The Negative Appendectomy Rate: Who Benefits From Preoperative CT?

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OBJECTIVE. The purpose of this article is to determine the negative appendectomy rates of patients who did and did not undergo preoperative CT and to determine, more specifically, whether men benefit from preoperative CT.

MATERIALS AND METHODS. We identified 512 patients who had a nonincidental appendectomy between July 1, 2002, and June 30, 2007. Pathology records were compared with a radiology records search to determine which patients underwent preoperative CT. Proportions of patients were compared between groups using the Fisher exact test.

RESULTS. Of 512 patients who had a nonincidental appendectomy, 465 (91%) underwent preoperative CT, and 47 (9%) underwent appendectomy only on the basis of clinical findings. Overall, 22 of 465 patients (4.7%) who underwent preoperative CT had a negative appendectomy compared with six of 47 patients who did not undergo preoperative imaging (negative appendectomy rate, 12.7%; $p = 0.03$). Among men, six of 237 (2.5%) with preoperative CT had a negative appendectomy, versus five of 42 without imaging (negative appendectomy rate, 11.9%; $p = 0.01$).

CONCLUSION. The negative appendectomy rate was decreased for adult patients who underwent preoperative CT compared with patients who did not undergo preoperative imaging. Although most prior studies have suggested that CT is efficacious only in decreasing the negative appendectomy rate among women, we found that men benefit from CT as well.

Keywords: appendicitis, CT, negative appendectomy rate

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Before the advent of CT, a negative appendectomy rate as high as 20% was considered acceptable to avoid missing cases of appendicitis. Complications of acute appendicitis, including perforation, peritonitis, and sepsis were used to justify the large number of negative appendectomies. This has been particularly true among reproductive-age women, among whom the negative appendectomy rate has been reported to be as high as 40%, largely as the result of gynecologic mimics.

Cited advantages of preoperative CT include reducing unnecessary hospitalizations and avoiding delays in the treatment of alternative conditions, in addition to decreasing the number of negative appendectomies. Despite the trend toward increased CT utilization in the diagnosis of acute appendicitis, controversy persists, and the value of preoperative imaging continues to be debated. Multiple studies from the surgical literature have suggested that CT confers no benefit in the evaluation of acute appendicitis. More specifically, these studies report no decrease in the negative appendectomy rate among patients who undergo preoperative CT compared with patients who do not [1–8]. However, other recent studies have shown a lower negative appendectomy rate associated with CT utilization [9–24], and it is generally accepted that CT is useful in the diagnosis of appendicitis.

The subset of patients who benefit most from CT remains less clear. Preoperative CT quite consistently has been shown to lower the negative appendectomy rate among women [9–16, 23–25]. Relatively few studies, however, have shown a lower negative appendectomy rate with preoperative CT for both sexes [12, 16, 23]. Furthermore, any suggested utility of preoperative CT in men is contradicted by a number of studies that have shown that men derive no benefit from preoperative CT when there is clinical suspicion of acute appendicitis [9–11, 13–15]. Nevertheless, CT is used routinely among men with suspected appendicitis at our institution and has been assumed by both surgeons and radiologists to be a useful practice. Therefore, we performed this study to determine the negative appendectomy rates of patients who did and did not undergo preoperative CT and to determine, more specifically, whether men benefit from preoperative CT.

Materials and Methods

Patients

This single-institution retrospective study was approved by our institutional review board and was compliant with HIPAA requirements. The requirement for informed consent was waived. To investigate the negative appendectomy rate at our institution, one author used a computerized search of the surgical pathology database to identify all patients 18 years old or older with nonincidental appendectomy specimens during a 5-year period from July 1, 2002, to June 30, 2007. The search term "non-incidental appendectomy specimens" automatically excluded appendectomies that were performed as part of a colon resection or incidentally during surgery for another indication. Patients were also excluded if the appendectomy was intentionally delayed for conservative treatment of perforated appendicitis (n = 18), if they underwent preoperative imaging only by an alternate modality (MRI [n = 1] or ultrasound [n = 15]), or if medical records indicated that they had preoperative imaging at another institution (n = 4). A total of 512 patients met these criteria during the study period. These patients were previously reported among a larger group of patients who underwent CT for suspected appendicitis in a study by Stengel et al. [26].

Pathology records for these 512 patients were cross-referenced to a computerized search of the radiology information system, the electronic medical record, and surgical reports to identify which patients underwent CT examination before appendectomy for suspected appendicitis (n = 465). The patients included 237 men and 228 women with a mean age of 40 years (range, 18–91 years). Forty-seven patients had an appendectomy for suspected appendicitis with no preoperative imaging, including 42 men and five women with a mean age of 32 years (range, 20–56 years).

CT Technique

All 465 patients who underwent imaging were scanned with 4-, 16-, or 64-MDCT scanners (HighSpeed or LightSpeed, GE Healthcare) using 1.25- or 5-mm slice thickness. Scans performed at 1.25-mm collimation were reconstructed to 5-mm slice thickness. The peak tube voltage was 120 kVp, and the tube current was automatically adjusted to attain a noise index of 12 HU. For 450 patients, 150 mL of iohexol (Omnipaque 350, Nycomed Amersham) was injected IV at a rate of 3–5 mL/s. Fifteen patients were scanned without IV contrast agent. Positive oral contrast agent was administered for 286 patients. The routine use of positive oral contrast agent was discontinued in 2006, and it was replaced by oral water. Forty-seven patients received rectal contrast agent.

Data Interpretation

Pathology records were reviewed by two authors, who were blinded as to whether preoperative imaging was performed, to identify patients with negative appendectomy specimens. A negative appendectomy was defined as either a normal appendix after resection for suspected appendicitis or a medically unnecessary appendectomy. A medically unnecessary appendectomy was defined as an appendectomy performed for any condition for which it would not typically be the indicated treatment. Incidental findings, such as fibrous obliteration of the lumen or fibrous strands, were commonly seen in asymptomatic patients [27] and were considered in the spectrum of normal [3, 27]. Final assignment of cases as negative medically unnecessary appendectomies was achieved by consensus of both reviewers.

Pathology records were compared with the radiology computer search list to determine which patients underwent preoperative CT. For patients without preoperative imaging, surgical reports were reviewed and the treating surgeon and date of scan were noted. To determine the negative appendectomy rate among patients with a positive CT result, radiology reports were reviewed by a single reader who classified the likelihood of acute appendicitis, according to the following 5-point scale: 1, definitely absent; 2, nonvisualized appendix with no secondary signs of inflammation; 3, equivocal; 4, probable; and 5, definitely present. If assignment into a particular category was not straightforward because of the report wording, consensus scoring was performed by the primary reader and a second radiologist. Scans scored as 4 (probable appendicitis) or 5 (definite appendicitis) were considered positive. Data utilizing this scoring system were previously reported by Stengel et al. [26] in a study of false-positive CT for appendicitis.

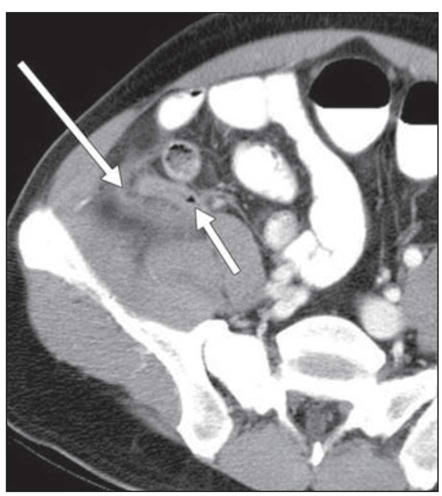

Fig. 1—52-year-old man with right lower quadrant pain. IV contrast-enhanced transverse CT image shows 9-mm appendix (*short arrow*) with adjacent periappendiceal fat stranding (*long arrow*). Scan was interpreted prospectively as representing acute appendicitis. However, pathologic examination revealed normal appendix with adjacent periappendicitis. This was considered negative appendectomy.

Statistical Analysis

Statistical analysis was performed using the Stata software package (version 8.0, StataCorp). The proportion of men versus women who underwent appendectomy without preoperative imaging was compared using the Fisher exact test. The proportions of negative appendectomies between groups with preoperative CT and without preoperative imaging were also compared using the Fisher exact test; 95% CIs were determined using the modified Wald method. Age was compared using the Mann-Whitney test. A p value less than 0.05 was considered to be statistically significant.

Results

Of 512 patients who had a nonincidental appendectomy, 465 (91%) underwent preoperative CT. Twenty-two of the 465 patients with preoperative CT had a negative appendectomy, corresponding to a negative appendectomy rate of 4.7% (95% CI, 0.93–0.97%). These included almost equal proportions of men (237/465 [51%]) and women (228/465 [49%]).

Among the men with preoperative CT, 231 of 237 (97.5%) had pathologic confirmation of appendicitis. Only six of 237 men with preoperative CT had a negative appendectomy, corresponding to a negative appendectomy rate of 2.5% (95% CI, 0.0.95–0.99%; Fig. 1 and Table 1). Eventual pathologic diagnoses in these six negative cases included periappendicitis with no inflammation of the appendix (n = 3), Kaposi sarcoma (n = 1), appendiceal diverticulum (n = 1), and fibrous obliteration of the lumen (n = 1).

Among the women with preoperative CT, 202 of 228 (89%) had pathologic findings of acute appendicitis. Another 10 patients had appendectomies for other medically necessary conditions listed in Table 2, and these scans were considered true-positives (Fig. 2). Sixteen of 228 women with preoperative CT had a negative appendectomy, corresponding to a negative appendectomy rate of 7% (95% CI, 0.89–0.96%; Fig. 3 and Table 1). Final pathologic diagnoses in negative appendectomies

TABLE 1: Negative Appendectomy Rates for Patients Who Underwent Preoperative CT (Regardless of Scan Interpretation) Versus Those Who Did Not

Patient Group	Appendicitis or Necessary Appendectomy	No Appendicitis	Total	Negative Appendectomy Rate, % (95% CI)	*p*
All patients					0.03
Preoperative CT	443	22	465	4.7 (0.93–0.97)	
No CT	41	6	47	12.7 (0.75–0.94)	
Men					0.01
Preoperative CT	231	6	237	2.5 (0.95–0.99)	
No CT	37	5	42	11.9 (0.72–0.94)	
Women					0.31
Preoperative CT	212	16	228	7.0 (0.89–0.96)	
No CT	4	1	5	20.0 (0.36–0.98)	

TABLE 2: Final Pathologic Diagnoses Among Women With Appendectomies Deemed Medically Necessary for Conditions Other Than Acute Appendicitis

Pathologic Diagnosis	No. of Patients
Chronic inflammation or chronic appendicitis	3
Appendiceal wall infarct and necrosis or acute ischemia	3
Crypt abscesses or cryptitis	2
Inflamed Meckel diverticulum with abscess	1
Mucinous cystadenoma with rupture	1

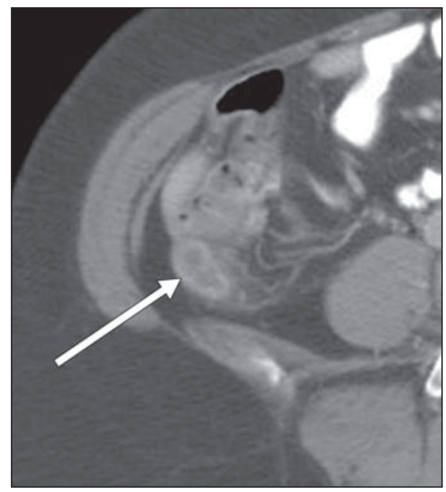

Fig. 2—55-year-old woman with lower abdominal pain. IV contrast-enhanced transverse CT image shows 13-mm fluid-filled appendix (*arrow*) with adjacent periappendiceal fat stranding. Acute appendicitis was diagnosed at CT, but pathologic examination revealed ruptured appendiceal mucinous cystadenoma. Although final diagnosis was other than acute appendicitis, this was nevertheless considered medically necessary appendectomy.

included normal appendixes ($n = 7$), appendicolith without inflammation ($n = 1$), impacted appendicolith with fibrous obliteration of the lumen ($n = 1$), cecal diverticulitis ($n = 1$), luminal ectasia ($n = 1$), ruptured ovarian cyst ($n = 1$), reactive lymphocytosis ($n = 1$), salpingitis-oophoritis ($n = 1$), luminal fibrosis ($n = 1$), and fat necrosis ($n = 1$).

Only 47 of 512 patients (9%) underwent appendectomy solely on the basis of clinical findings. Surgical reports for all 47 cases were reviewed. The 47 appendectomies without preoperative imaging were performed by a total of 18 different attending surgeons over the 5-year study period. All patients were clinically evaluated by an attending surgeon before appendectomy. The mean number of appendectomies performed without preoperative imaging was 2.6 per individual surgeon (median, 3; range, 1–6). The cases were not clustered over any particular time point between 2002 and 2007, with the median number of cases occurring in 2004.

Most patients who underwent appendectomy with no preoperative imaging (42/47 [89%]) were men ($p < 0.0001$). Thirty-six of 42 men (86%) had histologic confirmation of acute appendicitis. One of 42 men had a ruptured Meckel diverticulum with abscess involving the appendix, which was considered a medically necessary appendectomy. Five of 42 men with no preoperative imaging had a negative appendectomy, for a negative appendectomy rate of 11.9% (95% CI, 0.72–0.94%; Table 1). The final pathologic diagnoses in these five negative cases included normal appendix ($n = 2$), fibrous adhesions ($n = 1$), Meckel diverticulum ($n = 1$), and lymphoid hyperplasia ($n = 1$). Of the five women who had appendectomy on the basis of clinical findings alone, four (80%) had pathologic confirmation of appendicitis. The remaining one case showed no acute inflammation, only focal endometriosis, corresponding to a negative appendectomy rate of 20% (95% CI, 0.36–0.98; Table 1).

When only patients with a CT interpreted as positive for appendicitis (scored 4 or 5) were considered in the analysis, there was a further decrease in the negative appendectomy rate, but again, this was only statistically significant for the group as a whole (from 4.7% to 2.4%) and for men (from 2.5% to 1.8%) but not for women (Table 3). The numbers of study patients with preoperative CT, with positive preoperative CT, and without preoperative imaging are summarized in Figure 4.

If final pathologic diagnoses were stratified into only "positive for acute appendicitis" or "negative for acute appendicitis" (i.e., medically necessary appendectomies for conditions other than acute appendicitis were included in the "negative for acute appendicitis" group), results were almost unchanged for men, but the negative appendectomy rate for women with preoperative CT decreased. Among men with preoperative CT, 231 of 237 (negative appendectomy rate, 2.5%; 95% CI, 0.95–0.99%) had acute appendicitis compared with 36 of 42 (negative appendectomy rate, 14%; 95% CI, 0.72–0.94%) in the group without imaging ($p = 0.004$). Among women with preoperative CT, 202 of 228 (negative appendectomy rate, 11%; 95% CI, 0.83–0.92%) had acute appendicitis compared with four of five (negative appendectomy rate, 20%; 95%

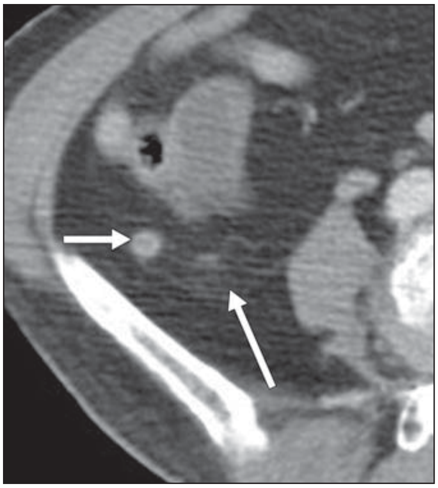

Fig. 3—72-year-old woman with right upper and lower quadrant pain. IV contrast-enhanced transverse CT image shows 6-mm appendix (*short arrow*) with subtle adjacent periappendiceal fat stranding (*long arrow*), prospectively interpreted as acute appendicitis. At pathologic examination, appendix was normal, and this case was considered negative appendectomy.

TABLE 3: Negative Appendectomy Rates for Patients With a Positive Preoperative CT Versus Those Who Did Not Undergo Preoperative Imaging

Patient Group	Appendicitis or Necessary Appendectomy	No Appendicitis	Total	Negative Appendectomy Rate, % (95% CI)	p
All patients					< 0.01
Positive CT	411	10	421	2.4 (0.96–0.99)	
No CT	41	6	47	12.7 (0.75–0.94)	
Men					< 0.01
Positive CT	221	4	225	1.8 (0.95–0.99)	
No CT	37	5	42	11.9 (0.75–0.95)	
Women					0.16
Positive CT	190	6	196	3.1 (0.93–0.99)	
No CT	4	1	5	20.0 (0.36–0.98)	

CI, 0.36–0.98%) in the group without imaging ($p = 0.46$; Table 4).

Discussion

Similar to prior studies, we found that the negative appendectomy rate was lower overall for adult patients who underwent preoperative CT (22/465 [4.7%]) compared with patients who did not undergo preoperative imaging (6/47 [12.8%]; $p = 0.03$). However, although most prior studies have shown no improvement in the negative appendectomy rate for men, we found that the negative appendectomy rate was significantly decreased among men with preoperative CT (6/237 [2.5%]) versus those without (5/42 [11.9%]; $p < 0.01$). For women, the negative appendectomy rate also decreased among those with CT (16/228 [7.0%] with CT vs 1/5 [20%] without CT), but the difference did not achieve statistical significance ($p = 0.32$). Negative appendectomies were even less common among the subset of patients with a positive preoperative CT. The negative appendectomy rate was 2.4% (10/421) overall and 1.8% (4/225) among men ($p < 0.01$, compared with patients without preoperative CT). In women with a positive CT for appendicitis, the negative appendectomy rate was reduced from 20% (1/5) to 3.1% (6/196), but this difference was not statistically significant.

The definition of a negative appendectomy that is most often used in the surgical literature is that it involves a normal appendix or is

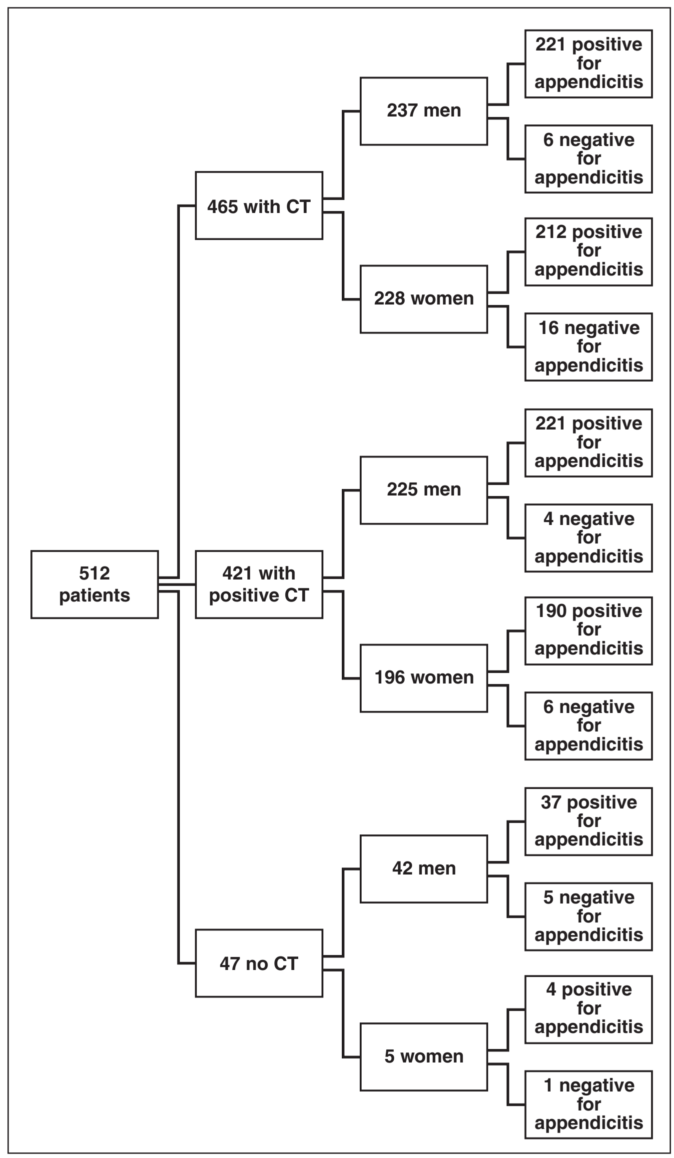

Fig. 4—Flowchart summarizing study patients with preoperative CT, with positive preoperative CT, and without preoperative imaging.

TABLE 4: Negative Appendectomy Rates for Patients Who Did and Did Not Undergo Preoperative Imaging

Patient Group	Appendicitis or Necessary Appendectomy	No Appendicitis	Total	Negative Appendectomy Rate, % (95% CI)	*p*
All patients					0.07
Preoperative CT	433	32	465	6.9 (0.90–0.95)	
No CT	40	7	47	14.9 (0.77–0.96)	
Men					0.004
Preoperative CT	231	6	237	2.5 (0.95–0.99)	
No CT	36	6	42	14.3 (0.72–0.94)	
Women					0.46
Preoperative CT	202	26	228	11.4 (0.83–0.92)	
No CT	4	1	5	20.0 (0.36–0.98)	

Note—In this comparison, cases were classified as either positive or negative for acute appendicitis. All diagnoses other than acute appendicitis were considered a "negative appendectomy."

a medically unnecessary appendectomy. This definition was also used for our primary analysis so that comparisons to the surgical literature would be more meaningful. However, assignment of a case as a medically unnecessary appendectomy introduces some potential subjectivity as to what constitutes unnecessary. Therefore, a substratified analysis was also performed with pathologic diagnoses categorized as positive for acute appendicitis or negative for acute appendicitis. In other words, all pathologic diagnoses other than acute appendicitis were considered negative. Although this changed the assignment of several cases from a positive to negative appendectomy, it did not have a large impact on the overall findings, particularly with regard to men. The negative appendectomy rate among men with preoperative CT was stable at six of 231 (2.5%), using either definition of negative appendectomy. Among men without imaging, the negative appendectomy rate was slightly higher using this definition (6/42 [14.3%]), compared with five of 42 (11.9%) when medically necessary appendectomies were excluded from the negative group.

The lower negative appendectomy rate associated with preoperative CT at our institution is similar to others reported in the literature, with recent rates in the range of 1.7–11.4% [9, 12, 16–18, 23, 24, 28]. The use of CT resulted in a 50% decrease in the negative appendectomy rate at one institution (11.4% with preoperative imaging vs 22.2% without) [16]. An even more substantial reduction in the negative appendectomy rate was observed in a multicenter study (6.6% vs 20.6%), which showed an inverse relationship between negative appendectomy rate and CT utilization [17]. Because of this evidence, many authors have argued in favor of routine use of CT when there is clinical suspicion of acute appendicitis.

Although our results detected no statistically significant difference in the negative appendectomy rate among women with CT, this was likely because of the very small sample of women who underwent appendectomy on the basis of clinical examination alone. Prior studies have consistently shown that women benefit from preoperative imaging for the diagnosis of appendicitis, likely because of the expanded differential diagnosis for abdominal pelvic pain associated with gynecologic disease [9–16, 24]. The same studies, however, have repeatedly failed to show any reduction in negative appendectomies for adult men with preoperative CT [9–11, 13–15, 24, 29]. Fuchs et al. [14] noted a markedly decreased negative appendectomy rate only in women; the negative appendectomy rate in men did not change. Another retrospective study of 75,452 patients found that preoperative CT resulted in a lower negative appendectomy rate for all women, but no significant reduction in the negative appendectomy rate was seen in men [11]. Those authors suggested that preoperative CT is not indicated for men with a typical clinical presentation of acute appendicitis.

At our institution, men (42/47 [89%]) were more likely than women (5/47 [11%]) to undergo appendectomy on the basis of convincing clinical findings alone ($p < 0.0001$). However, the negative appendectomy rate remained relatively high among these men (5/42 [11.9%]), despite the fact that they presumably had very "typical" clinical presentations, apparently obviating CT. In contrast, when CT was used in the workup for abdominal pain, the negative appendectomy rate among men decreased to just 2.5%, and when the preoperative CT scan was interpreted as positive, the negative appendectomy rate was even further decreased to 1.8%.

Ours is not the first study to suggest that men may benefit from preoperative CT. Several prior studies, including a recent study performed by Raja et al. [23], have suggested that preoperative CT is efficacious in decreasing the negative appendectomy rate for both sexes [12, 16]. In another prospective study, the combination of an evidence-based diagnostic algorithm, early surgical evaluation, and objective criteria for preoperative CT resulted in a decreased negative appendectomy rate for both men and women when compared with earlier rates before the use of CT [30]. However, comparatively, there is little literature that supports the use of CT in the workup of acute appendicitis among adult men, despite the fact that this remains a common practice pattern in this country. Our findings lend further support to this small body of literature.

This study has several limitations. First, it is a retrospective study and data are from a single institution. CT scans were obtained over a period of 5 years from 2002 to 2007, and the techniques used were necessarily heterogeneous, a result of both protocol changes and equipment upgrades that occurred over this interval. Also, relatively few women undergo appendectomy without preoperative imaging at our institution, resulting in a small sample size for this patient subgroup. Although the number of men who underwent appendectomy without preoperative CT was comparatively large enough to achieve statistical significance, the sample size was still small. Additionally, because patients who underwent appendectomy solely on the basis of clinical presentation tended to be younger (mean age, 32 years vs 40 years for those with preoperative CT) and presumably had more convincing clinical presentations, bias may be introduced between groups. However, because the negative appendectomy rate was actually higher among these patients, compared with older patients with possibly less-typical symptoms, this seems to further substantiate the utility of CT and does not detract from our findings. Finally, CT images were not retrospectively reviewed to stratify positive from negative scans. Rather, the CT reports were reviewed and classified by a single reader. However, most prior studies [4, 12, 13, 15, 16] have only reported the difference in negative appendectomy rate between those without prior imaging versus those who had CT (regardless of the scan interpretation). We undertook the additional step of determining negative appendectomy rates for patients with a positive CT interpretation for acute appendicitis, because CT can hardly be expected to decrease the negative appendectomy rate when patients with prospectively normal scans are subsequently taken for appendectomy. Furthermore, the study was designed to determine the actual impact of CT use on negative appendectomy rate in clinical practice (using prospective clinical interpretations). We believe that this is a more applicable real world metric than would be the case with retrospective image review.

In summary, we found that the negative appendectomy rate was decreased for adult patients who underwent preoperative CT (22/465 [4.7%]) compared with patients who did not undergo preoperative imaging (6/47 [12.8%]; $p = 0.03$). Although most prior studies have suggested that CT is efficacious only in decreasing the negative appendectomy rate among women, our study shows that adult men benefit from CT as well, as evidenced by a decrease in negative appendectomies among men who underwent preoperative CT to 2.5% (6/237), compared with 11.9% (5/42; $p = 0.01$) for those who did not undergo preoperative imaging.

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