Complications and Cost of Syndactyly Reconstruction in the United States: Analysis of the Pediatric Health Information System

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Abstract

Background: Syndactyly is one of the most common congenital differences of the upper extremity and offers an exceptional opportunity to evaluate value-based care in pediatric orthopedic surgery. We designed a study to characterize complications and cost associated to syndactyly surgery among US pediatric hospitals. **Methods:** A total of 2047 patients were identified for syndactyly surgery at 38 pediatric hospitals from 2009 to 2012 using the Pediatric Health Information System (PHIS) database. We examined costs as well as complication rates across hospitals stratified by patient and hospital variables. **Results:** The postoperative complication rate was 1.9% (95% confidence interval [CI]: 1.3%-2.5%). Postoperative infection rate was 1.6% and surgical complication rate was 0.3%. Median adjusted standardized cost was \$4112.5 (interquartile range: \$2979-\$6049). Patients with more than 1 diagnosis had 19 times higher risk of complications and were associated with 13% more hospital cost than those with syndactyly as single diagnosis ($P < .001$). Finally, there was a wide variation in cost across hospitals; 8 (21%) yielded confidence limits above the benchmarked value. **Conclusions:** In the United States, it is important to recognize variations in practice of syndactyly surgery in hopes of developing quality improvement strategies in pediatric orthopedic surgery.

Keywords: syndactyly surgery, database, complications, cost, value

Introduction

Given the escalating costs of medical care in the United States, there has been increasing movement by the federal government, regulatory agencies, and health care experts to determine and improve the value of care.^{23,26} Value, by definition, seeks to increase patient outcomes and optimize cost. However simple in appearance, value-based care requires a multilevel expertise to establish baseline measures for clinical outcomes and costs.¹⁶ The complexity of the health care system, variation in practice, and complications constitute a source of high expenditures that have to be considered prior to quality improvement initiatives.

Syndactyly is one of the most common congenital differences of the upper extremity^{12,31} and therefore offers a particular opportunity to evaluate value-based care. Surgical reconstruction is the recommended treatment for all patients.^{13,36} As such, it may be one of the most frequent pediatric procedures performed by hand surgeons throughout their careers.¹ The timing of surgical intervention varies depending on web space involvement, patient age, and syndactyly type.³¹

Numerous retrospective case studies have reported clinical results of syndactyly surgery, outcomes such as web creep,^{1,5,17,22,30,31} as well as functional and aesthetical outcomes.¹⁴ Authors consistently reported that younger patients, associated congenital hand anomalies, and complex syndactyly were the factors related to less successful outcomes. Though much has been published about the treatment of syndactyly, there is a paucity of information regarding the complications and the expenditures during the episode of care across institutions, geographic regions, and surgical subspecialties.

With these considerations in mind, the objectives of this study were to (1) describe early complications of syndactyly surgery in a large cohort of pediatric hospitals and (2) identify variations in practice and cost among hospitals, in

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hopes of establishing benchmarks. With this information, ultimately collaborative initiatives at quality improvement and cost containment may be developed to improve the value of pediatric care.

Materials and Methods

We performed a retrospective cohort study of patients treated for hand syndactyly at 38 pediatric hospitals from January 2009 to December 2012. Data for this study were obtained from the Pediatric Health Information System (PHIS), an administrative database that contains inpatient, emergency department, ambulatory surgery, and observation encounter-level data from more than 45 not-for-profit, tertiary care pediatric hospitals in the United States.⁶ These hospitals are affiliated with the Children's Hospital Association (Overland Park, Kansas). Data quality and reliability are assured through a joint effort between the Children's Hospital Association and participating hospitals. For the purposes of external benchmarking, participating hospitals provide encounter data including demographics, diagnoses, and procedures. Nearly all of these hospitals also submit resource utilization data (eg, pharmaceuticals, imaging, and laboratory) into PHIS. Data are de-identified at the time of data submission, and data are subjected to a number of reliability and validity checks before being included in the database.

Study Subjects

Children between 0 and 18 years of age discharged with an ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) procedure code for syndactyly repair (86.85) were identified in the PHIS database and were considered for study eligibility. We limited the analysis to those patients who had syndactyly repair as the principal procedure during their admission. The cohort was further refined by utilizing the ICD-9-CM diagnosis for finger syndactyly (755.10, 755.11, 755.12) to exclude patients treated for syndactyly of the foot. Hospitals not currently submitting data for ambulatory surgery were eliminated, as were hospitals with missing billing data.

Outcome Measures

The first outcome of interest was early postoperative complications, defined as those patients who during the index surgical admission for syndactyly reconstruction presented an ICD-9 code for at least 1 complication and were recorded in PHIS according to standard definitions. We performed a stepwise search strategy in PHIS that identified all patients who triggered an affirmative response for complication. Postoperative complications were later categorized into 2 groups: Complications were divided into perioperative

infection and noninfectious surgical complications. The organ system affected by the identified complication were separated into skin and tegument, respiratory, ear and nose, gastrointestinal tract, vascular, cardiac, genitourinary, and not otherwise specified (NOS).

The second outcome was the cost associated to the syndactyly repair as measure of resource utilization²⁵ and the variation in practice among pediatric hospitals. We analyzed adjusted total cost, which was derived from the ratio of cost to charge submitted by participating hospitals and was adjusted for inflation using CPI (Consumer Price Index)³² for medical care, providing estimates in 2012 US dollars.

Independent Variables

We collected PHIS data regarding a number of patient-related variables. Age at admission in months was categorized into 3 groups: 0 to 24 months, 25 to 60 months, and older than 60 months. Patient gender, ethnicity (Hispanic or non-Hispanic), and race (white, black, Asian, American Indian, Pacific Islander, others) were recorded. Associated diagnoses were identified and classified into the following groups: upper extremity conditions, other orthopedic pathologies, and medical conditions. Source of payment was categorized as government, private, self-pay, and other. Hospitals were classified into 4 groups by geographic region according to the US Census Bureau³³ as follows: Northeast, Midwest, South, and West. We also obtained information regarding surgeon subspecialty, classified as orthopedic surgery (including hand), plastic and reconstructive surgery, pediatric general surgery, and NOS.

Statistical Analysis

The overall study population was characterized using descriptive statistics. The effect of patient and treatment characteristics on each outcome, including age, gender, the number of diagnoses, the hospital the patient was treated, the region of the country the patient was treated, and the specialty of the physician, was considered. Univariable and multivariable logistic regression analysis was used to analyze factors associated with complication. Penalized likelihood logistic regression was implemented to reduce bias due to small numbers of events and bias-adjusted effects were estimated. For significant predictors, penalized likelihood odds ratios with corresponding 95% CIs were estimated. A multivariable linear regression model of the log-transformed cost data using a normal bias correction factor was used to model total cost by hospital and to identify factors that affected the cost of syndactyly for each hospital. Stepwise model selection procedures were implemented to identify the best models. Deviance residuals were analyzed to verify the fit of each final regression model. Unadjusted and

adjusted effects with 95% CIs were estimated for significant factors. All tests were 2-sided and P values less than 0.05 were considered significant.

Benchmarking

To determine variation in cost among hospitals, a benchmark value was calculated. The average cost for each hospital was sorted from lowest to highest and a cumulative number of patients recorded. The benchmark point was defined as the hospital per patient cost at which 10% of total patients were included in the cumulative patient count.³⁷ This point was at the fourth hospital in the ordered list. Using this breakpoint, the average cost per patient was calculated using all cost and patients from the hospitals that had an average cost at or below this value.

Results

Demographics

During the study period, a total of 2047 syndactyly procedures were identified in 38 hospitals. The median age at the time of syndactyly repair was 18 months (interquartile range: 11-37 months). Among all patients, 1277 (62%) were between 0 and 24 months of age, 1364 (66.6%) were male, 1221 (59.6%) were white, and 1063 (51.9%) had government insurance. Orthopedic surgeons accounted for 48% of the physicians who performed surgical repairs. Among associated conditions, 397 (19.3%) patients had another upper extremity condition, 286 (13.9%) had other orthopedic conditions, and 705 (34.4%) had associated medical conditions. In addition, 1725 (85%) of the patients had simple syndactyly. The distribution of demographic characteristics per groups is shown in Table 1.

Clinical Outcomes

There were 39 complications documented during the index admission for syndactyly reconstruction in 38 patients (1.9%, 95% CI: 1.3-2.5). One case presented concomitantly with both an infection and a surgical complication. The perioperative infection rate was 1.6% ($n = 32$), including respiratory infections ($n = 12$), skin and nail infections ($n = 10$), ear and nose infections ($n = 9$), and infections not otherwise specified ($n = 1$). The surgical complication rate was 0.3% ($n = 7$), including mechanical complications of graft tissue ($n = 2$), constipation ($n = 2$), accidental cut with laceration and hemorrhage ($n = 1$), dysrhythmia ($n = 1$), and postoperative urethral obstruction ($n = 1$). The nature of the complication by system affected is shown in Table 2.

The average hospital length of stay was 1 day (95% CI: 0.99-1.08 days). The majority of patients had ambulatory

surgery with same day admit and discharge. Median adjusted standardized cost was \$4112.5 (range: \$2979.4-\$6049.2).

Univariate and Multivariate Regression Models

Covariates that had significant association with outcomes are presented in Table 3. Univariate analysis demonstrated that patients with additional orthopedic or medical diagnoses had significantly higher complication rates. This group had 20 times higher risk of a complication when compared with patients who had only syndactyly as single diagnosis ($P < .001$). Also patients from the South and West region had significantly lower risk of complications compared with the Northeast region ($P = .02$, $P = .03$, respectively). There was no significant association between the risk of complications and patient age, surgeon subspecialty, or syndactyly type. Because univariable analyses can overestimate or underestimate the influence of individual covariates, a multivariable regression model was developed. The only covariate found to be independently associated with higher risk of complications was syndactyly with additional associated diagnoses, with an adjusted odds ratio of 19.2 ($P = .001$).

Similarly, univariable regression analyses demonstrated that subjects with associated diagnoses, younger patients (<24 months), complex syndactyly, the Northeastern region, and orthopedic-trained providers were covariates associated with significantly higher costs. However, after multivariable analysis, the only covariates found to be independently associated with higher cost were younger age ($P = .001$) and number of associated diagnoses. Patients with additional diagnosis presented 13% higher cost for the procedure compared with cases with syndactyly as a single diagnosis ($P = .001$).

There was significant variation in treatment cost between centers for patients who underwent surgical repair of hand syndactyly. The overall unadjusted mean cost was \$4874, and ranged by center from \$2358 (CI 95%: 1063-3652) to \$9976 (CI 95%: 8194-28146; $P < .001$) (Figure 1). After applying the steps for benchmarking described above, we estimated the benchmark point to be \$3096 per syndactyly treatment. Using this value as a reference, 8 of the 38 hospitals (21%) yielded confidence limits above the benchmarked value (Figure 2).

Discussion

In this analysis of more than 2000 patients treated at 38 US pediatric hospitals, we found that syndactyly surgery had a perioperative complication rate of 1.9%, with low perioperative infection (1.6%) and surgical complication (0.3%) rates. Average length of stay was 1 day. In addition, age at time of surgery and number of associated diagnoses were found to be the primary factors influencing complications and costs of

Table 1. Demographic Characteristics of 2047 Cases of Syndactyly Reconstruction at 38 Children's Hospitals From 2009 to 2012.

Variable	Groups	Frequency	%	Median	IQR
Gender	Male %	1364	66.63		
Age (months)				18	11-37
Age group (months)	0-24	1277	62.38	12	9-16
	25-60	460	22.47	34	28-44
	>60	310	15.14	95	72-130
Race	White	1221	59.65		
	Black	291	14.22		
	Asian	54	2.64		
	American Indian	7	0.34		
	Pacific Islander	6	0.29		
	Other	314	15.34		
	Missing	154	7.52		
	Non-Hispanic	1340	65.46		
Ethnicity	Hispanic	352	17.20		
	Unknown	355	17.34		
Insurance ^a	Government	1063	51.93		
	Private	842	41.13		
	Self-pay	3	0.15		
	Other/unknown	139	6.79		
Region	Northeast	341	16.66		
	Midwest	480	23.45		
	South	724	35.37		
	West	502	24.52		
Surgeon subspecialty	Orthopedic surgery	987	48.21		
	Plastic surgery	781	38.15		
	Pediatric general	37	1.82		
	NOS	242	11.82		
Associated conditions	Upper extremity	397	19.39		
	Polydactyly	72	3.5		
	Orthopedic	286	13.97		
	Acrocephalosyndactyly	72	3.5		
	Medical	705	34.44		
Type of syndactyly	Asthma	55	2.6		
	Simple	1725	84.27		
	Complex	295	14.41		
	Syndactyly multiple NOS	27	1.32		

Note. HMO = health maintenance organizations; IQR = interquartile range; NOS = not otherwise specified; PPO = preferred provider organization.

^aInsurance: Government includes In-State Medicaid, Out-of-State Medicaid, Medicare, TRICARE, Charity, and Other government health care programs. Private includes HMO, PPO, and other commercial.

care. Furthermore, the analysis revealed wide variation in cost of syndactyly repair among pediatric hospitals, with 8 outlying institutions with costs above the estimated benchmark level.

Value encompasses efficiency and may be defined as clinical outcome divided by cost.²³ However simple this definition may seem, application of the value equation to the US health care system is complex. The first step in improving health care value is measurement; specifically, clinical outcomes and costs must be quantified to better understand the current state of affairs and identify opportunities for future improvement. The purpose of this investigation was to measure complications and cost for a

fundamental procedure in pediatric orthopedic surgery, syndactyly reconstruction.

To our knowledge, this is the first study to describe perioperative infection and early surgical complications rates for syndactyly surgery; indeed, most of the existing literature only describes the mid- to longer term clinical results of syndactyly repair.^{5,9,17,19,20,22,31} As noted above, current quality improvement strategies place early complications higher in the hierarchy of outcome measurements than longer term clinical results.²³

The rate of postsurgical infection is currently considered a standard indicator of the quality of care; therefore,

Table 2. Distribution of 39 Early Postoperative Complications After a Syndactyly Reconstruction According to the System Affected.

System	Description	Frequency	%
Skin and tegument	Pyogenic granuloma, finger paronychia, carbuncle, ingrown nail, graft complications	12	30.7
Respiratory	Cough, acute upper respiratory infection	12	30.7
Ear and nose	Otitis media, nasal and sinus discharge	9	23.1
Gastrointestinal tract	Constipation	2	5.1
Vascular	Accidental cut with laceration and hemorrhage	1	2.6
Cardiac	Dysrhythmia	1	2.6
Genitourinary	Urethral obstruction	1	2.6
Not otherwise specified	Infection not otherwise specified	1	2.6
Total		39	100

our findings establish the first benchmark value for syndactyly surgery. Others have similarly utilized administrative databases to report the incidence of acquired infections as quality indicators^{28,29} and characterized the impact of surgical infections on cost.^{4,8,10,21,38} Infection rates in orthopedic surgery varied from 0.6% to 1.4%, with approximately double the cost for procedures with acquired infections compared with those without infection.⁸ Although it is unlikely to prevent all possible complications, efforts should continue to minimize the number and severity of complications in efforts to improve the value of care provided to our patients.

Although several prior reports suggest that complex syndactyly is associated with poorer clinical results,^{1,7,18,19,22,31} we did not find an increased risk of complications or infection rates in this group. However, the presence of other orthopedic and medical conditions was associated with higher risk of infection and higher cost. Furthermore, patients with additional diagnoses had a 20-fold higher risk of complications, which raises the importance of meticulous surgical planning to consider the postoperative care of more complex patients. Another intriguing finding was the association of higher cost in younger patients. Possible explanations include selection bias, given that the majority of operations were performed in younger patients, with complex deformities and medical comorbidities. In addition, although variation in costs was seen across different surgeon subspecialties, these differences may be justified by greater expertise and/or formal training in pediatric hand surgery. This highlights the importance of assessing surgical outcomes with greater detail and framing all conclusions regarding cost within the value proposition.

Similar to other studies within orthopedic surgery,^{3,11,24,34} there was great variability in cost for syndactyly procedures among pediatric hospitals across the United States. This highlights an opportunity to provide improved value by identifying best practices which produce equivalent or better clinical outcomes at lower costs.

Increasing transparency and shared information regarding clinical outcomes and costs may foster collaborative strategies and promote underperforming institutions to improve value-based care.² Measurement of outcomes and cost alone will have little utility if it is not followed by development of treatment guidelines to standardize practice in order to reduce variation.^{27,35} It should be noted, however, that additional effort is needed to risk stratify patients based on complexity of syndactyly or associated conditions, as well as to understand the differences in indirect costs across geographic regions and institutions; these factors may contribute to higher costs and are not well captured within the PHIS database.

There were a number of limitations to this investigation. The use of an administrative database has inherent restrictions. These institutional data were gathered for administrative purposes and therefore lack robust clinical information regarding specific patient characteristics, treatment, or clinical outcomes. For example, the donor site and technique of skin grafting could not be determined based on the available data, and it is possible that aspects of skin grafting might have influenced clinical results (eg, infection). However, administrative databases do provide valuable information about large numbers of patients across geographic regions; for relatively uncommon conditions such as syndactyly, such analysis may provide generalizable information representative of the population of interest.¹⁵ In addition, this analysis did not include any evaluation of long-term clinical outcomes, such as infections presenting beyond the episode of care, as PHIS does not include linked data from subsequent outpatient visits. For the aforementioned reasons, this study did not capture patient-derived outcome measures or costs associated with persistent impairment or need for secondary surgery. Creation of prospective multicenter databases or registries is needed to monitor these patients over time. Finally, this analysis was restricted to the episode of care, and complications during this period cannot be attributed directly to the syndactyly reconstruction; we believe more likely they were due to patient comorbidities.

Table 3. Multivariate Analysis of the Outcome Measures and Associated Covariates of 2047 Cases of Syndactyly Reconstruction at 38 Children's Hospitals From 2009 to 2012.

Outcome	Covariates	%	Unadjusted risk ratios			Adjusted risk ratios		
			OR	95% CI	P value	OR	95% CI	P value
Complication	Associated diagnosis							
	Syndactyly only diagnosis	0.2	—	—	—	—	—	—
	Syndactyly + associated diagnosis	4.1	20.0	5.5-72.4	<.001	19.2	5.7-68.0	<.001
	Age groups							
	0-24 months	1.7	—	—	—			
	25-60 months	2.4	1.43	0.70-2.93	.34			
	>60 months	1.6	1.00	0.39-2.58	.99			
	Regions							
	Northeast	3.8	—	—	—			
	Midwest	1.7	0.44	0.18-1.05	.06			
	South	1.4	0.36	0.16-0.81	.02			
	West	1.7	0.37	0.15-0.91	.03			
	Subspecialty							
	Orthopedic surgery	1.4	—	—	—			
	Pediatric Surgery	2.7	2.76	0.49-15.6	.31			
	Plastic surgery	2.0	1.45	0.71-2.95	.31			
	Type of syndactyly							
	Simple	1.7	—	—	—			
	Complex	3.1	1.65	0.78-3.53	.22			

Outcome	Covariates	Median	Unadjusted risk ratios			Adjusted risk ratios		
			Effect	95% CI	P value	Effect	95% CI	P value
Total standardized cost	Associated diagnosis							
	Syndactyly only diagnosis	\$3800.4						
	Syndactyly + associated diagnosis	\$4530.5	1.21	1.15-1.26	<.001	1.13	1.08-1.16	<.001
	Age group							
	0-24 months	\$4273.0						
	25-60 months	\$3927.3	0.92	0.87-0.97	.004	0.92	0.87-0.95	<.001
	>60 months	\$3793.4	0.89	0.84-0.95	<.001	0.86	0.82-0.90	<.001
	Regions							
	Northeast	\$5525.3						
	Midwest	\$4128.4	0.87	0.81-0.94	<.001			
	South	\$3780.3	0.72	0.67-0.77	<.001			
	West	\$4023.2	0.81	0.75-0.87	<.001			
	Subspecialty							
	Orthopedic Surgery	\$4168.7						
	Pediatric Surgery	\$3135.4	0.69	0.59-0.80	<.001			
	Plastic Surgery	\$4138.5	0.95	0.90-0.99	.02			
	Type of syndactyly							
	Simple	\$3931.9						
	Complex	\$5242.3	1.24	1.17-1.33	<.001			

Note. Values in bold indicate statistical significance. OR = odds ratio; CI = confidence interval.

Despite these limitations, we conclude that surgical release of syndactyly in the United States has low perioperative complication rate with low infection and surgical complication rates. Younger age at the time of surgery and presence of associated diagnoses were found to be significant risk factors for higher complication rates and

cost. Through benchmarking methodology, significant variability in cost was found among US children's hospitals. Further investigation is needed to identify the sources of this variation in hopes of developing value-based, quality improvement strategies in pediatric orthopedic surgery.

Figure 1. Unadjusted average cost by hospital.

Note. This bar graph indicates variability in treatment costs across 38 pediatric hospitals.

Figure 2. Average patient cost by hospital with back-transformed asymmetric confidence limits and benchmarked average patient cost.

Note. Marked squares represent 8 of the 38 hospitals that yielded confidence limits above the benchmarked value.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

No identifying information about participants is available in this article; all the data obtained from the Pediatric Health Information System database were de-identified.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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