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Introduction of Appendiceal CT

Impact on Negative Appendectomy and Appendiceal Perforation Rates

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Objective

To evaluate the impact of appendiceal computed tomography (CT) availability on negative appendectomy and appendiceal perforation rates.

Summary Background Data

Appendiceal CT is 98% accurate. However, its impact on negative appendectomy and appendiceal perforation rates has not been reported.

Methods

The authors reviewed the medical records of 493 consecutive patients who underwent appendectomy between 1992 and 1995, 209 consecutive patients who underwent appendectomy in 1997 (59% of whom had appendiceal CT), and 206 patients who underwent appendiceal CT in 1997 without subsequent appendectomy.

Results

Before appendiceal CT, 98/493 patients (20%) taken to surgery had a normal appendix. After CT availability, 15/209 patients (7%) taken to surgery had a normal appendix; 7 patients did not have CT, 5 patients had surgery despite a negative CT, and 3 patients had a false-positive CT. Negative appendectomy rates were lowered overall (20% to 7%), in men (11% to 5%), in women (35% to 11%), in boys (10% to 5%), and in girls (18% to 12%). Appendiceal perforation rates dropped from 22% to 14% after CT availability. CT excluded appendicitis in 206 patients in 1997 who avoided appendectomy and identified alternative diagnoses in 105 of these patients (51%).

Conclusion

The availability of appendiceal CT coincided with a drop in the negative appendectomy rate from 20% to 7% in all patients, and to only 3% in patients with a positive CT. Perforation rates decreased from 22% to 14%. Appendiceal CT can be advocated in nearly all female and many male patients.

Patients with acute appendicitis frequently have characteristic findings on history, physical examination, and laboratory analysis. However, there are a multitude of reasons why patients with appendicitis can have atypical clinical presentations; conversely, patients with a variety of alternative conditions can present with findings clinically indistinguishable from those of appendicitis.[1,2] Up to half of all patients admitted for suspected appendicitis have it excluded, and 15% to 50% of all patients undergoing primary appendectomy prove to have a normal appendix at surgery and pathology.[3–5]

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Appendiceal ultrasound is used at many centers in an attempt to improve the accuracy of clinical diagnosis; reported accuracies range between 71% and 95%.[6–11] However, a 1993 investigation[11] noted that 24% of patients had a false-negative appendiceal ultrasound, and a 1994 investigation[12] reported that the overall accuracy for diagnosing appendicitis decreased at one hospital after introduction of appendiceal ultrasound, despite the added cost.

Appendiceal computed tomography (CT) is also used at some centers; reported accuracies range between 93% and 98%.[10,13–17] A 1998 investigation noted that 59% of patients who underwent CT had improvement in their planned management, including prevention of unnecessary hospital admissions, appendectomies, and delays before necessary appendectomy or treatment for CT-diagnosed alternative conditions.[18]

Although appendiceal CT has been shown to improve patient management in a majority of patients with suspected appendicitis who actually undergo CT, the impact of appendiceal CT on a hospital's overall negative appendectomy and appendiceal perforation rates has not yet been reported. In this study we analyzed the impact of appendiceal CT on our hospital's negative appendectomy and appendiceal perforation rates.

PATIENTS AND METHODS

Patient Eligibility and Characteristics

Over the 38 months before introduction of appendiceal CT (between July 1992 and September 1995), 493 patients underwent primary appendectomy at the Massachusetts General Hospital (MGH). There were 267 male (54%) and 226 female (46%) patients. There were 129 pediatric patients (ages 5–18 years) (26%) and 364 adult patients (74%) (mean age, 29 years; range 5–90 years). The medical records of all patients were available and were reviewed, including pathology reports on appendectomy specimens. Negative appendectomy rates were calculated for all patients, male and female subgroups, and pediatric and adult subgroups. The appendiceal perforation rate was calculated for the entire group of patients with appendicitis as well as the pediatric subgroup of patients.

Appendiceal CT was introduced, refined, and investigated at our hospital between October 1995 and December 1996. From two prospective investigations on appendiceal CT accuracy, we reported 98% to 100% sensitivity, 95% to 98% specificity, 97% to 98% positive predictive value, 95% to 100% negative predictive value, 62% to 80% alternative diagnosis identification rates, and 98% overall accuracy for confirming or excluding appendicitis.[14,15] By December 1996, an appendiceal CT technique had been established, radiologists were experienced in its performance and interpretation, and it was frequently requested for patients with suspected but clinically uncertain appendicitis.

After establishment of a standard appendiceal CT protocol, 209 patients underwent primary appendectomy at the MGH in 1997. There were 128 male (61%) and 81 female (39%) patients. There were 59 pediatric (28%) and 150 adult (72%) patients with an average age of 27 years (range 2–78 years). One hundred twenty-three of the 209 patients (59%) underwent appendiceal CT before appendectomy. The negative appendectomy rates for all patients, male and female subgroups, pediatric and adult subgroups, and patients who did and did not undergo preoperative appendiceal CT were determined. The appendiceal perforation rate was calculated for the entire group of patients with appendicitis as well as the pediatric subgroup of patients.

During 1997, 206 additional patients underwent appendiceal CT and subsequently did not undergo appendectomy. There were 74 male and 132 female patients. There were 161 adult and 45 pediatric patients, with a mean age of 28 years (range 2–81 years). The CT alternative diagnosis identification rate in these patients was determined.

Statistical analysis was performed comparing changes in negative appendectomy rates in all patients and all patient subgroups as well as changes in appendiceal perforation rates in all patients. A two-sided Fisher's exact test was used. This investigation was reviewed and approved by our hospital's Subcommittee on Human Studies.

CT Technique and Interpretation

Patients were eligible for appendiceal CT only if appendicitis was the leading clinical suspicion. Patients were referred for CT through our emergency department by general surgeons, pediatric surgeons, obstetric and gynecologic surgeons, and emergency medicine physicians.

Appendiceal CT examinations were obtained on a General Electric HiSpeed Advantage scanner (General Electric Medical Systems, Milwaukee, WI). Helical scanning was performed with 5 mm collimation, 7.5 mm/sec table speed (1.5 pitch), and 5 mm image spacing. An approximately 15-cm region of the lower abdomen and upper pelvis was scanned, centered approximately 3 cm above the tip of the cecum, as identified on an initial CT digital radiograph. Additional decubitus or extended scanning was performed on an individual basis.[19]

Patients were placed on the CT scanner table and contrast material was instilled into the colon, up to 1500 ml (average adult volume, 900 ml) of a 3% meglumine diatrizoate solution (Gastrografin, Bristol-Meyers Squibb, Wallingford, CT) through a small rubber rectal catheter. No patient initially received contrast material administered intravenously or by mouth.

Most scans were performed within 1 hour of request; nearly all appendiceal CT scans required 10 to 20 minutes of CT scanner time. All scans were interpreted as either positive or negative for appendicitis, and results were immediately made known to referring clinicians. There were no CT complications.

Appendiceal CT scans were interpreted as negative for appendicitis if an appendiceal lumen filled completely with contrast material, air, or both, or if an appendix measured 6 mm or less in maximum diameter (Fig. 1). Appendiceal CT scans were interpreted as positive for appendicitis if an enlarged (>6 mm in outer diameter), unopacified appendix was noted with adjacent inflammatory changes, such as fat stranding, phlegmon, or fluid collection (Fig. 2).[19,20] Appendicitis was diagnosed in cases of nonvisualization of an appendix only in the presence of specific CT signs of appendicitis, including an appendolith, focal cecal apical thickening, arrowhead sign, or cecal bar.[21,22] Alternative conditions were reported when present, including mesenteric adenitis and/or ileitis (Figs. 3 and 4), ovarian cystic disease, diverticulitis (Fig. 5), small bowel obstruction, epiploic appendagitis, ureteral stone, and other conditions.[23–27]

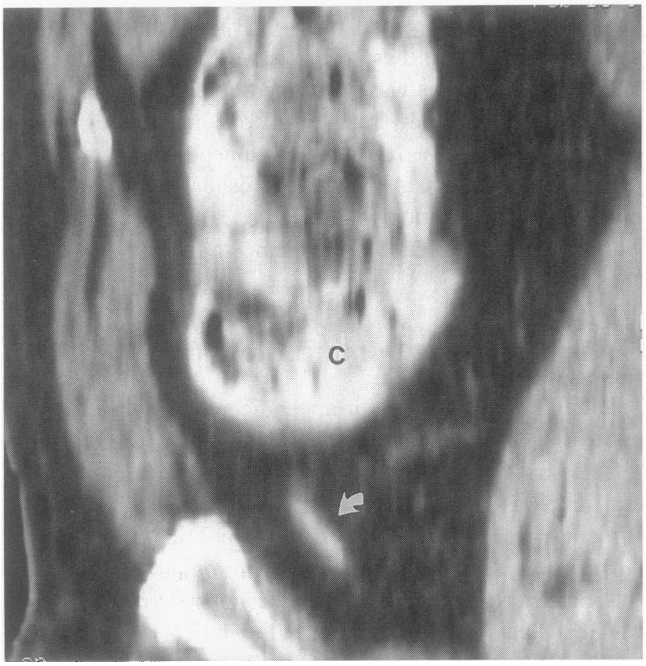

Figure 1. Coronally reformatted CT image of a 64-year-old man with a patent lumen, normal appendix (*arrow*) caudal to the cecum (C).

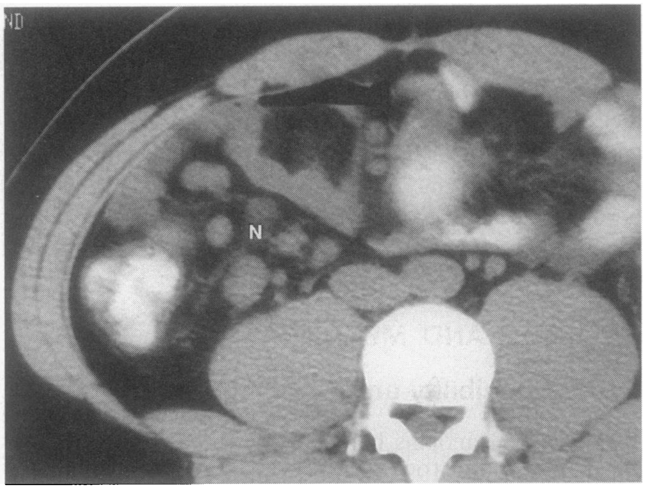

Figure 3. Axial CT scan of a 24-year-old man with clumped, enlarged lymph nodes (N), a finding consistent with mesenteric adenitis.

RESULTS

Before Appendiceal CT Introduction

Of the 493 patients who underwent primary appendectomy in the 38 months preceding appendiceal CT introduction, 395 (80%) had appendicitis or other appendiceal disease; 98 (20%) had a normal appendix at pathologic examination (Tables 1 and 2). Of the 267 male and 226 female patients, 28 male (10%) and 70 female (31%) patients had a normal appendix. Of the 364 adult and 129 pediatric patients, 81 adult (22%) and 17 pediatric (13%) patients had a normal appendix. Of the 194 adult male and 73 pediatric male patients, 21 adult male (11%) and 7 pediatric male (10%) patients had a normal appendix. Of the 170 adult female and 56 pediatric female patients, 60 adult female (35%) and 10 pediatric female (18%) patients had a normal appendix.

After Appendiceal CT Introduction

Of the 209 patients who underwent primary appendectomy in 1997, 194 (93%) had appendicitis (see Table 1); 15 (7%) had a normal appendix at pathologic examination. Of the 128 male and 81 female patients, 6 male (5%) and 9 female (11%) patients had a normal appendix. Of the 150 adult and 59 pediatric patients, 11 adult (7%) and 4 pediatric (7%) patients had a normal appendix. Of the 86 adult male and 42 pediatric male patients, 4 adult male (5%) and 2 pediatric male (5%) patients had a normal appendix. Of the 64 adult female and 17 pediatric female patients, 7 adult female (11%) and 2 pediatric female (12%) patients had a normal appendix. The statistical significance of changes in

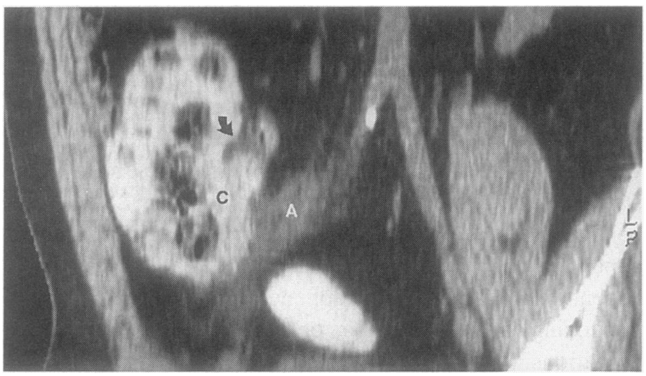

Figure 2. Coronally reformatted CT image of a 40-year-old man with a distended, inflamed appendix (A) arising off the cecum (C) caudal to the ileocecal valve (*arrow*).

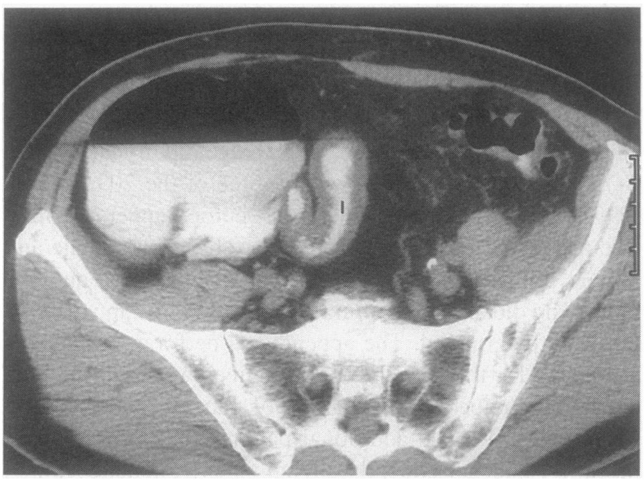

Figure 4. Axial CT scan of an 81-year-old man with a thickened terminal ileum (I), a finding consistent with infectious ileitis.

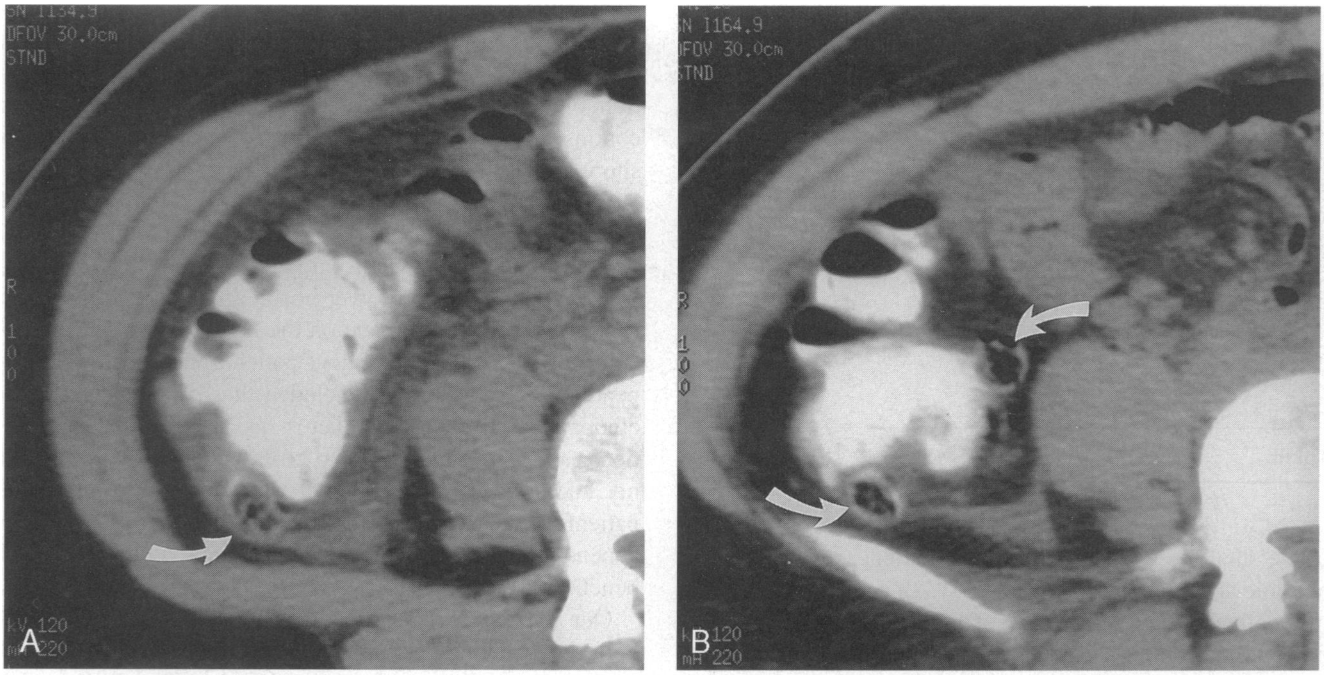

Figure 5. Axial CT scans of a 27-year-old woman with multiple right-sided diverticula (*arrows*) and adjacent inflammatory fat stranding and fluid, findings consistent with right-sided diverticulitis.

negative appendectomy rates for all patients and all patient subgroups are listed in Table 1.

Appendiceal CT was obtained in 123 of 209 patients (59%) who underwent appendectomy and was interpreted as positive for appendicitis in 117 patients; 114 of these 117 patients (97%) had appendicitis, and 3 patients (3%) had a normal appendix. Appendiceal CT was interpreted as negative for appendicitis in six patients who underwent appendectomy; five of these six patients (83%) had a normal appendix, and one patient (17%) had appendicitis. Appendiceal CT was not obtained in 86 of 209 patients (41%); 79 of these 86 patients (92%) had appendicitis, and 7 patients (8%) had a normal appendix.

Appendiceal CT correctly excluded appendicitis in 211 of 214 patients (99%) who underwent appendiceal CT and who did not have appendicitis. Also, CT confirmed appendicitis in 114 of 115 patients (99%) who underwent appendiceal CT and who did have appendicitis.

Of the 15 of 209 patients (7%) who underwent negative primary appendectomy in 1997, 7 patients did not undergo appendiceal CT, 5 patients underwent appendectomy despite a negative CT scan, and 3 patients had a false-positive appendiceal CT scan.

Of the 206 patients who underwent appendiceal CT and subsequently did not undergo an appendectomy, CT reports included identification of a normal appendix or no specific CT evidence for appendicitis in all cases. A specific alternative condition was noted at CT in 105 patients (51%): ileitis, ileocolitis, or colitis (including infectious and Crohn's disease) in 27 patients (26%); right ovarian cystic disease in 22 patients (21%); mesenteric adenitis in 19 patients (18%); sigmoid or cecal diverticulitis in 6 patients

Table 1. NEGATIVE APPENDECTOMY RATES

Patient Group	No. of Patients		Negative Appendectomy Rate (%)		
	Baseline	1997	Baseline	1997	P Value
All patients	493	209	20	7	< .001
Male patients	267	128	10	5	= .057
Female patients	226	81	31	11	< .001
Adults	364	150	22	7	< .001
Children	129	59	13	7	= .224
Men	194	86	11	5	= .114
Boys	73	42	10	5	= .483
Women	170	64	35	11	< .001
Girls	56	17	18	12	= .720

Table 2. IMPACT ON ADULT FEMALE PATIENTS (1997)

Patient Group	No. of Patients	Negative Appendectomy Rate (%)
Adult females	64	11
Had CT	45	7
No CT	19	21
All others	145	7
Had CT	78	3
No CT	67	9

Table 3. ALTERNATIVE CONDITIONS NOTED AT APPENDICEAL CT

Alternative Condition	No. of Patients (%)
Ileitis, ileocolitis, or colitis	27 (26)
Right ovarian cystic disease	22 (21)
Mesenteric adenitis	19 (18)
Sigmoid or cecal diverticulitis	6 (6)
Small bowel obstruction	5 (5)
Primary epiploic appendagitis	4 (4)
Right ureteral stone	3 (3)
Duodenal perforation	2 (2)
Omental infarction	2 (2)
Other	15 (14)
Total	105 (100)

(6%); small bowel obstruction in 5 patients (5%); primary epiploic appendagitis in 4 patients (4%); right ureteral stone in 3 patients (3%); duodenal perforation in 2 patients (2%); omental infarction in 2 patients (2%); and one episode each of another specific condition in 15 patients (14%) (Table 3).

Appendiceal Perforation Rates

Between 1992 and 1995, 395 of 493 patients undergoing primary appendectomy had appendicitis. In 87 of 395 appendicitis cases (22%), the appendix was perforated. In 1997, 194 of 209 patients undergoing primary appendectomy had appendicitis. In 28 of 194 appendicitis cases (14%), the appendix was perforated. This difference in perforation rates achieved statistical significance ($p = 0.038$). In the pediatric population between 1992 and 1995, 26 of 112 patients with appendicitis (23%) had perforation; in 1997, 8 of 55 pediatric patients with appendicitis (15%) had perforation. This difference in perforation rates, however, failed to achieve statistical significance ($p = 0.224$).

DISCUSSION

An accurate preoperative diagnostic test for confirming or excluding appendicitis has long been sought.[28,29] Hospital observation can aid in clinically differentiating patients with and without appendicitis. However, delaying surgery in patients with appendicitis can lead to increased perforation and complication rates, and diagnostic delay in patients who have an alternative condition can also lead to complications.[29] From a hospital resource use perspective, one day of hospital observation is more than twice as costly as one appendiceal CT scan.[18]

Appendiceal CT is 93% to 98% accurate for diagnosing appendicitis.[14,15,19] The highest CT accuracy has been reported with focused appendiceal CT techniques that include colon contrast material, which allows immediate patient scanning and minimal patient radiation exposure and cost. The costs and risks associated with oral and intravenous contrast material administration have also been eliminated.[14,15,19] The use of oral contrast material exposes a potentially preoperative patient to a greater risk of aspiration on induction of anesthesia. The use of intravenous contrast material exposes a patient to the risks of injection site extravasation, renal damage, and contrast material allergy, including skin rash, respiratory compromise, and even death.

Routine use of appendiceal CT has been shown to improve patient care and lower hospital resource use relative to management plans made on the basis of clinical impression in emergency department patients with suspected appendicitis.[18] This study concluded that if *all* patients with clinically suspected appendicitis had appendiceal CT, patient care would improve and costs would decrease. It did not address, however, whether there may be a subset of patients with such a high clinical accuracy for diagnosing appendicitis that appendiceal CT would be of little practical benefit.

Our current investigation determined that concomitant with the availability of appendiceal CT, the MGH's overall negative appendectomy rate was lowered from 20% to 7% in all patients undergoing primary appendectomy, and to just 3% in patients who underwent primary appendectomy only after appendiceal CT confirmed appendicitis. Further, negative appendectomy rates were lowered in all patient subgroups, including men (11% to 5%), women (35% to 11%), boys (10% to 5%), and girls (18% to 12%).

The negative appendectomy rate dropped from 13% to 7% in pediatric patients, but this did not achieve statistical significance ($p = 0.224$). The pediatric perforation rate also was lowered, from 23% to 15%, again without achieving statistical significance. These results may reflect the fact that clinical accuracy is generally higher in pediatric patients (except the very young), or simply that the small sample size prevented statistical significance from being attained.

Female patients with suspected appendicitis also deserve special mention. Although this group had the most dramatic drop in negative appendectomy rate (31% to 11%), female patients also continued to have the highest negative appendectomy rate of all patient subgroups. Obtaining appendiceal CT in all or nearly all female patients would have had a relatively greater impact on further reduction of the negative appendectomy rate than increased scanning of male patients. This is particularly true of adult female patients, who in 1997 had a 7% negative appendectomy rate after CT but a 21% negative appendectomy rate without CT (see Table 2).

Despite the already significant lowering of the negative appendectomy rate, results suggest the potential for further decline in the negative appendectomy rate. Of the 15 patients who underwent negative primary appendectomy in 1997, 7 did not undergo appendiceal CT, 5 underwent appendectomy despite a negative CT scan, and 3 had a false-positive appendiceal CT scan. Obtaining appendiceal CT more often or avoiding appendectomy in patients with a definitely negative appendiceal CT could lower the negative appendectomy rate further, perhaps to as low as 3%. However, a CT-augmented negative appendectomy rate of 7% remains a significant improvement over clinical accuracy alone.

Patients are often observed in an attempt to improve preoperative accuracy. Although negative appendectomy rates can be lowered with this strategy, appendiceal perforation rates may be increased because of the delay before necessary appendectomy.[29] With the availability of appendiceal CT, however, negative appendectomy rates were lowered while appendiceal perforation rates were also lowered, from 22% to 14%; this reduction achieved statistical significance.

There were several limitations and strengths of this investigation. This study was retrospective in nature, and the pre-CT control group was similar but not identical in age and sex distribution to the post-CT study group. Although the only difference in patient evaluation we identified was the introduction of appendiceal CT, this study compared a 1997 patient population to an historical control group (1992–1995), and it remains possible that an unidentified factor contributed to differences in negative appendectomy or appendiceal perforation rates. The decision to perform an appendectomy or an appendiceal CT in 1997 was made by one of >37 individual surgeons whose decision criteria were certainly not identical. CT scans were interpreted by one of 12 radiologists whose levels of experience varied considerably. One strength of this study was that for comparing negative appendectomy and perforation rates, all patients underwent surgery, and final diagnoses were based on pathologic findings. Also, this investigation reflected the actual practice patterns of physicians making patient care decisions.

In conclusion, concomitant with the availability of appendiceal CT, the MGH's overall negative appendectomy rate was lowered from 20% to 7% in all patients and to only 3% in patients who had a positive appendiceal CT before surgery. Also, our hospital's appendiceal perforation rate was lowered from 22% to 14%. We believe the results of this investigation emphasize the value of appendiceal CT use in all patients in whom there is suspicion but not clinical certainty for the diagnosis of appendicitis. In nearly all female patients, appendiceal CT use can be advocated. However, in male patients with a high clinical likelihood of appendicitis, appendiceal CT use should be more selective.

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