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The contemporary appendectomy for acute uncomplicated appendicitis in children

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ABSTRACT

Background: National, procedure-specific clinical registries are increasingly available in surgery, although data about children have lagged behind. Data related to the surgical management of appendicitis in children have become available recently and can be used to inform patient and family expectations and to identify clinical areas in need of ongoing improvement.

Methods: Cases of acute, uncomplicated appendicitis in children (<18 years of age) were extracted from the 2017 pediatric appendectomy-targeted file of the American College of Surgeons National Surgical Quality Improvement Program. Epidemiologic data were generated across 5 domains: (1) patient characteristics/severity, (2) preoperative imaging patterns, (3) characteristics of the operation, (4) pathologic outcomes, and (5) postoperative morbidity and mortality.

Results: The final sample included 9,507 appendectomies for acute, uncomplicated appendicitis performed at 106 hospitals. The population was predominantly male (60.6%), involving children 6 to 12 years of age (55.3%). Only 2.9% of patients did not have imaging before their appendectomy. Overall, 38.2% received a computed tomography; however, patients transferred with imaging received computed tomography at 3.8 times the rate of those with only local (ie, operating hospital) imaging. Laparoscopy was used in 94.6% of cases, with 1.1% converted to open. Negative appendectomy and complication rates were 3.3% and 2.1%, respectively. Children ≤5 years of age had 2.3 greater odds of negative appendectomy than children 6 to 17 years of age.

Conclusion: Children undergoing operation for acute, uncomplicated appendicitis have excellent clinical outcomes, although children ≤5 years of age have an increased risk of negative appendectomy. Despite guidelines against their use, more than one-third of children received a computed tomography before operation, driven predominantly by transferring hospitals.

Introduction

The lifetime incidence of appendicitis is 9%, with a peak presentation between the ages of 10 and 14 years.[1] Despite more than 100 years of experience with appendectomy in children,[2] the management of appendicitis continues to evolve. Early epidemiologic studies included the open approach, infrequent imaging, and lengthy postoperative stays, which do not reflect the experiences of patients undergoing appendectomy today.[3–5]

Much of the focus of appendicitis research today relates to nonoperative therapy, but these data cannot be used for epidemiologic purposes because these studies include small samples with restrictive inclusion criteria.[6–11] Recent analyses that have attempted to provide regional or national data on appendectomy have been largely limited to single topics (eg, imaging), a select group of pediatric hospitals, and administrative data (Table I).[12–16]

Here we present data for the surgical management of appendicitis, using extensively validated data from a national clinical registry from a diverse group of pediatric hospitals. We provide comprehensive descriptive data across five domains: (1) patient

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Table I
Recent epidemiologic and nonoperative studies providing data for the operative management of appendicitis in children

Author, year	Population	Study design	Years*	Open approach	Conversion	Negative appendectomy	Received no imaging	Received preoperative CT	Overall morbidity	LOS (days)
Multicenter, state, or national epidemiologic studies										
Jen and Shew, 2010[4]	All California hospitals	Retrospective cohort	1999–2006	48% (2006)†	4.2%†					1.9 (lap) 2.1 (open)†
Lee et al, 2011[16]	12 hospitals Southern California	Retrospective cohort	1998–2007	30% (2007)						1.7 (lap) 2.1 (open)†
Cheong and Emil, 2014[14]	KID Database	Retrospective cohort	2006, 2009	33%–57%‡		4.3%				1.7†
Bachur et al, 2015[13]	35 freestanding pediatric hospitals	Retrospective cohort	2010–2013			4.7% (2010) 3.6% (2013)	51% (2010) 48% (2013)§	21% (2010) 11% (2013)		
Kotagal et al, 2015[15]	32 Washington state hospitals	Retrospective cohort	2008–2012			4.6%	0.3%	53%‖		
Surgical arms of nonoperative therapy studies¶										
Svensson et al, 2015[9]	Single center, Sweden, 5–15 (years), 26 patients	RCT	2012–2013	0%		0%	0%		0%	1.4#
Tanaka et al, 2015[10]	Single Center, Japan, 5–16 (years), 86 patients	Prospective cohort	2007–2013						2.3%	6.5
Minneci et al, 2016[8]	Single Center, USA, 7–17 (years), 65 patients	Prospective cohort	2012–2013			6.2%		28%	7.7%	20 hours

CT, computed tomography; *KID*, Kids' Inpatient Database; *LOS*, length of stay; *RCT*, randomized controlled trial.
* Years data were collected (distinct from publication year).
† Uncomplicated disease-specific values.
‡ Open rates were only provided within age groups, not for the entire cohort.
§ The Bachur et al[13] definition of no imaging was no CT or US at the operating hospital, other imaging (eg, MRI) and outside hospital imaging was not included.
‖ Proportion of patients receiving CT as their first imaging study. The overall CT rate (including patients receiving multiple studies) was not reported.
¶ All data are presented for the surgical arms of these studies.
# Time was provided from randomization (not from surgery) to discharge and was 34.5 hours.

characteristics and severity, (2) preoperative imaging patterns, (3) characteristics of the operation, (4) pathologic outcomes, and (5) postoperative utilization, morbidity, and mortality. Combined, these data can inform patient expectations and identify clinical areas that warrant improvement.

Patients and Methods

Data source and ethics review

This study utilized data from the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) Pediatric. The ACS NSQIP program began in adults nearly 20 years ago. Institution-based trained nurses extract comprehensive and validated data on surgical patients. These data are then uploaded to the ACS, which provides feedback to sites about their quality metrics. In addition, the ACS annually releases a participant use file (PUF) to participating sites, enabling research.

Using this same framework, ACS NSQIP Pediatric began in 2008 and now enrolls 109 pediatric hospitals around the nation.[17] Pediatric hospitals are defined broadly and include freestanding pediatric hospitals, children's hospitals within a larger hospital, specialty children's hospitals, and general acute care hospitals with a pediatric wing. As with adults, NSQIP Pediatric releases an annual PUF with a host of generic variables across operative procedures. Starting in 2015, in addition to these generic variables, a subset of sites began collecting procedure-specific data. The 2017 data set includes a separate file for 14,463 appendectomies performed at 106 pediatric hospitals.[18] We merged the 2017 generic file with this appendectomy-specific data file. The ACS NSQIP and the hospitals participating in the ACS NSQIP are the source of the data used herein. They have not verified the data and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors. Data are disseminated in a Health Insurance Portability and Accountability Act–compliant fashion, including the removal of identifiers, and therefore this analysis did not meet the definition of human participant research.

Exclusion criteria

To focus the analysis on children younger than 18 years of age undergoing appendectomy for acute, uncomplicated appendicitis, we excluded patients undergoing the following: (1) elective operation, (2) operation for an indication other than acute abdominal pain (eg, interval appendectomy), (3) operations performed on or after hospital day 2, (4) operations performed by a provider other than a pediatric or general surgeon (eg, gynecology), and (5) operations with an intraoperative diagnosis of complicated appendicitis (eg, perforation). The decision to exclude patients with operations performed on hospital day 2 or later was based on earlier research that suggested this cohort may capture patients that "failed" nonoperative therapy who may have a distinct physiology that would bias outcomes.[19]

Analytic approach

We evaluated data in the following five domains: (1) patient characteristics and severity, (2) preoperative imaging patterns, (3) characteristics of the operation, (4) pathologic outcomes, and (5) postoperative utilization, morbidity, and mortality. For each domain, we first generated comprehensive descriptive data. Then, for outcomes that may be confounded by other patient-level variables (use of computed tomography [CT], negative appendectomy, and postoperative outcomes), we performed bivariate and

multivariable analysis to understand the primary drivers of each outcome. In the following, we detail each domain, the descriptive variables extracted for each and, when relevant, covariates included in comparisons and multivariable models.

Patient characteristics and severity

Variables included sex, age (categorized as ≤5 years of age, 6–12 years of age, and 13–17 years of age), race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic other, Hispanic), body mass index (BMI), comorbidities, the physical status classification of the American Society of Anesthesiologists (ASA), and preoperative sepsis and septic shock. Comorbidities included those utilized in the pediatric NSQIP risk calculator that have been shown to correlate to postoperative outcomes in the pediatric population, such as ventilator dependence and neuromuscular disorders.[20] BMI was converted to a weight category (overweight, obese) using the Stata package zbmicat (StataCorp, College Station, TX, USA), which uses age/sex BMI cutoffs recommended by the International Obesity Taskforce.[21]

Preoperative imaging patterns

Dichotomous variables indicated whether the child had received preoperative ultrasonography (US), CT, or magnetic resonance imaging (MRI), including where the imaging occurred (operating hospital [hereafter referred to as "local"] or outside hospital/facility [hereafter referred to as "transferring"]). When more than one study was performed at a single institution, data were not available regarding the sequence of tests. Imaging patterns were first analyzed across the patient factors of age and sex and then by surgeon specialty (general surgery, pediatric surgery) and by institution (local versus transferring), with a focus on receipt of CT.

Characteristics of the operation

We extracted the timing of operation (hospital day 0, hospital day 1), approach (laparoscopic, planned open, conversion from laparoscopic to open), and operative time (minutes). The laparoscopic and planned open approaches were compared on age, sex, surgeon specialty, and operative time.

Pathologic outcomes

Pathologic outcomes fell into three categories based on the review by the clinical abstractors of the pathology report: (1) consistent with appendicitis, (2) normal appendix, and (3) other appendiceal pathology. Other appendiceal pathology is a residual category that includes several additional pathologies, such as appendiceal neuroma and fibrous obliteration of the appendix. The negative appendectomy rate was calculated after excluding other appendiceal pathology because of the ambiguity of how to classify these results. The negative appendectomy rate was evaluated across preoperative imaging strategy, age, sex, and surgeon specialty.

Postoperative utilization, morbidity, and mortality

The 30-day morbidity and mortality were collected from data available in the medical record and from phone calls to family members by the clinical abstractor to ascertain follow-up at outside facilities. The definition of "any complication" was derived from the NSQIP online risk calculator.[20] For some complications, such as pneumonia, patients with the diagnosis preoperatively were excluded from the numerator to generate "true complication rates."

Table II
Demographics and comorbidity burden

Demographics	
	Proportion (%) $n = 9,507$
Female	39.4
Age (years)	
≤5	6.9
6–12	55.3
13–17	37.8
Race[*]	
Non-Hispanic white	61.5
Non-Hispanic black	7.3
Non-Hispanic other	3.1
Hispanic	28.2
Medical comorbidities and clinical status before surgery	
Medical comorbidities	
Weight[†]	
Normal	61.6
Overweight	21.6
Obese	16.8
Any comorbidity[‡]	3.7
Developmental delay	1.3
Cardiac risk factors	1.3
Hematologic disorder	0.7
Structural CNS abnormality	0.4
Neuromuscular disorder	0.2
Nutritional support	0.1
Ventilator dependence	0.1
Oxygen support	0.05
Preoperative clinical status before surgery	
ASA[§]	
I	50.4
II	45.2
III	4.2
IV	0.1
Sepsis	5.0
Septic shock	0.04

CNS, central nervous system.
[*] A total of 1,253 individuals (13.2%) missing race/ethnicity information. Proportions are based on nonmissing data.
[†] Weight categories generated using zanthro add-on package in StataCorp (College Station, TX, USA). A total of 2,337 (25%) individuals with missing data because of (1) <2 years of age, (2) height and weight information incomplete, or (3) absolute z score >5. Proportions are based on nonmissing data.
[‡] Any comorbidity includes one or more comorbidities from the list presented.
[§] A total of 14 individuals (0.1%) missing ASA score. Proportions are based on nonmissing data.

Complication rates were compared across several covariates (age, sex, approach, and surgeon specialty).

In addition to complications, we extracted five postoperative measures of health care utilization, including postoperative duration of stay (days), visits to the emergency department (ED), postoperative imaging (CT, US, MRI), unplanned readmission, and reoperation. Postoperative imaging included both imaging obtained while the patient was in the hospital and postdischarge imaging. Finally, a dichotomous variable was available for whether the clinical abstractor believed the readmission or reoperation was related to the initial procedure.

Sensitivity analyses

It is conceivable that the omission of patients with complicated disease based on intraoperative findings may have biased some of our results. For example, preoperative CTs may have been performed to identify complicated disease. Furthermore, because younger children are more likely to have complicated disease, surgeons may adopt a lesser threshold of proceeding to the

Table III
Imaging patterns by patient age and sex

	Overall		Males		Females		*P* value*
	N = 9,507		*N* = 5,763		*N* = 3,744		
	Frequency (number)	Proportion (%)	Frequency (number)	Proportion (%)	Frequency (number)	Proportion (%)	
No imaging	277	2.9	193	3.3	84	2.2	.002
One imaging Study							
CT only	2,316	24.4	1,486	25.8	830	22.2	< .001
US only	5,373	56.5	3,253	56.4	2,120	56.6	NS
MRI only	58	0.6	37	0.6	21	0.6	NS
Two imaging studies							
CT and US	1,292	13.6	693	12.0	599	16.0	< .001
US and MRI	169	1.8	88	1.5	81	2.2	.02
CT and MRI	9	0.1	7	0.1	2	0.1	NS
All three modalities	13	0.1	1	<0.1	4	0.1	NS
Received US	6,847	72.0	4,040	70.1	2,807	75.0	< .001
Received additional study	1,474	21.5	787	19.5	687	24.5	< .001

CT, computed tomography; *MRI*, magnetic resonance imaging; *NS*, not significant at an alpha of 0.05; *US*, ultrasonography.
* *P* value generated via χ^2 test of independence for the comparison of males versus females.

operating room (OR) in ambiguous situations, accepting an increased risk of negative appendectomy. To check for the extent and magnitude of these biases, we repeated our analyses of preoperative imaging patterns and pathologic outcomes, including patients with intraoperative diagnoses of complicated disease.

Statistical analysis

All analyses were performed using STATA v15.1 (StataCorp) with statistical significance determined using two-sided tests and an α of 0.05. Most data were available for all patients. The only exceptions were weight category (25% missing), race/ethnicity (13% missing data), pathology (0.1% missing), and ASA score (0.1% missing). No attempt was made at imputation, and the statistical analyses are based on complete case analysis. Descriptive data included frequency and proportions for categorical variables and mean and standard deviation (SD) or median/interquartile region (IQR) for continuous variables. Bivariate comparisons were made using the χ^2 test of independence, *t* tests, or rank sum tests. Multivariable logistic models were fit for preoperative imaging, negative appendectomy, and postoperative complication rates. For common events (eg, CTs), rate ratios were generated in lieu of odds ratios, using Poisson regression.[22] Postestimation margin plots were generated with 95% linear confidence intervals to illustrate these findings graphically.

Results

Final cohort, patient characteristics, and patient severity

Of 14,463 appendectomies performed between January 1, 2017, and December 31, 2017, a total of 4,956 (34%) did not meet the inclusion criteria. The final cohort of 9,507 patients were predominantly male (60.6%), between 6 and 12 years of age (55.3%), and non-Hispanic white (61.5%; Table II). One-third of patients were overweight or obese (overweight 21.6%, obese 16.8%). Most had no comorbidities (96.3%) and were ASA I or II (95.6%). Few patients had systemic sepsis (5.0%) or septic shock (0.04%) going into the OR.

Preoperative imaging patterns by patient age and sex

Overall, 2.9% of children underwent appendectomy without imaging (Table III). When including those with multiple imaging studies, 38.2% of patients received a CT at some point before their operation. The majority (81.5%) received only 1 preoperative imaging modality with 56.5% receiving only a US and 24.4% receiving only a CT.

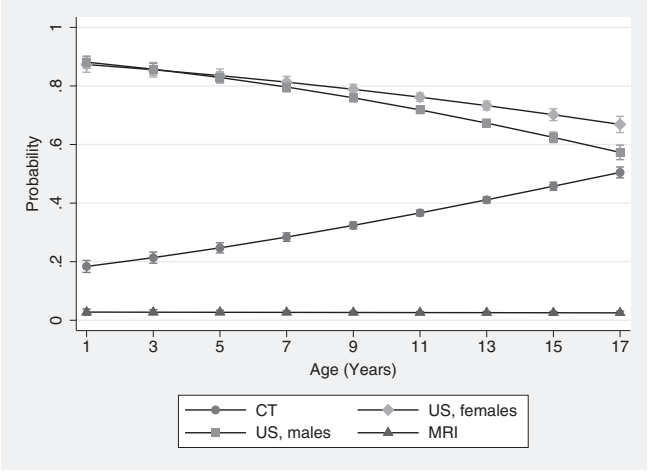


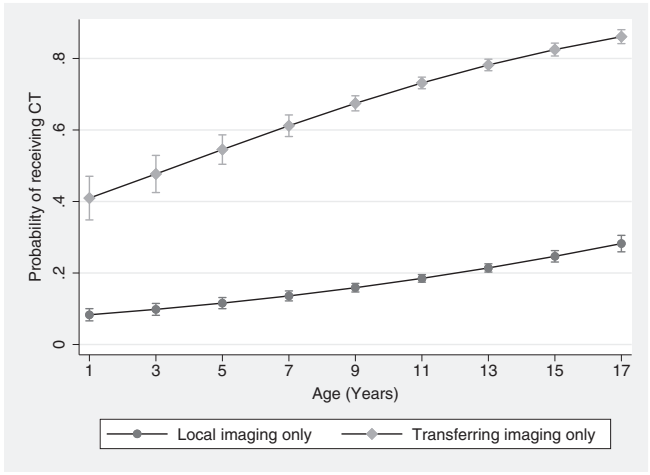
Fig 1. Imaging patterns by age (CT, MRI) and by age and sex (US). *CT*, computed tomography; *MRI*, magnetic resonance imaging; *US*, ultrasonography. Note: Figures generated as postestimation linear margins following logistic regression, using each imaging modality as a dichotomous variable.

The differences in imaging according to sex were similar. Males were slightly more likely to go to the OR without an imaging study (3.3% vs 2.2%, $P = .002$, respectively). Females were somewhat more likely to receive an US during their workup (75.0% vs 70.1%, $P < .001$), and they were also more likely to receive an additional study (24.5% vs 19.5%, $P < .001$), most commonly a CT.

The relationship between imaging, age, and sex is illustrated in Fig 1. MRI was utilized infrequently. With increasing age, there was a decreasing probability of receiving an US and an increasing probability of receiving a CT. We observed a positive interaction between age, sex, and probability of US, with a more evident decline in the use of US with increasing age in boys as compared with girls. There was no interaction between age and sex for CT or MRI.

Preoperative imaging patterns by institution and provider

The majority of patients (58.7%) received imaging only at their local institution, with 32.3% receiving imaging only at the



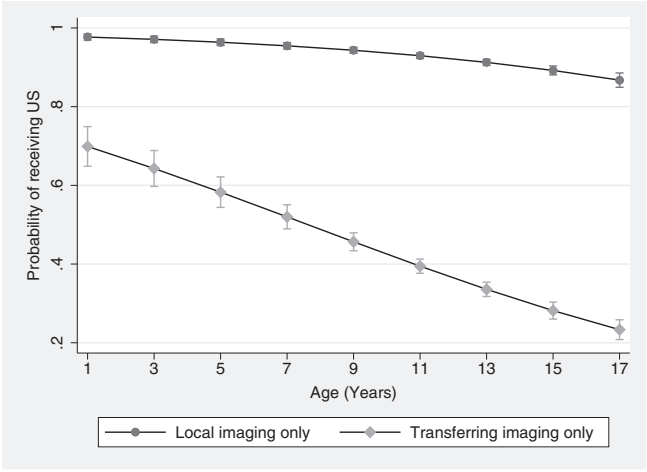


Fig 2. Imaging patterns by institution. *CT*, computed tomography; *US*, ultrasonography. Note: Figures generated as postestimation linear margins after logistic regression using each imaging modality as a dichotomous variable.

transferring institution, 6.1% at both, and 2.9% at neither. Transferring facilities used CT more frequently (Fig 2, *A*, rate ratio 3.8 [CI 3.5–4.1], $P < .001$) and US less frequently (Fig 2, *B*, rate ratio 0.41 [CI 0.38–0.43], $P < .001$) across all ages.

Most patients (94%) were operated on by pediatric surgeons, with the remainder operated on by general surgeons. Rates of no imaging were similar between surgeon specialties (pediatric surgeon 2.8% vs general 4.0%, $P =$ NS); however, patients operated on by pediatric surgeons more frequently received US only (57.2% vs 45.4%, $P < .001$) and less frequently CT only (23.7% vs 34.9%, $P < .001$).

Characteristics of the operation

The laparoscopic approach was used in 94.6% of cases, and a planned open approach was used in 4.3%. The overall conversion rate from laparoscopic to open was 1.1%. Most patients (70.1%) underwent appendectomy on the day of admission.

The open approach was performed somewhat more commonly on younger children (≤5 years of age: 6.5%, 6–12 years of age: 4.9%, 13–17 years of age: 3.3%, $P = .001$) and by pediatric surgeons (pediatric surgeons 5.9%, general surgeons 1.1%, $P < .001$). After controlling for patient age and sex, pediatric surgeons used the open approach 3.9 times more frequently (rate ratio CI 1.7–8.7, $P = .001$) than general surgeons. The open approach had lesser operative times (mean 36 minutes vs 41 minutes, $P < .001$).

Pathologic outcomes

Overall, 92.1% of appendiceal specimens were consistent with appendicitis, 3.1% were normal (ie, negative), and 4.8% had "other" appendiceal pathology. After excluding other pathologies, the overall negative appendectomy rate was 3.3% (Table IV). On multivariable analysis, the negative appendectomy rate was lower among children only receiving a CT than for both patients receiving no imaging (OR 0.34, CI 0.19–0.61, $P < .001$) and for patients receiving US only (OR 0.68, CI 0.49–0.94, $P = .02$). Females had a greater odds of negative appendectomy than males (OR 1.65, CI 1.3–2.1, $P < .001$), and children 5 years of age or younger had 2.3 times greater odds than older children or adolescents (CI 1.7–3.3, $P < .001$). No association was observed between surgeon specialty and negative appendectomy rates.

Utilization, morbidity, and mortality

We observed that 1 death occurred within 30 days, and the overall 30-day complication rate was 2.1% (Table V). The most common complication was a surgical site infection (1.6%), namely superficial site infections (0.9%) and organ space infections (0.7%). No other complication had an incidence greater than 0.25%.

Most children were discharged either the same day or the day after their operation (88.7%). Of note, 6.7% of children returned to the ED after their operation, 3.7% received an additional postoperative imaging study, 2.0% were readmitted, and 0.5% had a reoperation. The most common reason for readmission was an organ space infection; however, this indication only accounted for 23.2% of readmissions. Approximately two-thirds of reoperations (37 of 50) were coded as resulting from the initial operation, thereby leaving a "true" reoperation rate of 0.39% (37 of 9,507).

On multivariable analysis, there was no association between patient age, sex, surgeon specialty, or operative approach and complication rates.

Sensitivity analyses

To check for possible biases related to the exclusion of complicated disease, we repeated our analysis of preoperative imaging patterns and pathologic outcomes including patients with intraoperative diagnoses of complicated disease. For preoperative imaging patterns, including patients with complicated disease did not alter the results significantly. For example, overall use of CT was 40.4% (compared to 38.2% when only including uncomplicated disease); males continued to be somewhat more likely to go to the OR without imaging than females (3.6% versus 2.4%, $P < .001$), and transferring facilities continued to use CTs at least 3 times more frequently than patients managed only at the operating hospital (rate ratio 3.4 [CI 3.2–3.6], $P < .001$).

For pathologic outcomes, including children with complicated disease decreased the odds ratio for negative appendectomy in younger children from 2.3 to 1.5 (CI 1.1–2.0, $P = .02$). The reason for this decrease is likely because the proportion of complicated disease was greater in children 5 years of age or younger compared with older children and adolescents (49.6% vs 24.5%, $P < .001$). The coefficients for imaging strategy, sex, and specialty remained essentially the same.

Discussion

The characteristics of the contemporary appendectomy for acute, uncomplicated appendicitis in children typically involve some modality of preoperative imaging, laparoscopic surgery, same

Table IV
Negative appendectomy rates

	Sample size	Frequency (number)	Proportion (%)	Odds ratio	CI	*P* value[†]
Overall negative appendectomy rate[*]	9,041	298	3.3	NA		
By imaging strategy						
If no imaging	256	16	6.3	Reference		
If CT only	2,238	50	2.2	0.34	(0.19-0.61)	< .001
If US only	5,094	176	3.5	0.50	(0.30-0.86)	.01[‡]
By age category (years)						
≤5	606	43	7.1	2.33	(1.61-3.38)	< .001
6–12	5,012	152	3.0	1.00	(0.78-1.30)	NS
13–17	3,423	103	3.0	Reference		
By sex						
Male	5,504	145	2.6	Reference		
Female	3,537	153	4.3	1.65	(1.31-2.08)	< .001
By specialty						
General surgery	298	17	5.7	Reference		
Pediatric surgery	8,743	476	5.4	0.92	(0.56-1.52)	NS

CT, computed tomography; *US*, ultrasound.

[*] Denominator (sample size) excludes patients with missing and "other appendiceal" pathologies.

[†] *P* values generated via multivariable logistic regression with a negative appendectomy rate as the outcome and imaging strategy, age category, sex, and specialty as predictors. The imaging strategy was operationalized as an 8-level categorical variable for each combination of imaging strategy (eg, none, US only, CT only, CT and US, etc). CT only and US only are presented, given very small sample sizes of other strategies.

[‡] A pairwise comparison of CT only versus US only was statistically significant with a *P* value of .02.

day or following day discharge, and a 97% to 98% chance of recovery without complication. Despite positive outcomes, there remain substantial challenges, primarily the overutilization of CTs before operation and the high rate of negative appendectomy in children ≤5 years of age.

Advances in imaging, technique, and postoperative care have shifted the focus of appendectomy from a once highly lethal disease to one in which mortality is prevented and morbidity is limited. Data from studies evaluating laparoscopic versus open operations showed that by the mid to late 2000s, the duration of stay was 2 days, complication rates were between 3% and 6%, and the laparoscopic to open conversion rate was about 4%.[3–5] Today, this study shows that the laparoscopic approach is the norm, conversion rates are 1%, postoperative complications continue to decline, and patients often go home the same day—a practice that appears to be safe.[23,24]

Several findings in this study are worth highlighting. First, with respect to preoperative imaging, we found that rates of CT increased linearly with age, perhaps reflecting a false dogma that the risk of radiation and age are inversely proportional. A 2013 study estimated that to cause one solid organ cancer, the number of abdominal/pelvic CTs needed was between 300 and 390 for females and 670 and 760 for males. Of note, these risks were similar across the studied aged categories (< 5, 5–9, 10–14 years of age). These data imply that the risk of a CT in a 12-year-old appears to be similar to that of a 4-year-old. Perhaps more notably, we found a large disparity between the use of CTs at local and transferring institutions. Despite guidelines against the practice,[25] more than three-quarters of children transferred with imaging received a CT compared with less than one-quarter of children with only local imaging. This observation has been noted before. A Washington state study using data from 2008 to 2012 found that evaluation at a non-children's hospital was associated with a nearly 8 times greater odds of receiving a CT.[15] Efforts to understand and decrease this disparity are needed, including identifying the intraorganizational and interorganizational aspects that may be at play. Possible factors include the availability of US at transferring hospitals, the policies on the part of accepting hospitals that may promote or require a CT before transfer, and the desires of patients and their families to avoid costly or unnecessary transfers. Although clinicians may be concerned about the sensitivity of US compared with CT, there is evidence that hospitals using US rather than CT do not risk worsening patient outcomes in appendicitis.[13] It is difficult to know how low we can drive the rate of CTs in children receiving appendectomy attributable to ambiguity in diagnosis, body habitus, and other factors, but the discrepancy between imaging patterns in local and transferring institutions is troublesome.

Second, negative appendectomy rates appear to be driven by patient age, preoperative imaging patterns, and risk of complicated disease. In contrast to the described risks, the use of CT may slightly decrease the rate of negative appendectomy; however, we must consider the argument that with an absolute risk reduction of 1.3% (number needed to treat ~ 77) compared with those children receiving US only, the clinical importance of this reduction is unclear. The finding that younger children had greater rates of negative appendectomy is not unprecedented, with one study finding negative appendectomy rates in young children as great as 17%.[12] Our study provides some insight into why this may occur. This study re-demonstrates that younger children appear to have greater rates of complicated disease. Because complicated disease is, by definition, not a negative appendectomy, analyses that include both complicated and uncomplicated disease may be biased toward finding no difference across age groups. Furthermore, this analysis suggests a possible mechanism for the underlying reason young children have greater rates of a negative appendectomy—that surgeons and patients may be choosing to accept a greater negative appendectomy rate to avoid missing complicated disease in this population. This suggests that strategies for differentiating uncomplicated from complicated disease in younger children may eliminate this disparity.

Finally, complication rates after appendectomy for acute, uncomplicated appendicitis are quite low and much less than the surgical arms of recent nonoperative therapy trials in children[8] and adults.[26] Accurate descriptions of the postoperative course are critical to educating patients and their family members and allowing them to make an informed decision about which treatment strategy is best for them.

This study has a number of limitations. First, NSQIP data represent a potentially biased sample of hospitals, and furthermore, the appendectomy-targeted PUF comes from a subsample of these hospitals. The fact that 94% of patients were operated on by

Table V
Postoperative morbidity, mortality, and utilization

	Frequency (number)	Proportion (%)
	N = 9,507	
Overall morbidity and mortality		
30-day mortality	1	0.01
30-day morbidity		
Any complication*	201	2.11
Individual complications, by frequency		
Any SSI	150	1.58
Superficial	81	0.85
Organ space	63	0.66
Deep	9	0.09
Wound disruption, superficial	24	0.25
Sepsis	15	0.16
Urinary tract infection	10	0.11
Bleeding event	9	0.09
Pneumonia	4	0.04
Reintubation	3	0.03
Seizure	2	0.02
Renal failure	1	0.01
Septic shock	1	0.01
Wound disruption, deep (ie, dehiscence)	1	0.01
Cardiac arrest	1	0.01
Venous thrombosis	1	0.01
Utilization measures		
ED visit	639	6.72
Any postoperative imaging	356	3.74
CT	169	1.78
US	242	2.55
MRI	20	0.21
Unplanned readmission	193	2.03
Related to initial operation	144	1.51
Related to organ space SSI	45	0.47
Reoperation	50	0.53
Related to initial procedure	37	0.39

Any complication rate comparisons

	Sample size	Frequency (number)	proportion (%)	Odds ratio	CI	*P* value†
Age category (years)						
≤5	657	18	2.7	1.19	(0.69-2.03)	NS
6–12	5,258	103	2.0	0.87	(0.64-1.18)	NS
13–17	3,592	80	2.2	Reference		
Sex						
Male	5,763	115	2.0	Reference		
Female	3,744	86	2.3	1.13	(0.85-1.51)	NS
Specialty						
General surgeons	544	9	1.7	Reference		
Pediatric surgeons	8,963	192	2.1	1.32	(0.67-2.60)	NS
Approach						
Laparoscopic	8,993	187	2.1	Reference		
Open (planned)	412	10	2.4	1.19	(0.62-2.27)	NS

CLABSI, central line associated blood stream infection; *CT*, computed tomography; *CVA*, cerebrovascular accident; *ED*, emergency department; *ICH*, intracranial hemorrhage; *MRI*, magnetic resonance imaging; *SSI*, surgical site infection; *US*, ultrasound.

* Any complication as defined by NSQIP and includes SSI, wound disruption (superficial and deep), sepsis, septic shock, bleeding event, urinary tract infection, pneumonia, reintubation, renal insufficiency, renal failure, seizure, septic shock, pulmonary embolus, CLABSI, coma, peripheral nerve injury, CVA, cardiac arrest, and venous thrombosis. Events that did not occur in this sample included renal insufficiency, pulmonary embolus, CLABSI, coma, peripheral nerve injury, and CVA.

† *P* values generated via multivariable logistic regression with any complication rate as the outcome and the following predictors: age category, sex, specialty, approach, and (*not presented*) an 8-level categorical variable for each combination of imaging strategy (eg, no imaging, US only, CT only, CT and US, etc).

pediatric surgeons is evidence for this bias. Second, for imaging, we do not have information about the outcomes of the study (eg, positive, equivocal), study protocol (eg, low dose), or sequence of studies. The presence of pediatric-trained ultrasound technicians and radiologists may contribute to the differences in US utilization seen between local and transferring hospitals. Third, NSQIP only collects outcome data to 30-days and therefore will miss late complications such as adhesive small bowel obstructions. Fourth, our data only reflect patients receiving appendectomy and not patients with suspected appendicitis. Finally, it is likely that some proportion of children with appendicitis are being managed nonoperatively, and therefore, the outcomes in this study may not be comparable with a nonoperative trial using randomization.

Nevertheless, this study provides a comprehensive overview of a recent large cohort of children undergoing appendectomy for acute appendicitis (ie, the contemporary approach to acute, uncomplicated appendicitis in children). The data were collected manually using trained clinical abstractors and a number of variables presented were specifically designed for appendectomy in a pediatric cohort.

In conclusion, children undergoing operation for acute, uncomplicated appendicitis receive preoperative imaging, laparoscopic surgery, a same day or next day discharge, and have a 97% to 98% chance of recovering without short-term complication. Despite guidelines against the use of CT, more than one-third of children still receive a CT before appendectomy, which appears to be driven predominantly by transferring institutions. Young children are at increased risk of negative appendectomy that may result from our inability to reliably differentiate complicated from uncomplicated disease in this population.

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