Hospital Volumes for Common Pediatric Specialty Operations

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Objectives: To describe hospital volumes for common pediatric specialty operations, to evaluate hospital and patient characteristics associated with operations performed at a low-volume hospital, and to evaluate outcomes with hospital volume.

Design: Retrospective cohort using the Kids’ Inpatient Database 2003.

Setting: Discharges from 3438 hospitals in 36 states from 2003.

Participants: Children aged 0 to 18 years undergoing ventriculoseptal defect surgery (n=2301), tracheotomy (n=3378), and posterior spinal fusion (n=4002).

Main Exposure: Hospital volume.

Main Outcome Measures: In-hospital mortality and postoperative complications.

Results: For tracheotomy and posterior spinal fusion, at least one fourth of the hospitals performed only 1 operation for children aged 0 to 18 years in 2003. For these same operations, at least half of hospitals treated 4 or fewer cases per year. For all operations, discharges from low-volume hospitals were less likely to be from children’s or teaching hospitals compared with discharges from higher-volume hospitals. For tracheotomy, children were less likely to experience postoperative complications in high-volume hospitals compared with low-volume hospitals (odds ratio, 0.48; 95% confidence interval, 0.21-1.09).

Conclusions: Many children undergoing common pediatric specialty operations had these procedures performed in low-volume hospitals. Low-volume hospitals were less likely to be children’s or teaching hospitals. Children undergoing tracheotomy experienced higher rates of complications in low-volume hospitals. Further research is needed to identify the reasons why so many children have these operations performed in low-volume hospitals.

Arch Pediatr Adolesc Med. 2007;161:38-43

A growing body of evidence suggests that outcomes of pediatric operations are better when they are performed in hospitals that have higher volumes of procedures. Higher-volume hospitals have been associated with decreased readmission rates after spinal fusion, decreased rates of misdiagnosis with appendectomy, and decreased rates of operation for intussusception. Higher-volume hospitals have also been associated with decreased mortality rates for children undergoing cardiac surgery, ventriculoperitoneal (VP) shunt placement, brain tumor resection, and tracheotomy.

Past research has suggested that pediatric specialty surgery is often performed in low-volume hospitals, but the existing studies have typically been limited to 1 type of operation or to specific localities. Information on hospital volume is a critical first step in exploring the factors that influence current hospital utilization and referral patterns for children undergoing specialty operations. Our objectives were to describe the hospital procedural volumes of common pediatric specialty operations, evaluate hospital and patient characteristics associated with having such an operation performed at a low-volume hospital, and evaluate the relationship of hospital volume to mortality and postoperative complications for the operations.

Methods

This study was a retrospective cohort analysis of the Healthcare Cost and Utilization Project Kids’ Inpatient Database (KID) 2003. The KID 2003 sampling design includes more than 2.9 million hospital discharges. The KID 2003 sampling design includes 10% of uncomplicated births and 80% of all other pediatric discharges from 3438 US hospitals. The data set includes a weight variable for each observation so that weighted analysis can produce national estimates, with confidence intervals (CIs), of total US discharges for specific diagnoses and procedures. Patients of interest are identified from International Classification of Diseases, Ninth Re-
vision, Clinical Modification (ICD-9-CM) diagnostic and procedural coding.

STUDY PARTICIPANTS
To identify common pediatric specialty operations for this study, we analyzed the national frequency of hospital discharge ICD-9-CM codes for cardiac, neurosurgical, orthopedic, and otophylogenic procedures for children aged 0 to 18 years. The ICD-9-CM tabular index of procedural codes was used to categorize the procedures as cardiac surgery (codes 35.00-39.99), neurosurgery (codes 01.00-03.99), orthopedic surgery (codes 76.00-84.99), and otophylogenic surgery (codes 18.00-31.99). We included procedures only if they were (1) predominantly performed in an operating room as opposed to an interventional catheterization suite or other site, (2) not described as a “revision” or “replacement” of a prior procedure, and (3) associated with a congenital malformation, chronic illness, major trauma, or malignancy. The third criterion was included because the American Academy of Pediatrics has recommended that these types of operations be managed by pediatric medical and surgical specialists. If 2 or more procedure codes described the same operation, their frequencies were combined.

The procedures that best met the inclusion criteria from the ICD-9-CM tabular index of cardiac, neurosurgical, orthopedic, and otophylogenic procedures were ventricular septal defect (VSD) surgery, VP shunt placement, posterior spinal fusion, and tracheotomy. The ICD-9-CM procedural codes used to identify the operations were repair of VSD (codes 35.53, 35.62, and 35.72), ventricular shunt to abdominal cavity and organs (code 02.34), dorsal and dorsolumbar spinal fusion (code 81.05), and tracheotomy (codes 31.1 and 31.2). For VSD surgery, only patients undergoing cardiopulmonary bypass (code 39.61) were selected to exclude patients with transcatheter VSD closure.

MAIN OUTCOME MEASURES
In-hospital mortality was determined at hospital discharge. Postoperative complications were identified using the Agency for Healthcare Research and Quality Pediatric Quality Indicator software (version 3.0b). We included inpatient indicators that were related to the chosen operations and were considered acceptable for hospital comparative reporting as determined from the Agency for Healthcare Research and Quality Pediatric Quality Indicator clinical panel review of February 2006. The indicators chosen for analysis were decubitus ulcer, foreign body left in after procedure, iatrogenic pneumothorax, postoperative hemorrhage and hematoma, transfusion reaction, and postoperative abdominal wound dehiscence.

HOSPITAL VOLUME
Hospital volume was defined as the number of annual surgical cases per hospital for the designated operation identified within the KID 2003. Caseload at each sample hospital was multiplied by 1.25 to correct the random 80% sampling rate from the KID 2003. Caseload at each sample hospital was multiplied by 1.25 to correct the random 80% sampling rate from the KID 2003. Caseload at each sample hospital was multiplied by 1.25 to correct the random 80% sampling rate from the KID 2003. Caseload at each sample hospital was multiplied by 1.25 to correct the random 80% sampling rate from the KID 2003.

STUDY POPULATION
We identified all KID 2003 discharges for VSD surgery (n=2301), tracheotomy (n=2674), VP shunt placement (n=3378), and posterior spinal fusion (n=4002) in children aged 0 to 18 years. We found that VSD surgery was associated with the lowest number of hospitals (n=113) and that tracheotomy was associated with the highest number of hospitals (n=435) (Table 1).
VOLUME OF OPERATIONS

For tracheotomy and posterior spinal fusion, at least one fourth of hospitals performed only 1 operation per year for children aged 0 to 18 years (Table 1). For these same operations, at least half of the hospitals performed 4 or fewer procedures per year. For VP shunt placement, one fourth of hospitals performed 1 to 3 cases per year. The median caseload for VSD surgery was larger than for the other operations (median, 18; interquartile range [IQR], 7-35). The number of cases performed in the lowest, second, third, and highest quartiles was 1-6, 7-18, 19-35, and 36-179, respectively.

CHARACTERISTICS OF HOSPITALS WITH LOW PROCEDURE VOLUMES

For all operations, discharges from low-volume hospitals were less likely to be from children’s or teaching hospitals than higher-volume hospitals. The findings for tracheotomy were similar: among operations at low-volume hospitals were less likely to be at children’s hospitals (5.6%-8.8%) than those at higher-volume hospitals (66.9%). For these 3 operations, approximately half to two thirds of discharges from low-volume hospitals were from teaching hospitals. The findings for VSD surgery differed among discharges from low-volume hospitals. For tracheotomy, admissions associated with trauma were more likely to occur in low- vs higher-volume hospitals (40.6% vs 20.4%). For VSD surgery, procedures performed at low-volume hospitals were conducted in urban hospitals (≥89.7%) and hospitals with a large number of beds (≥63.6%).

PATIENT CHARACTERISTICS ASSOCIATED WITH LOW-VOLUME HOSPITALS

For tracheotomy and spinal fusion, patients discharged from low-volume hospitals were older (Table 3). The median age at admission of low- and higher-volume hospitals for VSD surgery and VP shunt placement was 0 years. The largest difference in age was associated with tracheotomy (median, 15 years; IQR, 0-16 years vs median, 1 year; IQR, 0-13 years). Income, insurance, and race/ethnicity were not consistently predictive of low-volume hospital use across the different operations (data not shown).

For tracheotomy, VP shunt placement, and VSD surgery, procedures at low-volume hospitals were less likely than those at higher-volume hospitals to be associated with transfers from another hospital (Table 3). For spinal fusion, admissions were more likely to be classified as emergent (18.1% vs 3.7%) and associated with trauma (17.0% vs 1.9%) when they occurred in low-volume hospitals vs higher-volume hospitals. For tracheotomy, admissions associated with trauma were more likely to occur in low- vs higher-volume hospitals (40.6% vs 20.4%).
HOSPITAL VOLUME AND OUTCOMES

The in-hospital mortality for the operations was 7.8% for tracheotomy, 2.0% for VSD surgery, 1.3% for VP shunt placement, and 0.3% for spinal fusion (Table 4). A significant trend of increasing mortality in lower-volume hospitals was not observed for any operation. However, children undergoing tracheotomy experienced the highest mortality in low- vs higher-volume hospitals (10.3% vs 7.7%).

The postoperative complication rate for the operations was 2.6% (n=70) for tracheotomy, 1.7% (n=40) for VSD surgery, 1.0% (n=40) for spinal fusion, and 0.3% (n=16) for VP shunt placement (Table 4). Decubitus ulcer was the most frequent complication for tracheotomy (n=59), spinal fusion (n=20), and VP shunt placement (n=12). Postoperative hemorrhage or hematoma was the most frequent complication for VSD surgery (n=39).

For tracheotomy, the rate of postoperative complications decreased as hospital volume increased (5.1% to 2.4%) (Table 4). Children were less likely to develop a decubitus ulcer during admission for tracheotomy in high-compared with low-volume hospitals (1.9% vs 4.4%; odds ratio, 0.44; 95% CI, 0.18-1.09) after controlling for diagnosis-related group severity and the comorbid conditions of hemiplegia, paraplegia, quadriplegia, spina bifida, anoxic brain injury, and mechanical ventilation lasting longer than 96 hours. A significant trend of higher postoperative complication rates in lower-volume hospitals was not observed for spinal fusion, VP shunt placement, or VSD surgery.

COMPARISON WITH OTHER STUDIES

Our finding that many common pediatric procedures are performed at hospitals with low procedure volumes is in accord with previous studies. Smith et al observed 87 patients who underwent VP shunt placement or revision in hospitals that performed 1 pediatric shunt operation during the same year. Low hospital caseloads (≤5 cases per year) have also been described in most hospitals that perform spinal fusion for scoliosis in California. In adults, Elixhauser et al reported a low-volume (≤3 cases per year) caseload of esophageal cancer surgery, pancreatic cancer surgery, and heart transplantation performed in a large number of hospitals.

We observed a smaller number of VP shunt placement operations in the lowest-volume quartile (1-3 cases per year) when compared with the study by Smith et al, who reported a low-volume quartile of 1 to 27 cases per year for pediatric shunt operations. Potential reasons for these differential findings are that the previous study included VP shunt revisions in the study population and included data over multiple years.
In our study, VSD surgery was centralized into high-caseload hospitals more than the other operations. The number of hospitals that perform VSD surgery was smaller than for the other operations. One previous study found that pediatric heart surgery was performed in relatively few hospitals compared with high-risk adult specialty operations. This is consistent with evidence that suggests that pediatric cardiac surgery is increasingly being centralized into tertiary care, high-caseload hospitals.

Our study is unique in that we compared hospital characteristics of low- and higher-volume centers. For 3 of the 4 operations studied, most of the discharges from low-volume hospitals were not from children’s hospitals. We did not identify previous research that evaluated children’s hospital designation in low-volume hospitals. Improved outcomes have been associated with children’s hospitals for children undergoing tracheotomy and splenectomy. For all operations, discharges from low-volume hospitals were less likely to be from teaching hospitals. Elixhauser et al found that low-volume hospitals in which adult specialty operations were performed tended to be nonteaching institutions.

One explanation for the use of low-volume hospitals that we were not able to test in this analysis is that low-volume hospitals may be geographically closer to some children who need urgent surgery. We found that children undergoing spinal fusion and tracheotomy associated with trauma were more likely to use low-volume hospitals. Dimick et al reported that half of adults undergoing 3 high-risk specialty operations in low-volume hospitals lived in an area without a high-volume hospital. However, Birkmeyer et al found that many adult patients undergoing complex cancer surgery traveled past a higher-volume center to undergo surgery at a low-volume hospital.

We observed that most low-volume hospitals were located in urban areas and had a large number of beds. Smith et al reported that most low-volume hospitals in which VP shunt operations were performed on children were urban. Overall, children who required specialty services have been shown to use urban hospitals more than rural hospitals. Future research using geographic information systems is needed to evaluate the proximity of children who require specialty operations to low- and higher-volume hospitals in which these procedures are performed.

In our study, a trend of increasing mortality with decreasing hospital volume was not observed for any operation. However, in accord with Lewis et al, we found that children undergoing tracheotomy in low-volume hospitals experienced the highest mortality. Previous studies have reported higher mortality in low-volume hospitals for children undergoing VP shunt and cardiac operations. We observed low mortality rates for VP shunt placement (1.3%) and VSD surgery (2.0%) with small variation in mortality with hospital volume.

We observed a higher risk of postoperative complications in low-volume vs high-volume hospitals for children undergoing tracheotomy. To our knowledge at date, no studies have evaluated hospital variation in complications of pediatric tracheotomy. In our study, decubitus ulcer was the most frequent tracheotomy complication. Lengthy hospitalizations have been reported in children undergoing tracheotomy. Length of stay has also been associated with the development of decubitus ulcers in hospitalized children. However, in a post hoc multivariate analysis, we found that controlling for length of stay did not reduce the increased likelihood of developing a decubitus ulcer within low-volume hospitals.

In the present study, a trend of increased postoperative complication rates in lower-volume hospitals was not observed for spinal fusion, VP shunt placement, or VSD surgery. Vitale et al observed similar findings for early postoperative complications and hospital volume for spinal fusion operations. However, the same study reported an increased rate of readmission after spinal fusion in low-volume hospitals. We did not identify previous studies that evaluated postoperative complications and hospital volume for children undergoing VP shunt placement or VSD surgery.

**STUDY LIMITATIONS**

Surgeon volume was not analyzed because of the large amount of missing surgeon data associated with the selected operations. Surgeon procedural volume has been associated with outcomes in children and adults undergo-
The postoperative complication decubitus ulcer could have developed before the selected operations for some children in the KID 2003. However, we excluded discharges with a principal diagnosis of decubitus ulcer, length of stay less than 5 days, admission source from a long-term care or acute care facility, and a procedural code for debridement or pedicle graft before or on the same day as the major operating room procedure to minimize this possibility.

Hospital variation in ICD-9-CM procedural coding for pediatric specialty operations could potentially lead to different results. Aside from VSD surgery, combinations of procedural codes were avoided to reduce the risk of falsely excluding patients within the KID 2003. It is possible that some institutions could have used procedural codes other than those used in the present study for the same operations.

CONCLUSIONS

Many children undergoing common pediatric specialty operations have these procedures performed in low-volume hospitals. For tracheotomy and posterior spinal fusion, at least one fourth of the hospitals performed only 1 operation for children aged 0 to 18 years during the year studied. Children undergoing tracheotomy in low-volume hospitals were more likely to experience postoperative complications. Further research is needed to identify the reasons why so many children undergoing specialty surgery have their operations performed at low-volume hospitals.

Accepted for Publication: July 26, 2006.

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Author Contributions: Dr Berry had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Berry, Lieu, and Goldmann. Acquisition of data: Berry and Goldmann. Analysis and interpretation of data: Berry, Lieu, and Forbes. Drafting of the manuscript: Berry, Lieu, and Goldmann. Critical revision of the manuscript for important intellectual content: Berry, Lieu, and Goldmann. Statistical analysis: Berry and Forbes. Study supervision: Lieu and Goldmann.

Financial Disclosure: None reported.

Funding/Support: Dr Berry was supported by a National Research Service Award (T32 HP10018). Dr Lieu was supported by a Mid-Career Investigator Award in Patient-Oriented Research from the National Institute of Child Health and Human Development (K24 HD047667).

Acknowledgment: Special thanks to Pedro del Nido, MD, Peter Black, MD, PhD, Alan Retik, MD, James Kasser, MD, and Gerald Healy, MD, for their surgical input.

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