Surgical Outcomes in Children According to Hospital Location and Designation: A National Study

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Abstract

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Introduction: The effects of hospital location and specialty designation on post-operative outcomes in children have not been extensively evaluated. We hypothesized that outcomes would be improved at urban centers, and that outcomes would differ at urban centers for children from rural versus urban counties.

Methods: We conducted a retrospective cohort study of children undergoing non-incidental appendectomy (n=129,507) and pyloromyotomy (n=17,109) using the 2006 and 2009 Kid's Inpatient Database and 2007, 2008 and 2010 Nationwide Inpatient Sample. Hospitals were defined as non-children's, children's unit in a general hospital, or freestanding children's hospitals, and were classified as urban or rural based on census data. Patient County of residence was classified as urban or rural based on census data. Outcomes included post-operative complications defined by ICD-9 codes and total hospital length of stay. Multivariate logistic and linear regression models were used to adjust for confounding.

Results: Among appendectomy patients, 12.1% were treated at rural hospitals, while 3.4% of pyloromyotomy patients received their operation at a rural hospital. For appendectomy patients, treatment at urban relative to rural hospitals was associated with a reduced odds of any post-operative complication (OR=0.82, 95% C.I. 0.73 – 0.92) and anesthesia-related complications (OR=0.75, 95% C.I. 0.59 – 0.96). This association was strongest in the youngest children (<5 years) and at freestanding children's hospitals, specifically. Among children receiving appendectomy at urban centers, adjusted length of stay was half a day shorter for urban children than for rural children (p<0.001). For pyloromyotomy patients, urban hospitals were associated with a reduced odds of any complication (OR=0.33, 95% C.I. 0.20 – 0.55), anesthesia-related complications (OR=0.12, 95% C.I. 0.05 – 0.29), and duodenal perforation (OR=0.36, 95% C.I. 0.16 – 0.82). These associations were strongest at freestanding children's hospitals.

Conclusion: Post-operative outcomes are improved at urban specialty hospitals for certain common procedures in children, and this effect seems to be most important in younger children. The specific factors responsible for these improved outcomes must be identified in order to improve care for children treated in all practice settings.

INTRODUCTION:

Hospital and physician characteristics have long been implicated in affecting outcomes in health care[1]. Specifically, authors have suggested that center and practitioner operative volume and comfort level with certain procedures are important drivers of post-operative surgical outcomes in adults[2-4]. A similarly rigorous body of evidence is missing in the pediatric surgical literature, and the effects of institution and surgeon-level variables on outcomes remain unclear. Specifically, the role of hospital location and designation has not been extensively evaluated in this field, despite the fact that many surgical procedures in children are performed at a wide variety of hospital types.

Previous research suggests that the difference in outcomes between center types reflects the differences in resources available at specialized versus non-specialized centers of care. Studies looking at hospital designation as an exposure variable for children's surgical outcomes have occasionally found superior outcomes at children's centers, but these studies are often small and results are inconsistent[5-8]. In addition, these studies do not specifically examine outcomes at rural centers. Recent studies in both adults and children have suggested that certain outcomes may be inferior for specific procedures performed at rural centers[8-10]. Furthermore, patients undergoing treatment far from home, specifically rural residents treated at urban centers, may experience different care than their urban counterparts. As such, both hospital location and patient residence are important factors that have the potential to influence outcomes for common pediatric surgical procedures.

The purpose of this study was to investigate the relationship between hospital location (urban vs. rural) and hospital designation (children's vs. non-children's) and post-operative outcomes for common pediatric surgical conditions (pyloromyotomy and appendectomy) treated at a wide variety of hospital types. Further, the study sought to determine whether outcomes at urban hospitals differ according to patient county of residence (urban vs. rural).

METHODS

Study Design & Setting

We performed a retrospective cohort study using the Healthcare Cost and Utilization Project's (HCUP) Nationwide Inpatient Sample (NIS) and Kid's Inpatient Database (KID) (http://www.hcup-us.ahrq.gov/)[11]. These databases include a sample of pediatric discharges from community, non-rehabilitation hospitals across the United States. All states participating in HCUP contribute to the sample. Up to 44 states are represented in the 2009 edition of KID and 45 states in the 2010 edition of NIS. The study utilized data from the 2006 and 2009 KID database releases and the 2007, 2008, and 2010 NIS releases. Research activities and data analysis were conducted at Seattle Children's Hospital and the University of Washington. The University of Washington Institutional Review Board reviewed the study and determined it to be exempt from Human Subjects review.

Study Subjects

The study included patients undergoing one of two general surgical procedures of interest: non-incidental appendectomy and pyloromyotomy. Outcomes for each procedure were analyzed separately. Non-incidental appendectomy admissions (drawn from KID 2006 and 2009) were defined as patients under age 20 with a procedure code for appendectomy (47.0, 47.01, 47.09) in the absence of any procedure code for incidental appendectomy (47.1, 47.11, 47.19). Patients with malignant or benign neoplasms of the appendix, cecum or right colon were excluded. Pyloromyotomy admissions (drawn from KID 2006 & 2009, and NIS 2007, 2008, &

2010) were defined as presence of a procedure code for pyloromyotomy (43.3) in conjunction with the presence of a diagnostic code for infantile hypertrophic pyloric stenosis (750.5). Patients older than one year of age were excluded in order to capture only patients with idiopathic infantile pyloric stenosis.

Covariates of Interest

The primary exposures of interest included hospital location and designation, as well as rurality of patients' county of residence. Hospital designations were defined using National Association of Children's Hospitals and Related Institutions (NACHRI) criteria as non-children's hospital, children's unit within a general hospital, and freestanding children's hospital. Hospital location was defined based on the United States Census Bureau's Core Based Statistical Area (CBSA) codes, with hospitals with CBSA type of *Metropolitan* or *Division* classified as urban (city with population ≥50,000), and those with CBSA type *Micropolitan* or *Rural* classified as rural (city with population <50,000). Patient County of residence was classified according to the urban-rural classification scheme developed by the National Center for Health Statistics (NCHS), broken down as urban (counties with a metro area of ≥50,000 population) or rural (counties without a metro area of ≥50,000 population).

Primary outcomes included post-operative complications (during initial hospitalization) and total hospital length of stay. ICD-9 diagnostic codes were used to identify general post-operative complications for all procedures of interest, and included the following: cellulitis/abscess (682.2, 682.9), acute lymphadenitis (683), complications peculiar to specific procedure (996), complications of specific body systems (997.1 – 997.9), other complications including shock, hemorrhage, and infection (998.0 – 998.9), complications of medical care NEC (999), other vascular complications (999.2), other infectious complications (999.3 – 999.32), transfusion reactions (999.4 – 999.89), adverse effects of anesthesia (995.22, 995.4, 995.86, 995.89), iatrogenic post-operative pneumothorax (512.1), and post-operative pulmonary complications (518.4, 518.5) . Anesthesia complications (i.e. adverse effects of anesthesia and complications of pulmonary system) were also considered independently. For pyloromyotomy patients, iatrogenic duodenal perforation was looked at specifically using the code for accidental puncture or laceration during a procedure (998.2). For appendectomy patients, negative appendectomy was considered as an outcome of interest and was defined as any operative ICD-9 code for non-incidental appendectomy (47.0, 47.01, 47.09) in the absence of a diagnostic code for appendicitis (540 – 542).

Covariates identified *a priori* were those we believed might differ systematically across hospital types and also might be correlated with our outcomes of interest. For both procedures of interest, covariates included gender, race, payer status (Medicaid vs. non-Medicaid), and comorbid conditions. Chronic comorbid conditions for appendectomy patients were defined using ICD-9 diagnostic codes for a broad spectrum of previously defined diagnoses commonly considered as potential confounders in pediatric outcomes research[12]. For infants undergoing pyloromyotomy, since chronic comorbidities are not an issue, comorbid conditions were defined differently and primarily focused on congenital anomalies. Comorbidities (according to ICD-9 diagnostic codes) for these patients included central nervous system anomalies (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). Perforation status was included as a covariate (considered as both confounder and potential effect modifier) for appendectomy patients and defined as presence of a diagnostic code for perforated appendicitis (540.0, 540.1).

Data Analysis

Patient characteristics were analyzed using descriptive statistics, and chi square homogeneity tests used to compare the distribution of these characteristics across different hospital designations and locations, as well as across different patient characteristics (urban vs. rural residents). Multivariate logistic and linear regression models were used to adjust for confounding. Two basic regression analyses were performed for each procedure of interest: 1) Analysis with hospital location and designation as the exposure of interest; 2) Analysis with rurality of county of residence as the exposure of interest in patients undergoing appendectomy or pyloromyotomy at urban centers. All of the covariates mentioned above were included *a priori* as potential confounders in these analyses. For appendectomy analyses, patient age and perforation status were each analyzed both as potential confounders and as potential effect modifiers by stratification according to those variables. Regression models were adjusted for clustering at the hospital level using a random-effects model in order to account for the non-independence of sampling. Risk estimates for binary outcomes are reported as odds ratios with 95% confidence intervals. For continuous outcomes, linear regression coefficients are reported along with 95% confidence intervals.

RESULTS

Appendectomy

A total of 129,507 children who underwent appendectomy met criteria for inclusion in the study. The mean age of these patients was 12.5 years, and 25.4% presented with perforated appendicitis (Table 1). 12.1% of children received their appendectomy in a rural hospital. Of those who received care in an urban hospital, two-thirds were treated at non-children's hospitals. 4.7% of children experienced post-operative complications.

Patient characteristics differed significantly across hospital types. Children treated at rural hospitals tended to be older than those treated at urban children's hospitals (mean age 13.1 vs. 9.8 years, $p<0.001$) (Table 2). Urban centers treated a significantly greater percentage of black and Hispanic patients than rural centers. A similar percentage of children at rural and urban hospitals had Medicaid as their primary payer (32.7% and 32.3%, respectively), but patients treated at freestanding children's hospitals were significantly more likely to be on Medicaid (41.4%, $p<0.001$). Perforated appendicitis was also more frequent at specialized hospitals, with 34.7% of patients at children's hospitals presenting with perforation. Complication rates were generally lower at urban compared to rural hospitals, but mean hospital length of stay was longer at urban hospitals (2.4 days vs. 3.0 days, $p<0.001$). Among children treated at urban hospitals, patients from urban counties were more likely to be black or Hispanic than those originating from rural counties (Table 3). Both perforation (29.4% vs. 25.4%, $p<0.001$) and chronic comorbid conditions (11.2% vs. 9.5%, $p<0.001$) were more common among children from rural counties. Although little difference was noted in post-operative complications according to county of residence, children from rural counties had a mean length of stay nearly one day longer than urban children (3.8 days vs. 3.0 days, $p<0.001$).

After multivariate adjustment, treatment at an urban hospital was associated with a nearly 20% reduced odds of post-operative complications relative to treatment at a rural hospital

(OR=0.82, 95% C.I. 0.73 – 0.92) (Table 4). Treatment at a children's hospital specifically was associated with an almost 60% reduced odds of complications (OR=0.44, 95% C.I. 0.35 – 0.55). These associations did not vary by patient age or perforation status. Urban hospitals also conferred a lower risk of anesthesia-related complications relative to rural hospitals (OR=0.75, 95% C.I. 0.59 – 0.96), with evidence of a greater protective effect for younger children (OR=0.42 for children <5 years, OR=0.69 for children 5-10 years, OR=0.77 for children 11-19 years). Similar to results for all complications, treatment at a children's hospital was associated with the greatest protective association (OR=0.35, 95% C.I. 0.22 – 0.54), and this association was also greater for younger children (OR=0.22 for children <5 years, OR=0.39 for children 5-10 years, OR=0.44 for children 11-19 years). Adjusted length of stay was longer at urban compared to rural hospitals, but when considering urban hospitals specifically, children from urban counties stayed half a day less than rural children (-0.49 days, 95% C.I. -0.71 – -0.27). The difference in adjusted length of stay between urban and rural children was most marked among non-perforated cases (-0.71 days, 95% C.I. -0.99 – -0.43).

Pyloromyotomy

There were 17,109 pyloromyotomy patients included in our study. The mean age of these patients was 36.5 days (Table 1). While only 3.4% of patients received an operation at rural hospitals, 19% of patients originated from rural counties. Post-operative complications were uncommon overall, with 2.2% experiencing any complication, 0.3% a complication attributable to anesthesia, and 0.9% duodenal perforation. The mean total length of stay for pyloromyotomy patients was 3.2 days.

Similar to appendectomy results, black and Hispanic children accounted for a larger percentage of patients at urban hospitals than at rural hospitals (Table 5). Medicaid insurance was more common at rural compared to urban hospitals (62.6% vs. 58.8%, p=0.02). Post-operative complications were noted much more commonly at rural compared to urban hospitals (5.7% vs. 2.0%, p<0.001), and the lowest complication rate was observed at freestanding children's hospitals (1.5%). Similarly, anesthesia-related complications (1.5% vs. 0.3%, p<0.001) and duodenal perforation (2.4% vs. 0.8%, p<0.001) were both significantly more common at rural hospitals than at urban hospitals. Among infants treated at urban hospitals, patients from urban counties were more likely to be black or Hispanic (Table 6). Medicaid insurance was more common among patients from rural counties (65.9% vs. 57.5%, p<0.001). Neither post-operative complications nor length of stay differed significantly by county of residence.

Multivariate analysis showed care at urban hospitals to be associated with significantly reduced odds of post-operative complications relative to rural hospitals (OR=0.33, 95% C.I. 0.20 – 0.55) (Table 7). Odds of complications was lowest at freestanding children's hospitals (OR=0.25, 95% C.I. 0.14 – 0.45). Treatment at urban hospitals and more specialized centers of care was associated with a marked reduction in odds of anesthesia-related complications. Receipt of pyloromyotomy at any urban hospital reduced the odds of anesthesia-related complications by nearly 90% (OR=0.12, 95% C.I. 0.05 – 0.29), and this effect was again most pronounced at freestanding children's hospitals. Duodenal perforation was also significantly less likely at urban hospitals (OR=0.36, 95% C.I. 0.16 – 0.82), and while this association was not remarkable for urban non-children's hospitals (OR=0.82, 95% C.I. 0.20 – 1.07), it became highly pronounced at freestanding children's hospitals (OR=0.21, 95% C.I. 0.08 – 0.56). Adjusted total length of stay did not differ significantly according to hospital location or patient county of residence for infants undergoing pyloromyotomy.

DISCUSSION

This study represents one of the largest national cohorts of pediatric appendectomies and pyloromyotomies yet compiled, and is the first to analyze the influence of hospital location on specific post-operative outcomes following these procedures. Using a national administrative database, we found that post-operative complications are less likely at urban hospitals, with children's hospitals associated with the greatest protective effect. For appendectomy, this association was strongest among the youngest children. We also found that children from rural counties receiving appendectomy in urban hospitals tended to have a significantly longer length of stay than children from urban counties.

Hospital characteristics, specifically specialty designation and hospital case volume, are known to influence outcomes after surgical procedures[2,13]. Recent studies in children's surgery have also demonstrated this association, specifically with regard to rare conditions such as biliary atresia and congenital diaphragmatic hernia[14,15]. The association is less clear for common procedures such as appendectomy and pyloromyotomy, as surgeon-level factors may be more important in driving outcomes in these cases[16]. Previous studies have suggested that hospital designation may impact post-operative outcomes for children undergoing these two common procedures[6,7,17]. Our results not only support these findings, but go even further in suggesting a stepwise reduction in the likelihood of post-operative complications after appendectomy or pyloromyotomy as a hospital's pediatric specialization increases. Certainly, greater surgeon experience in treating young children may be a major factor underlying our results, especially in reducing purely technical complications such as duodenal perforation during pyloromyotomy. It may also be that hospitals specializing in the care of infants and children may have certain characteristics beyond surgeon training and experience that decrease the likelihood of post-operative complications. Increased utilization of post-operative care pathways and protocols is an example of such a characteristic.

In addition to specialty designation, hospital location is an important consideration in post-operative outcomes studies. Hospitals in rural environments may face specific resource constraints that influence outcomes, and such differences cannot be detected if hospital location is not considered independent of hospital designation. Research on the influence of hospital rurality on outcomes has been limited, with some evidence of differences in operative utilization, negative appendectomy rates, and rates of perforated appendicitis between rural and urban hospitals[10,18,19]. Ours is the first study to look specifically at the influence of hospital location on post-operative complications, and we found a decreased risk of complications for both appendectomy and pyloromyotomy at urban hospitals relative to rural hospitals. While surgeon training may drive part of this association, the fact that even urban non-children's hospitals, which generally do not employ pediatric surgeons, show improved outcomes relative to rural hospitals, suggests that other hospital-level resources may be influencing these outcomes.

One way to analyze resources separate from surgeon-level factors is to separate out the specific post-operative complications of interest. We chose to look specifically at anesthesia-related complications, which presumably are attributable to anesthesiologist training and experience rather than to surgeon experience. The presence of fellowship-trained pediatric anesthetists, or the presence of anesthetists with significant experience in caring for children, has been implicated as an important driver of post-operative outcomes, as well as a benchmark for certain types of accreditation[20,21]. Our results showed a marked reduction in the odds of anesthesia-related complications as hospital specialization increased, with the most striking associations noted in younger children (appendectomy patients <5 years of age and pyloromyotomy patients). These results suggest that certain features of the perioperative environment at pediatric specialty centers facilitate improved outcomes in the youngest of children.

Another point highlighted by our results is the importance of considering age as a modifying factor with regard to outcomes following appendectomy. While older children with appendicitis may present similar to adults, younger children are more likely to present with atypical symptoms, a longer duration of symptoms, and a greater likelihood of perforation[22]. As such, one might hypothesize *a priori* that adult surgeons and adult facilities might produce better outcomes in the treatment of older children. Previous work by our group has suggested that the relationship between surgeon training and post-operative outcomes following appendectomy in children is modified by patient age, with the greatest effect noted in children <5 years of age (McAteer J, LaRiviere C, Oldham K, Goldin A, data submitted for publication, May 2013). Our results in this study further support this, as the largest protective associations are noted in the youngest children.

Given the increasing focus on health care economics, it is also increasingly important to focus on outcomes other than medical complications. Measures of health care utilization, such as length of stay, can be important metrics in such analyses. While the increased length of stay noted at urban relative to rural hospitals in our study may not be a negative (potentially a marker of increased adherence to beneficial post-operative care pathways), the differences in post-operative length of stay at urban hospitals for children from rural vs. urban counties may represent a true difference in care based on the patient's county of origin. Rural children treated for appendicitis at an urban center in our study stayed in the hospital an average of half a day longer than urban children after multivariate adjustment, and this difference was nearly three-quarters of a day for children with non-perforated appendicitis. This could represent a greater reluctance to discharge families who have traveled a long distance, or may be a more complex measure of socioeconomic differences. Travel burden is an important consideration in efforts aimed at care optimizations, as centralization efforts can have negative effects with regard to access to care[23]. Need for pediatric care is a common reason for transfer in many local emergency departments, and so delineating the situations in which certain children may be safely treated without transfer to a higher level of care is essential[24]. Although further data is needed to substantiate these findings, it is possible that older children with clearly non-perforated appendicitis might benefit most from treatment by a local, qualified adult surgeon, potentially curtailing additional costs and length of stay that are associated with transfer to a more specialized center. Ultimately, defining the characteristics of specialized hospitals that are most important in producing good outcomes will enable us to improve the care of children treated in all practice environments.

This study has a number of limitations. These data are observational, and thus are susceptible to unmeasured confounding. As such, results should be interpreted as associations and not assumed to be causal in nature. The data are also subject to potential misclassification, though we have attempted to utilize stringent inclusion criteria for our populations of interest in order to minimize this. Miscoding is a potential problem with NIS and KID data; we therefore tried to limit our outcomes to those that would be likely to be captured using billing data[25]. Since appendectomy and pyloromyotomy patients are generally otherwise healthy, it can be difficult to adequately risk stratify, even with the measures of disease severity and comorbid conditions we have employed. Thus, residual confounding due to differences in case mix across hospitals is possible. With regard to patients' County of residence, this variable is not a pure measure of travel distance for children originating from rural counties, and some children would have had to travel further than others to seek care at an urban center. The results on length of stay should therefore be interpreted as preliminary hypothesis-generating results that can guide further work using more detailed population-level data. Lastly, the specific factors in play at urban and specialty hospitals that lead to improved outcomes in these data cannot be determined, and are almost certainly multifactorial in nature. As noted above, further work is necessary to identify these factors in more detail.

Our findings show that outcomes for these two common procedures are improved when care is administered at urban specialty centers. These associations, however, appear to be most important for the youngest children. The diminished returns for older children with regard to post-operative complications, as well as the evidence for increased length of stay for rural children undergoing appendectomy at urban centers, suggests that any recommendations for patient referral may need to be tailored based on patient age and other disease characteristics. While prior position statements have urged referral of certain pediatric cases to specialized centers, further data are needed in order to refine these recommendations and make them more specific in guiding providers[26,27]. For some common procedures, the best outcomes may be realized by focusing on the optimization of resources at many centers rather than formal recommendations for referral and regionalization. Defining those resources is the next key step in this process.

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Table 1. Descriptive characteristics for appendectomy and pyloromyotomy patients. Urban peds unit = children's unit in an adult general hospital. (sd=standard deviation)

	Appendectomy (n=129,507)		Pyloromyotomy (n=17,106)	
	n	%	n	%
Sex				
Male	73,381	59.1	14,121	82.9
Female	50,804	40.9	2,907	17.1
Unknown	5,322		78	
Age (mean, sd)	12.5 yrs	4.6 yrs	36.5 days	18.3 days
Race				
White	55,921	56.2	7,898	58.3
Black	6,521	6.6	1,055	7.8
Hispanic	29,317	29.5	3,480	25.7
Asian/Pacific Islander	2,172	2.2	150	1.1
Native American	862	0.9	89	0.7
Other	4,715	4.7	872	6.4
Unknown	29,999		3,562	
Medicaid Primary	42,066	32.5	10,086	59.0
Unknown	213		18	
Perforation	32,889	25.4	N/A	N/A
Comorbid Condition	12,176	9.4	656	3.8
Treating Hospital				
Rural	15,099	12.1	549	3.4
Any Urban Hospital	109,768	87.9	15,453	96.6
Urban Non-Children's	74,223	59.4	3,378	21.1
Urban Peds Unit	19,388	15.5	4,733	29.6
Urban Children's	14,118	11.3	3,596	22.5
Urban Unspecified	2,039	1.6	3,746	23.4
Unknown	4,640		1,104	
County of Residence				
Rural	19,636	15.4	3,195	19.0
Urban	107,733	84.6	13,651	81.0

Unknown	2,138		260	
Post-op Complications				
Any Complication	6,119	4.7	369	2.2
Anesthesia Complication	840	0.7	59	0.3
Duodenal Perforation	N/A	N/A	150	0.9
Length of Stay, days (mean, sd)	3	6.3	3.2	7.6

Table 2. Appendectomy patient characteristics by treating hospital.

	Rural		Any Urban		Urban Non-Children's		Urban Peds Unit		Urban Children's		
	n	%	n	%	n	%	n	%	n	%	p-value
Sex											
Male	8,798	58.7	61,807	59.1	41,103	59	11,341	59.5	8,176	59.4	0.40
Female	6,187	41.3	42,753	40.9	28,586	41	7,734	40.6	5,581	40.6	
Unknown	114		5,208		4,534		313		361		
Age, years (mean, sd)	13.1	4.1	12.5	4.6	13.3	4.4	11.1	4.8	9.8	4.1	<0.001
Race											
White	8,371	79.3	45,566	53.7	32,016	56.5	8,319	52.6	4,223	38.6	<0.001
Black	370	3.5	5,878	6.9	3,507	6.2	1,541	9.7	694	6.3	
Hispanic	1,084	10.3	26,755	31.5	16,776	29.6	4,555	28.8	5,220	47.7	
Asian/Pacific Islander	141	1.3	1,900	2.2	1,273	2.3	385	2.4	227	2.1	
Native American	225	2.1	577	0.7	296	0.5	190	1.2	50	0.5	
Other	364	3.5	4,151	4.9	2,756	4.9	832	5.3	528	4.8	
Unknown	4,544		24,941		17,599		3,566		3,176		
Medicaid Primary	4,913	32.7	35,415	32.3	22,027	29.7	6,910	35.7	5,833	41.4	<0.001
Unknown	76		131		106		10		15		
Perforation	3,419	22.6	27,911	25.4	16,739	22.6	5,697	29.4	4,893	34.7	<0.001
Comorbid Condition	1,174	7.8	10,551	9.6	6,620	8.9	2,436	12.6	1,247	8.8	<0.001
County of Residence											
Rural	13,843	92	5,154	4.8	3,300	4.5	1,137	6	545	4	<0.001
Urban	1,206	8	102,539	95.2	69,711	95.5	17,715	94	13,249	96	

Unknown	50		2,075		536		324		16		
Post-op Comlications											
Any Complication	849	5.6	5,056	4.6	3,399	4.6	1,043	5.4	492	3.5	<0.001
Anesthesia Complication	126	0.8	685	0.6	473	0.6	139	0.7	49	0.4	<0.001
Length of Stay, days (mean, sd)	2.4	2.4	3	6.6	2.6	4.7	4.2	10.7	3.6	6.8	<0.001

Table 3. Appendectomy patient characteristics for children treated at urban hospitals, by county of residence.

	Rural		Urban		
	n	%	n	%	p-value
Sex					
Male	3,032	59.1	57,578	59.1	0.99
Female	2,095	40.9	39,797	40.9	
Unknown	27		5,164		
Age (mean, sd)	11.8	5	12.5	4.6	<0.001
Race					
White	2,884	78.5	41,268	52.3	<0.001
Black	119	3.1	5,669	7.2	
Hispanic	599	15.5	25,813	32.7	
Asian/Pacific Islander	21	0.5	1,834	2.3	
Native American	105	2.7	469	0.6	
Other	146	3.8	3,935	5	
Unknown	1,280		23,551		
Medicaid Primary	1,680	32.7	33,297	32.5	0.79
Unknown	15		114		
Perforation	1,515	29.4	26,045	25.4	<0.001
Comorbid Condition	575	11.2	9,733	9.5	<0.001
Treating Hospital					
Urban Non-Children's	3,300	64	69,711	68	<0.001
Urban Peds Unit	1,137	22.1	17,715	17.3	
Urban Children's	545	10.6	13,249	12.9	
Urban Unspecified	172	3.3	1,864	1.8	
Post-op Comlications					
Any Complication	263	5.1	4,730	4.6	0.10
Anesthesia Complication	43	0.8	633	0.6	0.05
Length of Stay, days (mean, sd)	3.8	9.4	3	6.3	<0.001

Table 4. Adjusted risk estimates for post-operative outcomes for appendectomy patients. County of residence risk estimates restricted to patients treated at urban hospitals only.

	*POST-OP COMPLICATIONS			*ANESTHESIA COMPLICATIONS			**LENGTH OF STAY		
	OR	95% CI	p-value	OR	95% CI	p-value	DAYS	95% CI	p-value
Urban Hospitals (Rural as Reference)	0.82	0.73 - 0.92	<0.001	0.75	0.59 - 0.96	0.02	0.54	0.32 - 0.75	<0.001
Hospital Designation (Rural as reference)									
Urban Non-children's	0.85	0.76 - 0.95	0.003	0.79	0.62 - 1.01	0.06	0.48	0.25 - 0.70	<0.001
Urban Hospital with peds unit	0.77	0.66 - 0.91	0.002	0.7	0.51 - 0.97	0.03	1.39	0.96 - 1.83	<0.001
Urban Children's Hospital	0.44	0.35 - 0.55	<0.001	0.35	0.22 - 0.54	<0.001	0.28	-0.44 - 1.01	0.44
County of Residence (Rural as reference)	1.02	0.87 - 1.19	0.82	0.91	0.62 - 1.33	0.62	-0.49	-0.71 - -0.27	<0.001
*Adjusted for age, gender, race, insurance status, perforation, comorbidities									
**Adjusted for age, gender, race, insurance status, perforation, comorbidities, post-operative complications									

Table 5. Pyloromyotomy patient characteristics by treating hospital.

	Rural		Any Urban		Urban Non-Children's		Urban Peds Unit		Urban Children's		
	n	%	n	%	n	%	n	%	n	%	p-value
Sex											
Male	455	83.0	12,757	83.0	2,806	83.6	3,881	82.2	2,971	83.2	0.41
Female	93	17.0	2,619	17.0	550	16.4	839	17.8	601	16.8	
Unknown	1		77		13		24		18		
Age, days (mean, sd)	39.7	19.1	36.3	18.3	35.8	17.7	36.9	19.0	36.0	17.9	<0.001
Race											
White	331	85.3	6,986	57.1	1,544	55.1	2,329	62.7	1,399	49.7	<0.001
Black	11	2.8	977	8.0	184	6.6	377	10.2	195	6.9	
Hispanic	19	4.9	3,261	26.6	823	29.4	719	19.4	1,028	36.5	
Asian/Pacific Islander	1	0.3	141	1.2	44	1.6	24	0.7	30	1.1	
Native American	9	2.3	60	0.5	17	0.6	19	0.5	7	0.3	
Other	17	4.4	820	6.7	192	6.9	246	6.6	158	5.6	
Unknown	161		3,208		574		1,019		779		
Medicaid Primary	342	62.6	9,070	58.8	1,923	57.0	2,783	58.8	2,153	59.9	0.02
Unknown	3		15		3		3		1		
Comorbid Condition	18	3.3	601	3.9	126	3.7	192	4.1	142	4.0	0.76
County of Residence											
Rural	458	83.4	2,423	16.0	439	13.0	922	19.9	422	12.0	<0.001
Urban	91	16.6	12,770	84.1	2,927	87.0	3,714	80.1	3,093	88.0	
Unknown	0		260		12		97		81		

Post-op Comlications											
Any Complication	31	5.7	315	2.0	97	2.9	101	2.1	54	1.5	<0.001
Anesthesia Complication	8	1.5	48	0.3	17	0.5	11	0.2	10	0.3	<0.001
Duodenal Perforation	13	2.4	126	0.8	38	1.1	45	1.0	19	0.5	<0.001
Length of Stay, days (mean, sd)	2.7	1.8	3.2	7.7	3.6	8.6	3.1	6.8	2.8	6.4	0.14

Table 6. Pyloromyotomy patient characteristics for children treated at urban hospitals, by county of residence.

	Rural		Urban		
	n	%	n	%	p-value
Sex					
Male	2,002	82.8	10,551	83.1	0.69
Female	417	17.2	2,146	16.9	
Unknown	4		73		
Age (mean, sd)	38.0	19.6	35.9	18.0	<0.001
Race					
White	1,344	80.0	5,492	53.2	<0.001
Black	66	3.9	905	8.8	
Hispanic	147	8.7	3,046	29.5	
Asian/Pacific Islander	6	0.4	132	1.3	
Native American	17	1.0	42	0.4	
Other	101	6.0	709	6.9	
Unknown	742		2,444		
Medicaid Primary	1,594	65.9	7,340	57.5	<0.001
Unknown	4		11		
Comorbid Condition	90	3.7	501	3.9	0.63
Treating Hospital					
Urban Non-Children's	439	18.1	2,927	22.9	<0.001
Urban Peds Unit	922	38.1	3,714	29.1	
Urban Children's	422	17.4	3,093	24.2	
Urban Unspecified	640	26.4	3,036	23.8	
Post-op Comlications					
Any Complication	50	2.1	258	2.0	0.97
Anesthesia Complication	8	0.3	39	0.3	0.84
Duodenal Perforation	24	1.0	100	0.8	0.30
Length of Stay, days (mean, sd)	3.1	6.4	3.2	7.9	0.28

Table 7. Adjusted risk estimates for post-operative outcomes for pyloromyotomy patients. County of residence risk estimates restricted to patients treated at urban hospitals only.

	*POST-OP COMPLICATIONS			*ANESTHESIA COMPLICATIONS			*DUODENAL PERFORATION			**LENGTH OF STAY		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	DAYS	95% CI	p-value
Urban Hospitals (Rural as Reference)	0.33	0.20 - 0.55	<0.001	0.12	0.05 - 0.29	<0.001	0.36	0.16 - 0.82	0.02	1.1	-0.5 - 2.6	0.18
Hospital Designation (Rural as reference)												
Urban Non-children's	0.48	0.28 - 0.81	0.007	0.19	0.07 - 0.55	0.002	0.82	0.20 - 1.07	0.07	1.5	-0.1 - 3.2	0.07
Urban Hospital with peds unit	0.33	0.19 - 0.56	<0.001	0.12	0.04 - 0.34	<0.001	0.33	0.14 - 0.78	0.01	0.5	-1.3 - 2.3	0.58
Urban Children's Hospital	0.25	0.14 - 0.45	<0.001	0.08	0.02 - 0.28	<0.001	0.21	0.08 - 0.56	0.002	0.1	-2.3 - 2.5	0.93
County of Residence (Rural as reference)	1.13	0.76 - 1.67	0.55	0.74	0.28 - 1.98	0.55	1.04	0.57 - 1.92	0.89	0.01	-0.4 - 0.4	0.96
*Adjusted for gender, race, insurance status, comorbidities												
**Adjusted for gender, race, insurance status, comorbidities, post-operative complications												