



The contemporary appendectomy for acute uncomplicated appendicitis in adults ☆☆☆



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ABSTRACT

Background: Epidemiologic data related to the surgical management of appendicitis are out of date. As we contemplate the role of nonoperative therapy in uncomplicated appendicitis, a contemporary profile of the risks and benefits of operative appendectomy is needed.

Methods: This study merged the 2016 National Surgical Quality Improvement Program essential and appendectomy-targeted participant use files. The appendectomy-targeted file provides procedure-specific variables related to imaging, approach, and outcomes. Epidemiologic data were generated across five domains for adults with uncomplicated appendicitis: patient characteristics/severity, imaging patterns, operative characteristics, pathologic outcomes, and postoperative morbidity/mortality.

Results: The merged data file contained 12,376 adult appendectomies from 115 National Surgical Quality Improvement Program sites. After exclusions, 7,778 cases were analyzed. Almost all patients (96.1%) received preoperative imaging, with most (79.2%) receiving a computed tomography scan only. Only 2.6% of appendectomies were performed open, and the laparoscopic to open conversion rate was 0.5%. Most patients (87.3%) were discharged the day of or the day after their operation. The rate of finding an incidental tumor was 1.1%, with greater rates in the elderly (2.7% among patients aged ≥ 65 years). The overall rate of a negative appendectomy (NA) was 3.8%; the negative appendectomy rate was 1.7% for patients with any positive imaging study and 19.4% for patients with no imaging. The 30-day mortality was 0.04%; 30-day rates of any complication and serious complications were 3.0% and 2.2%, respectively. **Conclusion:** Preoperative imaging, a laparoscopic approach, and excellent clinical outcomes have become the norm for the surgical management of uncomplicated appendicitis. As surgeons contemplate the role of nonoperative therapy for uncomplicated appendicitis, the data presented here should be used to inform the ongoing debate.

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Introduction

Despite more than a century of experience with appendectomy, the management of acute uncomplicated appendicitis continues to evolve. In the 1990s, the majority of appendectomies were performed open,¹ the negative appendectomy rate was 15%,² the conversion rate of laparoscopic operations was up to 10%,³ and the postoperative duration of hospital stay was 2 to 3 days.^{3,4} By the

early 2000s, as preoperative imaging and laparoscopic approaches became common, the rates of negative appendectomy and conversion to an open operation decreased to approximately 6%,^{3,5} and the average duration of stay declined to 1 to 2 days.³

During the past decade, the conversation has shifted from a debate about the optimal operative approach (ie, laparoscopic versus open) to a question of whether patients can be treated successfully with antibiotics rather than appendectomy.^{6–9} When considering competing therapies, such as medical and surgical management of appendicitis, patients must be counselled appropriately about the risks and benefits of each approach to facilitate an informed decision. Currently, however, epidemiologic data related to the surgical management of appendicitis is out of date, with most studies reporting data more than 10 years old (Table 1).^{25,26} If investigations evaluating medical (nonoperative) versus operative

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Table 1
Select epidemiologic data related to the surgical management of appendicitis.

First author, year	Population	Study design	Years*	Open approach	Conversion	Negative appendectomy	Tumor/Malignancy	Morbidity	Mortality	LOS (days)
Flum, 2001 ²	Washington State	Retrospective cohort	1987–1998	97% (1996) 85% (1998)	-	15.5%	-	-	-	-
Guller, 2004 ¹	National Inpatient Sample	Retrospective cohort	1997	83%	-	-	-	8.7% (lap) 11.1% (open)	0.05% (lap) 0.3% (open)	2.6 (lap) 3.8 (open)
Nguyen et al, 2004 ⁴	University Healthsystem Consortium	Retrospective cohort	1999–2003	80% (1999) 57% (2003)	-	-	-	6.1% (lap) 9.6% (open)	-	2.5 (lap) 3.4 (open)
SCOAP Collaborative, 2008 ⁵	Washington State	Retrospective cohort	2006–2007	-	-	5.6%	-	-	-	-
Sporn et al, 2009 ³	National Inpatient Sample	Retrospective cohort	2000–2005	65% (2000) 40% (2005)	4.9% (2000) 3.5% (2005)	-	-	-	-	1.5 (lap) 1.8 (open)
Vons et al, 2011 ⁷	French RCT [†]	RCT	2004–2007	35%	-	-	-	-	-	3.0
Masoomi et al, 2014 ²⁶	National Inpatient Sample	Retrospective cohort	2004–2011	53% (2004) 22% (2011)	6.3% (overall) 5.6% (2011)	-	-	5.3% (lap) 10.8% (open)	0.05% (lap) 0.4% (open)	1.8 (lap) 3.6 (open)
Salminen et al, 2015 ⁶	Finnish RCT ²	RCT	2009–2012	94%	-	0.7%	1.50%	20.5%	0.4%	3.0
Teixeira et al, 2017 ²¹	-	Systematic Review	1960–2013	-	-	-	0.98%	-	-	-

Note: RCT = Randomized Controlled Trial; lap = Laparoscopic; SCOAP = Surgical Care and Outcomes Assessment Program. Most studies included both complicated and uncomplicated disease and a mix of adults and children. When studies stratified by adults versus children or complicated versus uncomplicated, data are presented for uncomplicated adult cases only.

* Years reflects the dates of data included, not the published date.

† Data are presented for the operative arm only.

management of appendicitis utilize epidemiologic data that no longer reflect current practice, the results of these studies may be inaccurate and misleading.^{10,11} Furthermore, if the benefit-to-risk ratio for appendectomy has improved, the threshold for a new approach may also need to increase. There are many reasons to believe the outcomes of appendectomy have improved, including further adoption and experience with minimally invasive approaches, routine and improved imaging, and enhanced recovery protocols including outpatient appendectomy.¹²

The objective of this study was to generate contemporary epidemiologic data for adult patients undergoing appendectomy for acute uncomplicated appendicitis across five domains—patient characteristics and severity, preoperative imaging, operative characteristics, pathologic outcomes, and postoperative morbidity and mortality.

Methods

Data sources and ethics review

This study utilized two data sources. The primary data source was the 2016 American College of Surgeons (ACS) adult (aged 18 years or older) National Surgical Quality Improvement Program (NSQIP) essential participant use file (PUF) merged with the appendectomy targeted PUF. The appendectomy-targeted PUF provided additional procedure-specific data beyond the standard NSQIP file, including variables for preoperative imaging, operative approach, pathologic outcomes, and the management of post-operative organ space infections. ACS NSQIP and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors. NSQIP collects and disseminates data in a Health Insurance Portability and Accountability Act-compliant fashion, including the removal of identifying information. Therefore, the analysis of this national data did not meet the definition of human participants research.

The second data source was a single-institution-focused chart review. Our 2016 institutional NSQIP data were used to identify appendectomy cases for chart review and data abstraction. The purpose and use of these data are described in more detail later in this report. Because these data included patient identifiers, this analysis was approved as part of an ongoing study with the University of California, Los Angeles Institutional Review Board, including a waiver of informed consent.

Exclusion criteria and rationale for the use of institutional data

To focus on appendectomies for acute uncomplicated appendicitis, we developed the following five exclusion criteria: (1) cases that were not performed laparoscopically or open (eg, robotically, endoscopically, or via single-incision laparoscopic surgery); (2) cases that were coded as elective or cases with missing elective case status; (3) cases performed on hospital day 2 or later; (4) cases including other or concurrent procedures; and (5) cases with an intraoperative diagnosis of perforation or abscess as determined by the report of the surgeon or pathologist. The first and last of these exclusion criteria were provided by the appendectomy-targeted PUF and were appendectomy specific. Criteria 2–4, however, relied on generic NSQIP variables and required validation before their use; therefore, we conducted a focused chart review of our institutional NSQIP cases meeting exclusion criteria 2–4.

Chart review to assess the validity of select exclusion criteria

Before focusing on the national data, we queried our institutional NSQIP data for all appendectomies performed in 2016. The

primary objective of this review was to determine whether the exclusion criteria based on the generic NSQIP criteria were identifying cases concordant with our a priori belief. A single clinician (C.C.) conducted a manual review of cases that met exclusion criteria 2–4. Abstracted data included an indication for elective operation (exclusion criterion 2), reason for delayed operation (exclusion criterion 3), and types of other procedures performed (exclusion criterion 4).

Analytic approach and variable definitions for the national analysis

After validating the exclusion criteria locally, all subsequent analyses utilized the national NSQIP data set. We generated comprehensive, epidemiologic data across the following five domains: patient characteristics and severity, imaging patterns, operative characteristics, pathologic outcomes, and postoperative morbidity and mortality.

Patient characteristics and severity

Variables included patient demographics (sex, age, race/ethnicity), risk factors (smoking status, body mass index [BMI]), medical comorbidities (eg, diabetes mellitus, chronic steroid use), and clinical status (physical status score of the American Society of Anesthesiologists [ASA], presence of preoperative sepsis [systemic inflammatory response syndrome + infectious source], and presence of septic shock [sepsis + end organ dysfunction]). Of note, pregnancy status was unavailable.

Imaging patterns

Dichotomous variables were available for whether the patient received preoperative ultrasonography (US), computed tomography (CT), or magnetic resonance imaging (MRI). The result of each study was further categorized as positive (consistent with appendicitis), equivocal, or negative (not consistent with appendicitis). The order of studies was not available. Although it may be reasonable to assume that an US would be obtained before a CT, this was not documented, and therefore results are presented reflecting this ambiguity.

Operative characteristics

Variables included time from admission to operation (0 or 1 day), approach (planned laparoscopic, planned open, and laparoscopic converted to open), operative time (minutes), and postoperative duration of stay (in days). Operative time and duration of stay were compared between approaches (planned laparoscopic, planned open).

Pathologic outcomes

The postoperative pathologic diagnosis was categorized as consistent with appendicitis, not consistent with appendicitis (ie, a “normal appendix” or negative appendectomy), tumor/malignancy, or other pathology, based on the review of the clinical abstractor of the pathology report. Because appendiceal tumors are more common in the elderly, we stratified the rate of finding a tumor by age category.¹³ To calculate negative appendectomy rates, we excluded tumors and other pathologies, given the ambiguity of how to classify these outcomes. Negative appendectomy rates were further stratified by imaging modality (US, CT, MRI) and imaging outcome (positive, equivocal, negative).

Postoperative morbidity and mortality

NSQIP reports outcomes up to 30 days after the operation. We extracted all complications and serious complications consistent with the definitions used by NSQIP.¹⁴ In addition to the usual NSQIP outcomes, the appendectomy-targeted PUF indicated the type of intervention required (eg, antibiotics only, percutaneous

drainage) for organ space surgical site infections (SSIs). For some complications (eg, pneumonia, urinary tract infection), NSQIP provides data regarding whether the complication was present at the time of surgery (PATOS), allowing identification of “true” complications as opposed to medical conditions that existed before the operation. Complication rates were analyzed by age category and approach (planned open, planned laparoscopic).

Statistical analysis

Descriptive data included measures of central tendency (mean/median with standard deviation [SD]/interquartile region [IQR]) for continuous variables and frequencies/proportions for categorical variables. Bivariate comparisons were made using unpaired *t* tests and rank sum tests for continuous variables with χ^2 and Fisher exact tests used for categorical variables. To assess the impact of approach on the highly skewed duration of stay, a univariable generalized linear model with log link and gamma distribution was fit. Overall, missing data were rare, with most variables having complete information. The only exceptions were race/ethnicity (21.5% of data were missing), BMI (13.4% of data were missing), pathologic outcomes (0.6% of data were missing), and ASA physical status (0.6% of data were missing). Data were not imputed for these variables, and estimates are provided on a complete case analysis. Sample sizes and denominators are included throughout Tables 1 through 6 and the Results section of this report. All analyses were performed using STATA v15.1 (StataCorp, College Station, TX), using two-sided tests and an α of 0.05.

Results

Evaluation of exclusion criteria 2–4, using institutional chart review

The institutional NSQIP-reported appendectomy data identified 182 cases between January 1, 2016, and December 31, 2016. Eight cases were coded as elective (exclusion criterion 2). Seven were truly elective, including five interval appendectomies and two appendectomies for patients with undiagnosed right lower quadrant chronic pain; 1 elective case was miscoded and was in fact an appendectomy for acute uncomplicated appendicitis. Eight cases were performed on hospital day 2 or later (exclusion criterion 3). Five of these were for patients who failed antibiotic therapy—either in the event of a phlegmon/abscess or, in uncomplicated cases, patients who failed initial nonoperative therapy. One patient in this exclusion criterion was undergoing an extensive operation for mucinous appendiceal tumor (that would have also been captured by exclusion criterion 4). Two of the 8 patients underwent appendectomy for uncomplicated appendicitis on hospital day 2 because the patients were admitted for a little more than 24 hours before the operation, but the medical record coded two midnights. Finally, 40 cases had another procedure coded (exclusion criterion 4), with the most common additional procedures being lysis of adhesions ($n=31$), diagnostic laparoscopy ($n=11$), and hernia repair ($n=2$); these other procedures add up to greater than 40 because answers were not mutually exclusive.

In summary, the chart review confirmed the a priori rationale for our exclusion criteria relying on generic NSQIP variables. Although some cases of interest were excluded as a result, the chart review confirmed that observations meeting these criteria represented a clinically heterogeneous group that, if added to our data set, may bias our results. We therefore applied all five exclusion criteria to the national data set (described later in this report).

Final appendectomy cohort, patient characteristics, and severity

The national data file contained 12,376 adult cases from 115 NSQIP participating sites performed between January 1, 2016, and

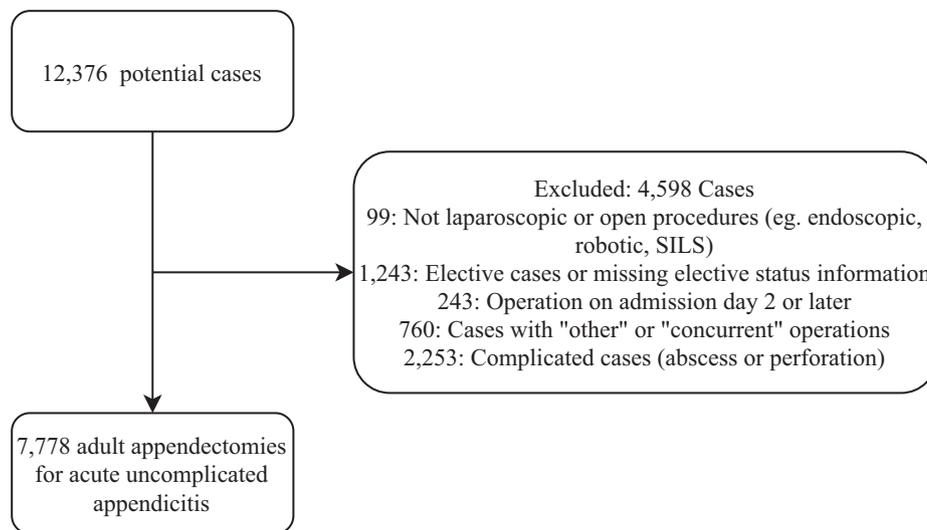


Fig. 1. Flow diagram of exclusion criteria to identify cases of acute uncomplicated appendicitis. SILS, single incision laparoscopic surgery.

December 31, 2016. We excluded 99 cases that were not performed laparoscopically or open (exclusion criterion 1), 1,243 elective cases or missing elective status (exclusion criterion 2), 243 cases performed on or after admission day 2 (exclusion criterion 3), and 760 cases with other or concurrent operations (exclusion criterion 4). Finally, we excluded 2,253 cases that had an intraoperative diagnosis of perforation of abscess (exclusion criterion 5). In total, we excluded 4,598 cases, leaving 7,778 adult appendectomies for uncomplicated appendicitis in our final cohort (Fig. 1).

Of the included cases ($n=7,778$), almost half (49.1%) of the patients were female, and the majority were <65 years of age (93.8%). In general, the cohort was healthy, with 84.2% having no medical comorbidities and 87.4% with an ASA physical status score of I or II (43 patients missing ASA data; 6,760 of 7,735). Very few patients had preoperative sepsis (0.6%) or septic shock (0.03%) before their operation (Table 2).

Imaging patterns, including stratification by sex

Almost all (96.1%) patients undergoing appendectomy received some form of preoperative imaging; most (79.2%) underwent a CT only (Table 3). Very few patients received an US only (7.8%). Of those receiving an US during the workup for their appendectomy (16.2% of the total, $n=1,256$), 47.8% also received a CT, and 4.2% also received a MRI.

With regard to US results, 53.6% had a positive finding, 30.3% were equivocal (eg, “appendix not identified”), and 16.2% were negative. Among patients with a positive US ($n=673$), 21.7% received at least one additional study (CT or MRI). Patients with equivocal and negative USs typically received at least one additional study (81.3% and 94.1%, respectively).

The rate of proceeding to the operating room without imaging was somewhat greater among men than women (men 5.0% versus women 2.8%, $P < .001$). Overall, women were more likely to receive an US during their workup (women 21.8% versus men 10.8%, $P < .001$), and the USs they received were more likely to be equivocal (women 34.2% versus men 22.5%, $P < .001$) or negative (women 17.7% versus men 13.1%, $P=.03$).

Surgery characteristics

Only 2.6% of appendectomies were performed open. The overall conversion rate from laparoscopic to open was 0.5%. The majority

Table 2

Demographics and clinical characteristics of patients undergoing appendectomy for acute uncomplicated appendicitis.

	N = 7,778	Proportion (%)
Demographics		
Sex	Male	50.9
	Female	49.1
Age, years	18–64	93.8
	65+	6.2
Race/Ethnicity*	Non-Hispanic white	72.1
	Non-Hispanic black	7.8
	Non-Hispanic other	6.0
	Hispanic	14.2
Risk factors, medical comorbidities, and clinical status before surgery		
Smoker		16.8
Body mass index†	< 18.5	1.5
	18.5–24.9	32.3
	25–29.9	33.9
	> 30	32.3
Medical comorbidities	Any comorbidity‡	15.8
	Hypertension, on medication	12.3
	Diabetes mellitus§	3.9
	Bleeding disorder	1.4
	Chronic steroids	1.3
	COPD	0.8
	Dyspnea	0.7
ASA¶	I	35.2
	II	52.2
	III	12.1
	IV	0.5
Sepsis		0.6
Septic shock		0.03

COPD, chronic obstructive pulmonary disease.

* A total of 1,675 individuals (21.5%) missing race/ethnicity information; proportions are based on nonmissing data.

† A total of 1,043 individuals (13.4%) missing BMI information; proportions are based on nonmissing data.

‡ Any comorbidity includes ascites, bleeding disorder, COPD, diabetes, dialysis, disseminated cancer, dyspnea, functional impairment, hypertension requiring medication, recent weight loss, renal failure, and steroid use.

§ Includes insulin and non-insulin dependent.

¶ A total of 43 individuals (0.6%) missing ASA score; proportions are based on nonmissing data.

(87.3%) of patients were discharged the same day or the day after their operation (Table 4).

No statistical difference was found between the operative times (open 52 minutes versus laparoscopic 48 minutes, $P=.59$) or the

Table 3

Imaging patterns for patients undergoing appendectomy for acute uncomplicated appendicitis, including stratification by sex.

	Overall N = 7,778		Men N = 3,962		Women N = 3,816		P value*
	Frequency (number)	Proportion (%)	Frequency (number)	Proportion (%)	Frequency (number)	Proportion (%)	
Imaging patterns							
No imaging	305	3.9	197	5.0	108	2.8	< .001
Received CT only	6,161	79.2	3,321	83.8	2,840	74.4	< .001
Received US only	610	7.8	232	5.9	378	9.9	< .001
Received MRI only	27	0.4	4	0.1	23	0.6	< .001†
Received CT and US	593	7.6	190	4.8	403	10.6	< .001
Other imaging‡	82	1.1	18	0.5	64	1.7	< .001
Imaging patterns among patients receiving US							
Received US	1,256	16.2	426	10.8	830	21.8	< .001
US positive	673	53.6	274	64.3	399	48.1	< .001
Received additional study	146	21.7	55	20.1	91	22.8	NS
US equivocal	380	30.3	96	22.5	284	34.2	< .001
Received additional study	309	81.3	84	87.5	225	79.2	NS
US negative	203	16.2	56	13.1	147	17.7	.03
Received additional study	191	94.1	55	98.2	144	98.0	NS

* P values generated via χ^2 test of independence, comparing men and women.

† Fisher exact test used, given small cell size.

‡ Includes CT and MRI ($n=29$), US and MRI ($n=46$), and patients receiving all 3 imaging modalities ($n=7$).**Table 4**

Operative characteristics for patients undergoing appendectomy for acute uncomplicated appendicitis.

General characteristics				
		Frequency (number) N = 7,778	Proportion (%)	
Days from admission to operation	Day 0	5,930	76.2	
	Day 1	1,848	23.8	
Approach	Laparoscopic	7,541	97.0	
	Open (planned)	199	2.6	
	Conversion	38	0.5	
Postoperative duration of stay, days	0	2,300	29.6	
	1	4,488	57.7	
	2	637	8.2	
	3	183	2.4	
	4 +	170	2.2	
Laparoscopic versus open comparisons				
		Mean (SD)	Median (IQR)	P value*
Operative time, minutes	Laparoscopic	48 (31)	43 (31–59)	NS
	Open (planned)	52 (50)	44 (33–61)	
Duration of stay, days	Laparoscopic	1.0 (2.2)	1 (0–1)	NS
	Open (planned)	1.3 (1.4)	1 (1–2)	
Body mass index	Laparoscopic	28 (6.4)	27 (24–31)	NS
	Open (planned)	28 (6.6)	27 (24–32)	
Age	Laparoscopic	37 (15.1)	33 (24–46)	NS
	Open (planned)	39 (16.0)	36 (26–50)	

* Operative time, body mass index, and age distributions compared, using both unpaired *t* tests and rank sum tests; length of stay compared, using a generalized linear model, with gamma distribution and log link.

postoperative duration of stay (open 1.3 days versus laparoscopic 1.0 days, $P=0.10$) between the planned open and planned laparoscopic groups. No difference was found in the average BMI (open 28 versus laparoscopic 28, $P=.99$) or average age (open 39 years of age versus laparoscopic 37 years of age; $P=.06$) between the planned open and planned laparoscopic groups.

Pathologic outcomes

Overall, 94.4% of pathologic specimens were consistent with a diagnosis of appendicitis (52 patients missing pathologic data; 7,293 of 7,726), 3.7% were a normal appendix, 1.1% had a tumor or malignancy, and 0.8% had another pathology (Table 5). The tumor rates in the geriatric cohort (65 years of age or older) were 2.7%

(13 of 476) and were greater than in the nongeriatric population (69 of 7,250 [1.0%]; $P < .001$ for comparison between age category 18–64 and ≥ 65 year of age).

After excluding tumor/malignancies and other pathologies ($n=147$), the overall negative appendectomy rate was 3.8% (286 of 7,579). For patients with any positive imaging study—CT, US, or MRI—the negative appendectomy rate was 1.7% (114 of 6,887). Among patients receiving only 1 study ($n=6,798$), those with a positive CT had a lower negative appendectomy rate than those with a positive US (positive CT: 76 of 5,761 [1.3%] versus positive US: 18 of 515 [3.5%]; $P < .001$). The negative appendectomy rate was 19.4% (56 of 228) in patients who did not receive any preoperative imaging. We also found a high rate of negative appendectomy among patients who received any equivocal or negative

Table 5
Pathologic outcomes for patients undergoing appendectomy for acute uncomplicated appendicitis.

Overall pathologic outcomes				
		Frequency (number) N = 7,726*	Proportion (%)	
Consistent with appendicitis		7,293	94.4	
Normal appendix		286	3.7	
Tumor or malignancy		82	1.1	
Other pathology		65	0.8	
Negative appendectomy rates				
	Sample size	Frequency (number)	Proportion (%)	P value†
Overall negative appendectomy rate	7,579‡	286	3.8	NA
Negative appendectomy rate, by imaging:				
If no imaging	288	56	19.4	< .001
If any positive imaging	6,887	114	1.7	
CT confirmed	6,305	92	1.5	< .001
CT equivocal	208	50	24.0	
CT negative	121	37	30.6	
US confirmed	654	20	3.1	< .001
US equivocal	363	44	12.1	
US negative	195	24	12.3	
Tumor rates				
By age category, years	Sample size	Frequency (number)	Proportion (number)	P value
18–64	7,250	69	1.0	< .001
65+	476	13	2.7	

* A total of 52 individuals with missing or indeterminate pathology; proportions are based on nonmissing data.

† P values generated via χ^2 test of independence.

‡ Reduced sample size reflects exclusion of tumor/malignancy ($n=82$) and other pathologies ($n=65$) given ambiguity of how to classify these with respect to negative appendectomy.

imaging studies, ranging from 12.1% (equivocal US) to 30.6% (negative CT).

Postoperative morbidity and mortality

The 30-day mortality was 0.04% (3 of 7,778) (Table 6). Two of these mortalities were in geriatric patients. The risk of any complication within 30 days was 3.0%, and the risk of a serious complication was 2.2%. The 3 most frequent complications were organ space SSI (1.0%), superficial SSI (0.9%), and unplanned reoperation (0.7%). All remaining complications had an incidence of <0.5%.

Any complication and serious complication were more likely in geriatric patients (any complication 5.6% among geriatrics versus 2.7% nongeriatric, $P=.001$; serious complication 4.6% among geriatrics versus 1.9% nongeriatric, $P < .001$). There was no difference in serious complication rate, any complication rate, organ space SSI, or superficial SSI between the planned laparoscopic and planned open approach.

Discussion

This study presents contemporary epidemiologic for adult patients undergoing appendectomy for acute uncomplicated appendicitis. We provide data in five domains: patient characteristics and severity, imaging patterns, operative characteristics, pathologic outcomes, and postoperative morbidity and mortality.

A number of findings in this study differ from traditional dogma or previously reported measures. First, with regard to imaging patterns, almost all patients (96%) received some form of preoperative study. Although this was most commonly a CT, 16% of patients underwent an US. Over half of patients receiving an US received another imaging study. Although there are many reasons to obtain an US first, such as an unclear diagnosis or pa-

tient preference, the results from this study suggest that, with respect to appendicitis, USs often come back equivocal or negative and, even when they do come back positive, a CT may still be performed before the patient goes to the operating room. It is important to remember that CT has been shown consistently to have greater sensitivity and specificity than US for the diagnosis of appendicitis¹⁵; indeed, the American College of Radiology favors CT over US for adult patients with potential appendicitis, except in the event of pregnancy.¹⁶ Furthermore, in this study, patients with a positive CT had half the negative appendectomy rate as patients with a positive US. Finally, it appears the days of a clinical diagnosis of appendicitis without imaging are almost gone, with only 4% of patients in this study undergoing appendectomy without preoperative imaging. Given the negative appendectomy rate of 19.4% in patients with no preoperative imaging, this trend may be justified.

Second, a noteworthy statistic related to the operative characteristics is the paucity of patients undergoing a planned open appendectomy with fewer than 3% of cases utilizing this approach. Laparoscopy appears to be the dominant approach, and comfort with this approach is demonstrated by the low conversion rate (< 1%) and mean operation time (48 minutes). Historically, laparoscopy has been associated with greater operative times and shorter durations of hospital stay¹⁷ and was advocated over the open approach for obese patients and the elderly.^{18,19} In our study, we found no difference in operative time, hospital stay, or demographic (age, BMI) characteristics between the laparoscopic and open groups. Our power to detect differences, however, especially of rare events, is limited in an era when so few appendectomies are performed open. One critique of the trials of nonoperative management is the inclusion of high proportions (eg, 94%) of open appendectomy.^{6,20} Given the findings presented here, this concern appears reasonable, and studies with much

Table 6
Postoperative morbidity and mortality after appendectomy for acute uncomplicated appendicitis.

	Frequency (number) N = 7,778	Proportion (%)		
Overall morbidity and mortality				
30-day mortality	3	0.04		
30-day morbidity				
Any complication*	235	3.02		
Serious complication†	169	2.17		
Individual complications, by frequency:				
Organ space SSI (N = 7,764)	76	0.98		
Proportion of organ space SSI requiring:				
Readmission	51	67.1		
Drainage	33	43.4		
Operation	14	18.4		
Superficial SSI	66	0.85		
Reoperation (unplanned)	58	0.75		
Proportion of reoperations related to principal operative procedure	44	75.9		
Sepsis (excluding PATOS)	21	0.27		
Urinary tract infection (excluding PATOS)	15	0.19		
Pneumonia (excluding PATOS)	12	0.15		
Unplanned intubation	9	0.12		
Deep vein thrombosis	7	0.09		
Pulmonary embolus	6	0.08		
Deep incisional SSI	5	0.06		
Myocardial infarction	4	0.05		
Progressive renal insufficiency	4	0.05		
Acute renal failure	3	0.04		
Septic shock (excluding PATOS)	3	0.04		
Ventilation >48 hours postop	3	0.04		
Wound disruption	3	0.04		
Cardiac arrest	2	0.03		
Stroke	0	0.00		
Complication rates by age category (years)				
	Sample Size	Frequency (number)	Proportion (%)	P value‡
Any complication				
18–64	7,609	208	2.7	.001
65+	479	27	5.6	
Serious complication				
18–64	7,609	147	1.9	< .001
65+	479	22	4.6	
Complication rates by approach				
	Sample Size	Frequency (number)	Proportion (%)	P value§
Any complication				
Laparoscopic	7,528	222	2.9	NS
Open (planned)	198	7	3.5	
Serious complication				
Laparoscopic	7,528	160	2.1	NS
Open (planned)	198	6	3.0	
Organ space SSI				
Laparoscopic	7,528	72	1.0	NS
Open (planned)	198	3	1.5	
Superficial SSI				
Laparoscopic	7,528	61	0.8	NS
Open (planned)	198	1	0.5	

PATOS, present at time of surgery; SSI, surgical site infection.

* Any complication as defined by NSQIP and includes all serious complication plus sepsis, stroke, superficial SSI, and patients requiring ventilation > 48 hours postoperatively; PATOS conditions not included.

† Serious complication as defined by NSQIP and includes organ space SSI, reoperation, urinary tract infection, pneumonia, unplanned intubation, deep vein thrombosis, pulmonary embolus, deep incisional SSI, myocardial infarction, progressive renal insufficiency, acute renal failure, septic shock, wound disruption, and cardiac arrest; PATOS conditions not included.

‡ P values generated via χ^2 test of independence, by age category.

§ P values generated via Fisher exact test.

greater proportions of the open approach may not be representative of the contemporary appendectomy performed in the United States.

Third, for pathologic outcomes, although the rate of finding an incidental tumor of 1% in this study was similar to that presented elsewhere,^{21,22} the rate of 2.7% among geriatric patients is much greater than reported previously. A few

studies have demonstrated high rates of finding a tumor in patients undergoing interval appendectomy after perforated appendicitis.^{21,23,24} Our study demonstrates that the risk of an underlying tumor, especially among the elderly, extends beyond perforated appendicitis but also into uncomplicated appendicitis as well.

Fourth, and finally, postoperative morbidity and mortality after appendectomy for acute uncomplicated appendicitis continue

to decline. The complication rate presented here (~ 3%) is less than the rate identified in the surgical arms of previously reported nonoperative trials, with some reporting complication rates as high as 20%.^{6,8} Although some of the difference in complication rates may reflect heterogeneity in measurement (eg, greater duration of follow-up or the inclusion of patient-reported outcomes, such as pain scales), it may also reflect improving surgical care and comfort with laparoscopic approaches. Evidence for the latter may be suggested by the lack of difference in outcomes across approaches. Not unexpectedly, complications clustered within the geriatric cohort.

The utility of the epidemiologic data presented here are manifold. First, shared decision-making relies on accurate descriptions of the patient's expected perioperative and postoperative course. A recent survey study is an exemplar.¹⁰ The expected management and outcomes of nonoperative and operative therapy for appendicitis were explained to a convenience sample of potential patients. Although the nonoperative data reflected contemporary expectations—with a hospital stay around 3 days and a recurrence risk of 1 in 3 to 1 in 4—the surgical expectations did not reflect current practice, including an equal choice of open and laparoscopic surgery, a 4% complication rate, a 1–2-day postoperative stay, and a 10% conversion rate. Although nearly 10% favored nonoperative over operative therapy in this survey, it is unclear how patients may have responded with only a laparoscopic approach, a 0.5% conversion rate, a < 24-hour stay, and a complication rate of 2%–3%. Second, as we consider alternative therapies, such as nonoperative therapy, contemporary statistics can be invaluable. A challenge of randomized trials is the inherent inability to generalize because of exclusion criteria and patient self-selection to participate. The data presented here provide a measuring stick with which to judge the external validity of an operative arm of a randomized trial. For example, high rates of open appendectomy, extended hospital stays, or increased rates of complications would need to be explored for selection bias or protocol issues. Demographics of included patients should reflect the national distribution, with respect to age, sex, race, and severity. Although appendicitis in the elderly is rare, it is a unique subgroup that has both more to gain from operative therapy by avoiding missed tumors, but also potentially more to lose from greater complication rates. Finally, there may come a time when surgical societies are asked their recommendations as it relates to nonoperative therapy for uncomplicated appendicitis. Although patient input is paramount to these conversations, the ultimate decision comes down to the best existing evidence of the risks and benefits of each approach. Here we present the risks and benefits of a surgical approach for acute uncomplicated appendicitis.

This study has a number of limitations. First, NSQIP data may not generalize to all hospitals in the United States, and furthermore, the data presented here only come from a select group of appendectomy-participating hospitals, a group that may be further biased. Second, this analysis only focused on acute uncomplicated appendicitis. This analytic decision reflected our ability to identify cases of interest. The variable structure of NSQIP does not appear to allow robust identification of complicated cases nor does it contain all of the necessary variables to assess this population adequately (eg, radiologic procedures). Third, an unknown proportion of acute uncomplicated appendicitis may be managed nonoperatively, which may bias the ability to generalize these data to a surgical arm of a randomized trial. For example, if only elderly sick patients are being managed nonoperatively, then our sample would represent a healthier cohort who may be less prone to adverse events. In contrast, the opposite may also be true, with only the healthiest patients being selected for nonoperative therapy, in which case our outcome rates would be conservative. We purposefully excluded patients hospitalized for two midnights before op-

eration to avoid including patients failing nonoperative therapy—a group that may have a distinct pathophysiology making them more prone to complications. Fourth, if a tumor was identified intraoperatively and the patient received a different operation (eg, right hemicolectomy), the patient would not be included in this data set, and therefore, our rate of finding tumors would be an underestimate of the true rate. Finally, NSQIP only collects outcome data to 30 days and does not currently collect patient-reported outcome measures.

Despite these limitations, the data presented are derived from a recent and diverse national cohort, using an extensively validated, clinical registry data. The sampling strategy may not generalize to the entire population in the United States, but the estimates presented should represent a benchmark for the contemporary appendectomy.

In conclusion, this study presents the patient characteristics, contemporary workup, operative characteristics, and pathologic and clinical outcomes of adult patients undergoing appendectomy for acute uncomplicated appendicitis. Preoperative imaging, a laparoscopic approach, and excellent clinical outcomes have become the norm for the operative management of acute uncomplicated appendicitis. Patients should be counselled using the most contemporary and patient-specific data available. As our field contemplates the role of nonoperative therapy for uncomplicated appendicitis, the data presented here should be used to inform the ongoing debate.

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