

The Impact of the Liberal Use of CT in the Work Up of Acute Appendicitis

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Abstract: *Background:* Acute appendicitis has historically been considered a clinical diagnosis, necessitating a CT scan only in the face of equivocal signs and symptoms. The purpose of this study is to determine whether or not the liberal use of CT in the work up of acute appendicitis results in a decreased negative appendectomy rate (NAR).

Methods: The medical records of 940 consecutive patients who underwent emergency appendectomy between January 2002 and December 2006 were reviewed. Data collected included patient demographics, length of stay (LOS), results of contrast enhanced CT scans, emergency department (ED) work up time, and final pathology.

Results: During the study period 940 patients (mean age 34.5±16.7 years, 53% males) underwent emergency appendectomy (64% laparoscopic). Eight hundred thirteen (86% patients, 50% males) underwent pre-operative CT scans. Final pathology was 76.1% acute appendicitis, 10% acute appendicitis with perforation, 7.7% gangrenous appendicitis, 1.2% acute appendicitis with abscess, 0.7% chronic appendicitis, and 4.3% negative for appendicitis. No difference was noted in the overall appendicitis rate by gender in the CT (Fishers exact test, $p=0.96$) or non-CT group (Fishers exact test, $p=0.75$). Similarly, no difference was noted by age (CT $p=0.14$, non-CT $p=0.26$). The NAR was lower for the CT group (3.4%) compared to the non-CT group (9.4%) ($p=0.002$). The NAR did not differ significantly by gender (Fishers exact test, $p=0.491$). Despite prolonging the ED work up time by 4.3 hours, the perforation rate did not differ between the CT (9.5%) and non-CT (12.6%) groups ($p=0.30$), nor did the LOS (3.67 vs. 3.63 days, $p=0.92$). The sensitivity, specificity, negative predictive value, and positive predictive value of CT scans was 99%, 61%, 68%, and 99%, with an overall accuracy of 98%. The positive and negative likelihood ratios were 2.52 and 0.02 respectively. The ROC for CT scans in predicting appendicitis was 79.8% (95% CI: 76.9%, 82.5%).

Conclusions: The use of CT in the work up of acute appendicitis is associated with a lower negative appendectomy rate independent of gender and age. The additional time spent obtaining a CT does not appear to increase the risk of perforation nor increase the LOS.

BACKGROUND

Despite sound clinical judgment and the availability of modern imaging modalities, negative appendectomy rates as high as 15% for the general population and 23% to 35% for women are still reported [1]. These high rates have traditionally been accepted by surgeons, comforted by a belief that the morbidity and the costs of a missed appendicitis greatly outweigh that of a negative appendectomy. Large population based studies however, disagree with this benign outlook reporting considerable clinical and economic cost [1]. For this reason, in an attempt to improve on the traditionally tolerated negative appendectomy rate, much attention has been turned towards redesigning the work up of acute appendicitis.

Acute appendicitis has historically been considered a clinical diagnosis, necessitating a CT scan only in the face of equivocal signs and symptoms. However, since its advent clinicians have struggled to expand the role of CT in the work up of right lower quadrant pain. Some recommend a selective approach justifying its use in specific age groups,

women of reproductive age, and in those with an equivocal presentation [2-6]. Others advocate its routine use citing 90% to 100% sensitivity, 91% to 99% specificity, and a positive predictive value of 95% to 97% [7]. Proponents of routine CT argue that it improves on the traditionally accepted 15% to 20% negative appendectomy rate without any additional morbidity [8-15]. Still, another subset of clinicians fail to report any clear benefit from either selective or routine strategies, believing it does not significantly decrease negative appendectomy rates and may furthermore negatively impact outcomes by delaying definitive management [16-19].

Most medical centers do not have an established protocol for the work up of acute appendicitis. However, an increasingly tolerant attitude exists among surgeons and emergency medicine physicians regarding the acquisition of a CT scan during the work up of acute right lower quadrant pain. In order to assess the influence of CT on our institution's negative appendectomy rate, a retrospective chart review was performed of all patients greater than age 13 who underwent appendectomy from January 2002 to December 2006. The purpose of the study was to determine whether or not the liberal use of CT in the work up of acute appendicitis significantly reduces the negative appendectomy rate and whether it negatively influenced perforation rates.

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Table 1. Demographics and Pathologic Data

	All Patients (n = 940, m = 499) Number (%)	CT Group (n = 813, m = 410) Number (%)	Non-CT Group (n = 127, m = 89) Number (%)	P Value ‡
Age (years)	34.5 ± 16.7	36.2 ± 18.1	35.4 ± 21.3	0.871
Length of stay (days)	3.6 ± 5.1	3.6 ± 5.2	3.6 ± 4.2	0.921
Pathology				
Acute appendicitis	716 (76.1)	626 (77.0)	90 (70.8)	0.143
Chronic appendicitis	7 (0.7)	5 (0.6)	2 (1.5)	0.242
Gangrene	72 (7.6)	65 (8.0)	7 (5.5)	0.471
Perforated	94 (10.0)	78 (9.5)	16 (12.6)	0.338
Phlegmon / abscess	11 (1.1)	11 (1.3)	0 (0)	0.377
Negative appendectomy rate				
All patients	40 (4.2)	28 (3.4)	12 (9.4)	0.007
Male	22 (4.4)	14 (3.4)	8 (8.9)	0.491
Female	18 (4.0)	14 (3.5)	4 (10.5)	

‡ Fisher's exact test.

PATIENTS AND METHODS

After obtaining approval from the Beth Israel Medical Center Institutional Review Board (IRB # 103-07) the medical records of 940 consecutive patients above age 13 who underwent emergency appendectomy for presumed acute appendicitis between January 2002 and December 2006 where retrospectively reviewed. CT scan of the abdomen and pelvis was performed with oral contrast only. Intravenous contrast was only administered in patients in whom inflammation around the appendix was determined to be equivocal by a radiologist. The Ct was immediately reviewed by a radiology resident and within 1 hour by an attending radiologist. Patients with clear right lower quadrant peritoneal signs did not undergo CT scan, but rather were transferred immediately to the operating room for appendectomy. All female patients of childbearing age underwent pelvic examination also. Data collected included patient demographics (age and gender), procedure type (open versus laparoscopic), length of stay, results of contrast enhanced CT scans, CT work up time, and final pathology. Data was analyzed using Statistical Package for the Social Sciences for Windows 16 (SPSS Inc. Chicago, IL). A p value less than 0.05 was considered statistically significant.

RESULTS

During the study period 940 patients (53% male, 47% female) underwent emergency appendectomy (70% completed laparoscopically) for suspected acute appendicitis. The mean age of the group was 34.5 ± 16.7 (range 13 to 95, CT 36.2 ± 18.1 vs non-CT 35.4 ± 21.3, p = 0.87), eight hundred thirteen (86% patients, 50% males) of which underwent pre-operative CT scans.

For the cohort, final pathology was 76.1% acute appendicitis, 10% acute appendicitis with perforation, 7.6% gangrenous appendicitis, 1.1% acute appendicitis with abscess, 0.7% chronic appendicitis, and 4.2% negative for appendicitis. No statistical significance was noted between the CT and non-CT group for acute appendicitis (p = 0.14), acute appendicitis with perforation (p = 0.33), gangrenous appendicitis

(p = 0.47), acute appendicitis with abscess (p = 0.37), and chronic appendicitis (p = 0.24). The overall negative appendectomy rate was lower for the CT group (3.4%) compared to the non-CT group (9.4%) (p = 0.007), and did not differ significantly by gender (Fishers exact test, p = 0.491). (Table 1) No difference was noted in the overall negative appendectomy rate by gender in the CT (Fishers exact test, p = 1.00) or non-CT group (Fishers exact test, p = 0.75). Similarly, no difference was noted by age (CT p = 0.14, non-CT, p = 0.26). (Tables 2 and 3) Despite the additional 4.3 hours required to obtain a CT scan, the perforation rate did not differ between the CT and non-CT group (9.5% vs 12.6%, p = 0.33), nor did the length of stay (3.67 vs 3.63 days, p = 0.92).

No statistically significant difference was noted in the number of CT scans obtained per year (Fishers exact test, p = 0.36). (Table 4) The sensitivity, specificity, negative predictive value, and positive predictive value of CT scans was 99%, 61%, 68%, and 99%, with an overall accuracy of 98%. The positive and negative likelihood ratios were 2.52 and 0.02 respectively (Table 5).

Table 2. Negative Appendectomy Rate by Age and Gender in the Non-CT Group

	Positive Appendectomy (n = 115) Number (%)	Negative Appendectomy (n = 12) Number (%)	P Value
Age (years)			
≤ 16	22 (19.6)	4 (36.4)	0.256†
17 - 30	43 (38.4)	1 (9.1)	
31 - 45	25 (22.3)	2 (18.2)	
46 - 60	13 (11.6)	2 (18.2)	
≥ 61	9 (8.0)	2 (18.2)	
Gender			
Male	81 (70.4)	8 (66.7)	0.751‡
Female	34 (29.6)	4 (33.3)	

† Chi-square test; ‡ Fisher's exact test.

Table 3. Negative Appendicitis Rate by Age and Gender in the CT Group

	Positive Appendectomy (n = 785) Number (%)	Negative Appendectomy (n = 28) Number (%)	P Value
Age (years)			
≤ 16	68 (8.7)	0 (0)	0.139†
17 - 30	301 (38.5)	8 (29.6)	
31 - 45	237 (30.3)	10 (37.0)	
46 - 60	115 (14.7)	4 (14.8)	
≥ 61	61 (7.8)	5 (18.5)	
Gender			
Male	396 (50.4)	14 (50.0)	1.000‡
Female	389 (49.6)	14 (50.0)	

† Chi-square test; ‡ Fisher's exact test.

Table 4. Number of CT Scans Obtained Per Year

Year	CT	No CT	Total	P Value ‡
2002	139	28	167	p=0.36
2003	156	28	184	
2004	175	26	201	
2005	162	26	188	
2006	181	19	200	

‡ Fisher's exact test.

Table 5. Validity of CT

Sensitivity	0.99
Specificity	0.61
Positive Predictive Value	0.99
Negative Predictive Value	0.68
Likelihood Ratio +	2.52
Likelihood Ratio -	0.02
False Positive Rate	0.39
False Negative Rate	0.01
Probability or Prevalence of disease	0.97
Overall Accuracy	0.98

DISCUSSION

Although the validity of CT in the diagnosis of acute appendicitis is well established [3,4,7] its appropriate utilization continues to be a topic of debate. Should CT be used mandatorily, selectively, or not at all in the work up of acute appendicitis? A review of the literature reveals inconsistent and sometimes conflicting data. While many previous studies report an improved overall negative appendectomy rates with the use of CT, most find the benefit limited to a specific age group or gender, while few report no benefit at all. Despite not having an established protocol for the work up of acute appendicitis, 86% of our 940 patients received a CT scan. The overall negative appendectomy rate at our institution over the 5 year study period was 4.2%, a rate considerably lower than the traditionally accepted 15 to 20%. The

negative appendectomy rate was significantly lower for the CT group compared to the non-CT group (3.4% vs 9.4%, p = 0.007). Studies with similar findings are abundant. A multicenter retrospective review by Kim, *et al.* revealed an inverse relationship (rho = - 1) between the utilization of CT and the overall negative appendectomy rate (20.6% vs 6.6%, p < 0.05) [12]. Guss, *et al.* reported a decrease in the overall negative appendectomy rate (15.5% vs 7.9%, p = 0.001) following the implementation of a protocol which included CT [13]. Jones *et al.* also found a correlation between increased utilization of CT (52% in 2000, 74% in 2001 and 86% in 2002) and progressively lower negative appendectomy rates (17% in 2000, 9% in 2001 and 2% in 2002) [14]. Similarly, Lee, *et al.*, who randomized patients into mandatory or selective CT groups, found the overall negative appendectomy rate to be significantly lower in the mandatory group (2.6% versus 11.3%, 95% CI = -3.5, 26.3) [10]. Unique to our series however, was that the negative appendectomy rate did not differ significantly by gender (Fishers exact test, p = 0.491). No difference was noted in the overall negative appendectomy rate by gender in the CT (Fishers exact test, p = 1.00) or non-CT group (Fishers exact test, p = 0.75), and similarly no difference was noted by age (CT p = 0.14, non-CT p = 0.26). This is in contrast to many studies which fail to categorize patients as homogenous, receiving uniform benefit from CT regardless of age or gender. DeArmond, *et al.* compared negative appendectomy rates before and after the ready availability of CT at his institution [2]. Data revealed a lower overall negative appendectomy rate in the CT group (14% vs 7%, p < 0.005), a benefit statistically significant only in males ages 13 to 50 (11% vs 3%, p < 0.01) [2]. A trend towards improved negative appendectomy rates in females ages 13 to 50 was noted (23% versus 14%, p = 0.07), but did not reach statistical significance [2]. McCorry, *et al.* who did not find CT to influence the overall (8% vs 9.4%, p = 0.36) or male (6.1 vs 6.0, p=0.84) negative appendectomy rate, found the utilization of CT improved the negative appendectomy rates only in females (13.7% vs 10.2%, p = 0.02), more specifically those ages less than 5 (0% vs 15%, p = 0.003) and greater than 45 (9.3% vs 15%, p = 0.001) [3]. Contrary to these reports, our data supports the routine use of CT in all patients regardless of age or gender.

Concerns have been raised regarding the additional time required to obtain a CT and whether it could negatively impact outcomes by delaying definitive management or imposing risks inherent to CT such as contrast related allergic reactions or oral contrast aspiration during anesthetic induction. Jones, *et al.*, found that despite the increase use of CT, average emergency room work up time was not significantly greater and the perforation rate declined from 25% to 9% [14]. Frei, *et al.*, who investigated the consequences of increased CT utilization in the work up of acute appendicitis during a seven year period (12.3% in 1998 to 84.4% in 2004, p = 0.001), found that the mean time to surgery was statistically greater (p = 0.001) during the last four years as compared to the first three [19]. Despite the longer time to surgery, a significant decline in the overall complication rate, defined as perforations, gangrene, or abscess, was noted (33% in 1998 vs 21.3% in 2004, p = 0.002) [19]. While in our series the mean time to complete a CT was 4.3 hours, we do not know whether or not it was associated with increased

emergency room work up times or longer times to surgery. We can however ascertain from our data that although not statistically significant, our CT group experienced a lower perforation rate than its non-CT counterpart (9.5% vs 12.6%, $p = 0.33$), and the rate of gangrenous (8% vs 5.5%, $p = 0.47$) and acute appendicitis with abscess (1.3% vs 0%, $p = 0.37$) were also not found to be significantly different. Furthermore, the length of stay of the CT and non-CT group were similar (3.67 vs 3.63 days, $p = 0.92$) making us strongly suspect that the additional CT related 4.3 hours did not negatively impact outcomes. In addition, although not reported in our statistics, we did not identify any CT related adverse reactions.

Eight hundred thirteen CT scans were obtained during the work up 940 patients who underwent surgery for acute appendicitis. Of the CT scans obtained, the sensitivity, specificity, negative predictive value, and positive predictive value was 99%, 61%, 68%, and 99%, with an overall accuracy of 98%. These findings are comparable with those reported by earlier series [3,4,7]. Because our cohort only includes patients who underwent surgery we concede to the possibility that we potentially underestimate our false negative rate by excluding patients with negative CT scans who were erroneously discharged home. However, given the known validity of CT, our institutions CT protocol established to limit non-diagnostic studies, twenty-four hour radiology attending availability, and the mandatory examination of all patients presenting with abdominal pain by a senior surgical resident, we believe very few patients, if any at all presenting with appendicitis, would not have been captured.

CONCLUSIONS

The use of CT in the work up of acute appendicitis is associated with decreased negative appendectomy rates regardless of age and gender, and without any obvious untowardly affect on outcomes. In light of this we recommend that whenever possible a CT should be obtained for all patients presenting with abdominal pain in whom the diagnosis of acute appendicitis is considered. Traditional teachings tolerating 15% to 20% negative appendectomy rates should be abandoned, and 4% adopted as a more acceptable standard. A large, randomized controlled study may need to be conducted in order to either validate our recommended mandatory approach or justify one which is more selective. In addition, cost analysis might be necessary to decide upon the necessity of performing a CT scan prior to appendectomy.

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