surgery, not a specific sub-specialty.

Although variability in costs for pediatric surgical procedures exist and has been described elsewhere,[40,41] our data do not suggest significant differences in overall costs between base case and optimized case scenarios. Previous work by Pasquali et al evaluating the variation in congenital cardiac surgery costs across hospitals found that costs increased with operation complexity and that there was up to a 9-fold difference between hospitals in adjusted cost/case analyses, with length of stay and complications accounting for only 28% of the between-hospital variation.[41] Interestingly, in that analysis, high volume hospitals had lower costs for the most complex operations, suggesting an interplay between case-volume, operation complexity, and healthcare costs that merits further investigation in future work. However, our preliminary findings suggest that the verification program is not likely to lead to higher costs for healthcare systems or for families. Aligning with prior work by Baxter et al, there was no significant difference in distance traveled between center levels in our study.[42] This suggests that the perceived social burden may be less than originally predicted.

Our study has a number of limitations. Hospitals are not currently classified by level nationally, so our team created the methodology de novo. While a multimodal approach was utilized, including AHA data, the CDC method for NICU classification via LOCATe, and state-based experts, this approach has not been verified. Our hospital classification system may not be perfectly accurate in its representation of the CSV standards based on the limited data available. Comprehensive data were available for the year 2011 for a limited number of states. None of the six states chosen had an ACS verified Level I children's surgery center at the time of analysis. We were unable to reliably confirm the presence of a comprehensive surgical program for performance improvement and patient safety program, patient ASA class, and ambulatory services, all of which are included to some extent in the CSV standards.[1] The system by which the sample population was defined was limited by the lack of granularity of ICD-9 codes in capturing high-risk children definitively warranting Level I care. Great care was taken to appropriately identify children who would likely benefit from highly resourced care, however these may have been incompletely captured in the database. Furthermore, CPT codes are not available in the HCUP family of databases. Also lacking are granular comorbidities, surgeon-specific volume, and procedure-specific outcomes could not be assessed. As with any administrative claims database, there is the inherent potential for coding error and complications are likely underestimated,[43,44] potentially biasing the results towards the null. Finally, certain costs were not available in the dataset and may affect overall costs to patients (e.g.; Graduate Medical Education departments).

1.5 Conclusion

This study demonstrates that many complex children's surgical procedures are currently performed at hospitals with limited pediatric resources. Our study did not identify measurable differences in healthcare outcomes, healthcare costs, or societal costs between centers, although, over time, with additional data evaluating the CSV process, these findings may change. These data suggest that optimizing families to a Level I center instead of the Level II or III center where they are currently being treated would not significantly increase travel burden, nor total healthcare or societal costs. Future work should be directed at prospective measurement of both the healthcare and the societal impact of centralizing pediatric surgical care, including patient and family-reported outcomes and experience. Ongoing evaluation of this ACS effort is needed to support the optimization of pediatric surgical care in the United States.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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*2 hospitals excluded (1 duplicate, 1 closed); hospital refers here to AHA Survey File ID, which may map to multiple HCUP hospital IDs.

Figure 1.
Hospital classification algorithm
Hospital Classification for all Healthcare Cost and Utilization Projectparticipating hospitals
in New York, Vermont, Florida, Iowa, Nebraska, and Utah, 2011

Table 1.

Patient demographic data by treating hospital level, base case scenario

	Level I (n=3,610)	Level II (n=2,391)	Level III (n=2,005)
	No. (%)	No. (%)	No. (%)
Female	1,599 (44.3)	905 (37.9)	773 (38.6)
Age			
< 1 month	573 (15.9)	402 (16.8)	367 (18.3)
1–11 months	1,134 (31.4)	795 (33.3)	549 (27.4)
1–2.9 years	665 (18.4)	349 (14.6)	266 (13.3)
3–5.9 years	568 (15.7)	434 (18.2)	381 (19.0)
6 years	670 (18.6)	411 (17.2)	442 (22.0)
Race			
White	1,915 (53.1)	1,069 (44.7)	987 (48.2)
Black	350 (9.7)	345 (14.4)	254 (12.7)
Hispanic	701 (19.4)	543 (22.7)	367 (18.3)
Other ¹	644 (17.8)	434 (18.2)	397 (19.8)
Insurance			
Public	1,897 (52.6)	1,406 (58.8)	1,170 (58.4)
Private	1,687 (46.7)	943 (39.4)	790 (39.4)
Self-pay	26 (0.7)	42 (1.8)	43 (2.2)
Comorbidity ²	1689 (46.8)	953 (39.9)	666 (33.2)
Median household income ³			
<\$39,000	893 (25.4)	577 (26.2)	538 (28.0)
\$39,000–47,999	934 (26.5)	568 (25.8)	625 (32.5)
\$48,000–63,999	1,021 (29.0)	609 (27.6)	473 (24.6)
>\$64,000	674 (19.1)	451 (20.5)	288 (15.0)
Patient home location: Metropolitan Statistical Area (MSA)	2,963 (82.8)	2,232 (93.7)	1,996 (81.5)

¹Includes Asian, Pacific Islander, Native American (American Indian or Alaska native), more than one race, and other²Defined by at least one of any chronic conditions[9]³Based on national quartile range for patient registered home ZIP code

Table 2.Distribution of diagnostic/operative classification⁴ by treating hospital level, base case scenario

	Level I (n=3,610)	Level II (n=2,391)	Level III (n=2,005)
	No. (%)	No. (%)	No. (%)
General Surgery	1,650 (40.9)	1,281 (31.7)	1,106 (27.4)
Omphalocele	30 (33.7)	31 (34.8)	28 (31.5)
Gastroschisis	101 (47.0)	60 (27.9)	54 (25.1)
Congenital diaphragmatic hernia	91 (58.7)	26 (16.8)	38 (24.5)
Tracheoesophageal fistula/esophageal atresia	58 (49.2)	29 (24.6)	31 (26.3)
Intestinal atresia	131 (41.1)	115 (36.1)	73 (22.9)
Appendicitis < 5years	278 (32.1)	286 (33.1)	301 (34.8)
Pyloric stenosis/pyloromyotomy	557 (38.8)	456 (31.8)	421 (29.4)
Fundoplication	189 (63.4)	68 (22.8)	41 (13.8)
Intussusception	150 (34.8)	174 (30.4)	107 (24.8)
Other (e.g. Hirschsprung's, malrotation w/volvulus, biliary atresia, lung anomaly)	95 (53.4)	58 (32.6)	25 (14.0)
Neurosurgery	165 (59.1)	67 (24.0)	47 (16.9)
Craniotomy for seizure or tumor	50 (54.3)	25 (27.2)	17 (18.5)
Laminectomy for intra-spinal lesion (non-neoplasm or neoplasm)	118 (59.9)	47 (23.9)	32 (16.2)
Otolaryngology	170 (55.7)	74 (24.3)	61 (20.0)
Tracheoplasty or laryngoplasty	123 (65.1)	39 (20.6)	27 (14.3)
Abscess drainage	47 (40.5)	35 (30.2)	34 (29.3)
Orthopedic Surgery	191 (35.3)	145 (26.8)	205 (37.9)
Trauma surgery	27 (21.4)	40 (31.8)	59 (46.8)
Osteotomy, tumor resection, congenital hand surgery	52 (37.7)	35 (25.4)	51 (36.9)
Spinal fusion	31 (39.7)	34 (43.6)	13 (16.7)
Relocation of hip	85 (39.5)	40 (18.6)	90 (41.9)
Plastic Surgery	462 (55.6)	257 (30.9)	112 (13.5)
Craniosynostosis	36 (69.2)	10 (19.2)	6 (11.5)
Cleft lip/palate repair	426 (54.7)	247 (31.7)	106 (13.6)
Urology	1,012 (48.9)	581 (28.1)	467 (23.0)
Nephrectomy	155 (45.3)	105 (30.7)	82 (24.0)
Pyloplasty	43 (36.8)	52 (44.4)	22 (18.8)
Ureteral repair	531 (62.5)	205 (24.2)	113 (13.3)
Cystostomy	99 (56.8)	42 (27.1)	25 (16.1)
Orchiopexy	141 (32.4)	122 (28.1)	172 (39.5)
Renal transplant	32 (34.4)	41 (44.1)	20 (21.5)
Bladder repair, bladder exstrophy	66 (61.1)	29 (26.9)	13 (12.0)
Uterine/vaginal anomalies	43 (36.4)	26 (22.0)	49 (41.5)

⁴Column totals do not sum to category totals because some patients may have had multiple procedures.

Table 3.

Surgical outcomes by level of treating hospital, base case scenario

	Level I (n=3,610)	Level II (n=2,391)	Level III (n=2,005)	p-value
	No. (%)	No. (%)	No. (%)	
Morbidity				
Composite morbidity score ⁵	277 (7.7)	186 (7.8)	139 (6.9)	0.5
Ventilator associated pneumonia	24 (0.7)	13 (0.5)	12 (0.6)	0.8
Surgical site infection	47 (1.3)	23 (1.00)	22 (1.1)	0.5
Other complications ⁶	277 (7.7)	186 (7.8)	139 (6.9)	0.5
Mortality	34 (0.9)	21 (0.9)	21 (1.1)	0.8
Healthcare utilization				
Unplanned readmissions, ⁷ 30 days	111 (3.1)	122 (5.1)	69 (3.4)	<0.001
Any readmission, 30 days	142 (3.9)	151 (6.3)	97 (4.8)	<0.001
Any ED-only return, 30 days	141 (3.9)	101 (4.2)	96 (4.8)	0.3
Median length of stay, days (IQR) ⁸	3 (24.5)	3 (23.0)	3 (20.0)	0.2

CLABSI, Central line associated blood stream infection; ED, emergency department; IQR, Interquartile range

⁵Composite includes all categories listed below and is not mutually exclusive⁶Includes: ICD9 codes 996–999, describing complications pertaining to specific procedures (grafts, implants, etc.), central line blood stream infection and cardiac⁷Unplanned readmissions defined by Berry et al[18]⁸Assessed using non-parametric equality of medians test

Table 4.

Adjusted⁹ incidence rate ratios (aIRR) and predicted difference in outcomes between the base case and optimal scenario¹⁰

	Level II vs. Level I		Level III vs. Level I	
	aIRR (95% CI)	Predicted difference in number of events per 1000 children (95% CI)	aIRR (95% CI)	Predicted difference in number of events per 1000 children (95% CI)
Morbidity				
Composite morbidity score ¹¹	1.08 (0.87, 1.33)	5.78 (−10.0, 21.5)	0.96 (0.77, 1.21)	−2.79 (−19.0, 13.4)
Mortality				
	1.04 (0.68, 1.61)	1.69 (−16.1, 19.5)	1.18 (0.92, 1.51)	7.14 (−4.16, 18.4)
Readmissions				
Any IP readmission, 30 days	1.61 (1.11, 2.34)	23.5 (6.48, 40.4)	1.39 (0.95, 2.03)	13.7 (−3.96, 31.3)
Any ED-only return, 30 days	1.00 (0.59, 1.69)	0.201 (−21.0, 21.4)	1.14 (0.86, 1.51)	5.85 (−6.24, 17.94)
	Level II vs. Level I		Level III vs. Level I	
	exp(β) (95% CI)	Marginal difference in utilization (95% CI)	exp(β) (95% CI)	Marginal difference in utilization (95% CI)
Healthcare utilization				
Mean (SD) length of stay, days	1.03 (0.93, 1.14)	0.260 (−0.661, 1.18)	0.92 (0.86, 1.14)	0.640 (−1.41, 0.129)
Healthcare costs	0.94 (0.79, 1.11)	−\$1475 (−5663, 2714)	0.90 (0.71, 1.13)	−\$2493 (−5618, 2691)
Societal costs	1.01 (0.92, 1.10)	\$26.7 (−177, 230)	0.93 (0.85, 1.02)	−\$156 (−384, 72)
--Travel costs	0.67 (0.55, 0.82)	−\$40.9 (−62.7, −19.1)	0.89 (0.69, 1.13)	−\$13.7 (−44.3, 16.8)
--Productivity costs	1.05 (0.94, 1.17)	\$106 (−142, 354)	0.93 (0.85, 1.01)	−\$166 (−380, 48.4)
Total costs	0.94 (0.80, 1.09)	−\$1548 (−5291, 2196)	0.89 (0.71, 1.12)	−\$2792 (−8440, 2855)

IP, inpatient; ED, emergency department; SD, standard deviation

⁹Adjusted for age, race, household income of zip code, insurance, comorbidity, and general surgery procedure.

¹⁰Base case scenario represents that in which all children are treated at Level I, II, and III centers as provided in the HCUP data. The optimal case scenario represents that in which all children are treated at a Level I center

¹¹Includes ventilator associated pneumonia, central line associated blood stream infection, surgical site infection, serious adverse event, and other complications as