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Original Contributions

IMPACT OF ABDOMINAL HELICAL COMPUTED TOMOGRAPHY ON THE RATE OF NEGATIVE APPENDICITIS

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□ **Abstract—Helical abdominal computed tomography (HCT) is a common test in the evaluation of patients with presumed appendicitis. Studies have demonstrated HCT to have high sensitivity, specificity, and positive and negative predictive value. Despite this, there has not been consistent demonstration that HCT has had beneficial effect on patient outcome. The objective of this study was to assess the impact of HCT on patient outcome as measured by the rate of negative appendicitis and perforated appendicitis. Patients were identified from a pathology department database that included all patients taken to the operating room with a pre-operative diagnosis of appendicitis. Pathologic specimen analysis was used to determine the presence of appendicitis and perforation. Two periods were studied: Period A, a 4-year interval before the arrival of HCT; and Period B, a 3-year period several years after the incorporation of HCT into the evaluation of suspected appendicitis. Primary outcome measures were the rates of negative appendicitis and perforated appendicitis. During Period A, 316 patients were identified; 12% had conventional computed tomography, none had HCT. The negative appendicitis rate was 15.5%; the perforated appendicitis rate was 11.6%. During Period B, 477 patients were identified; 81.5% had HCT. The negative appendicitis rate was 7.9%; the perforated appendicitis rate was 14.4%. The difference in negative appendicitis rates was 7.6% (3.0%, 12.4%), and in perforated appendicitis it was −2.8% (95% CI −8.0%, 2.1%). At the study institution, there was a 48% decrease in the rate of negative appendicitis encountered in association with the common use of HCT.** © 2008 Elsevier Inc.

□ **Keywords—appendicitis; helical computed tomography**

INTRODUCTION

Appendicitis is the most common operative surgical problem presenting to the Emergency Department, with about 250,000 cases occurring annually in the United States (1). Although classic descriptions of the symptoms and clinical signs of appendicitis abound in all medical texts, an accurate diagnosis of this disease remains difficult. The challenge of timely and accurate diagnosis is reflected in historical negative appendicitis rates at the time of laparotomy ranging from 10% to 50% and perforation rates over 20% (2–4). Over the last 10 years, there have been numerous studies reflecting on a variety of imaging modalities and their utility as adjuncts in the evaluation of patients with suspected appendicitis. Both helical computed tomography (HCT) without and with contrast and ultrasonography have been demonstrated to perform well from the perspective of sensitivity, specificity, and positive and negative predictive value (5). More important than these test characteristics is whether deployment of these diagnostic modalities has had a positive impact on patient outcome. All tests have potential for adverse events. Although concerns related to ultrasound would seem to be limited to cost, HCT can be costly, and when intravenous contrast is used, may be associated with allergic reactions and compromised renal function. Furthermore, abdominal HCT does expose the

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patient to ionizing radiation. Although the risk of radiation from a single study is probably quite small, it can become significant in younger patients and pregnant females, and for patients who have multiple studies over an extended period (6–9).

One important patient outcome measure that is readily identifiable for patients with suspected appendicitis is the rate of negative appendicitis at the time of surgery. Most would agree that if a diagnostic test could avert unnecessary surgery, this benefit could offset the cost and the limited risks associated with the test. A limited search of the medical literature reveals a considerable number of publications related to the issue of negative appendicitis rates and HCT, however, the conclusions have often been disparate. Many studies demonstrate dramatic decreases in negative appendicitis rates, with a comparable number indicating no benefit (2,3,10–20). The reasons for this discrepancy are speculative and probably related to several factors. Some studies have utilized historical controls for comparison, whereas others have compared patients undergoing computed tomography to those taken directly to the operating room rather than cohorts managed with and without HCT.

At the authors' study institution, helical computed tomography was initially introduced in 1996 as part of a study protocol. Use of HCT has since become standard practice in the diagnostic evaluation of suspected appendicitis. The decision to image a patient with HCT and the use of contrast agents is at the discretion of the evaluating physician. We chose to examine the rates of negative appendicitis in all patients taken to the operating room with a pre-operative diagnosis of appendicitis during a time period before the introduction of HCT and compare it to a time period several years after introduction of HCT. This study approach should limit the number of co-variables not accounted for, hence providing for a more realistic "apples to apples" comparison.

METHODS

Setting

The study was conducted at an academic medical center with a residency in Emergency Medicine and all other major specialties.

Design

This was a retrospective study comparing all adult patients (age $\geq$ 18 years) taken to the operating room with a pre-operative diagnosis of appendicitis. We chose to look at adult patients only due to a change in the character of the hospital population between the two study periods resulting from the discontinuation of in-patient pediatric services. Period A, 1990–1994, ended 1 year before the arrival of the study institution's HCT. Period B, 2001–2004, was during a time interval when the use of HCT had become an established part of the diagnostic armamentarium in the evaluation of suspected appendicitis. Subjects were identified from a Pathology Department database that contained the names and hospital identifiers of all patients taken to the operating room with a pre-operative diagnosis of appendicitis, along with post-operative specimen evaluations. Data collected from the database included patient gender, age, and post-operative pathology findings. A separate search of each patient's medical record was conducted to determine if the patient had abdominal HCT scan before surgery. Negative appendicitis was defined as a normal appendix by pathologic report. Cases of perforated appendicitis were identified from these same pathology reports. Patients with incidental appendectomy were not included.

The rate of negative appendicitis and of perforated appendicitis was determined for each time period and these were the primary outcome variables. Patients in both study periods were compared with respect to gender and age. Categorical variables, gender, and proportion of negative appendicitis were compared with two-sided Fisher's exact test. The continuous variable of age was compared using Mann-Whitney test due to non-normal distribution of patient ages. Statistical significance was set at $p \leq 0.05$.

The Human Research Protection Program of the study institution approved this study.

RESULTS

During Period A, 316 patients were identified: mean age 33.2 years (SD 12.7), 201 (63.6%, 95% confidence interval [CI] 58.2–68.7) men. During Period B, 477 patients were identified, mean age 35.5 years (SD 14.0), 276 (57.9%, 95% CI 53.4–62.2) men (Table 1). During Period A, 12% of the patients had a conventional (non-HCT) abdominal computed tomographic (CT) study before surgery; none had HCT scan. During Period B, 389 patients (81.5%) had HCT scan before surgical intervention. The number of patients without appendicitis at the time of surgery and the rates of negative appendicitis along with rates of perforated appendicitis are summarized in Table 1. The rate of negative appendicitis decreased during Period B by an absolute amount of 7.6% (95% CI 3.0–12.4%). The rate of perforated appendicitis increased during period B by an absolute amount of 2.8% (95% CI −2.1–8.0).

Table 1. Comparison of Pre-HCT to HCT Periods on Rate of Negative Appendicitis

Category	Period A	Period B	p Value
Number	316	477	
Men (%)	63.6	57.9	0.12*
Mean age, years (SD)	33.2 (12.7)	35.5 (14.0)	0.051†
Percent standard CT scan	12	0	
Percent helical CT (HCT) scan	0	81.5	
Number positive appendicitis	267	439	
Number negative appendicitis	49	38	
Percent negative appendicitis	15.5	7.9	<0.001*
Percent perforated appendicitis	11.6	14.4	0.37*

* Fisher's exact test.
† Mann-Whitney test.

DISCUSSION

In this retrospective study at a single institution, several years after the introduction of HCT as a tool in the evaluation of patients with suspected appendicitis, the use of the modality has became very common. There is no formal protocol for the use of contrast agents, and our patients were evaluated without contrast, with i.v. contrast, and with i.v. and oral contrast as dictated by the judgment of the managing physicians. The use of rectal contrast was very infrequent. In the HCT group, 148 (38%) patients had noncontrast studies and 62% had some form of contrast (i.v., i.v. and oral) administered. The deployment of this imaging technique was associated with a 48% decrease in the rate of negative appendicitis. The characteristics of the patient populations during the two study periods with respect to age and gender were not significantly different; however, there was a non-statistically significant greater percentage of women in Period B and the patients were slightly older. The reasons for this shift in patient demographics are not readily apparent. Furthermore, the number of patients with appendicitis was larger in a shorter time frame of period B as compared to period A. This may in part be a consequence of increased Emergency Department and hospital census, which was lower during period A; however, precise census figures were not available.

Coincident with the decrease in negative appendicitis rate, there was a slight increase in the rate of perforated appendicitis. The confidence interval for the difference in perforated appendicitis crossed unity and therefore may not be significant. However, an increase in this complication might offset the benefit associated with reduced negative appendicitis rates.

The findings in this study are similar to a number of others that have demonstrated similar decreases in the rate of negative appendicitis attributed to the use of HCT (2,3,10–13). Our findings are in contrast to studies in which there was no significant decrease in the rate of negative appendicitis reported (16,18–20). In the study by Flum et al., patients were collected from a Group Health Cooperative during a period spanning from 1980 to 1999 to determine the rate of negative appendicitis over time (16). Their reported rate of negative appendicitis overall was 15.5%, without decrease over time. In the final year of the study, only 40% of the patients had either HCT scan or ultrasound as part of their preoperative evaluation. Several things stand out in this study that may explain the discrepancy with the findings in our study. First is the relatively low rate of preoperative imaging in the latter years of the study and the admixture of both HCT and ultrasound data. Second, the reported sensitivity for HCT in their study was 88.3%, which is significantly lower than the average 92–97% rate commonly reported (5,21–23). Finally, their investigation likely included only a limited number of years during which HCT was performed. Based upon a study we conducted utilizing a cohort of patients with suspected appendicitis collected in the first few years after deployment of HCT, there is evidence to suggest that the radiologists become more proficient with the interpretation of the images and the surgeons become more comfortable with the readings over time (15). Martin et al. investigated the impact of HCT on a pediatric population (18). In their study, HCT use increased from 17.3% of patients to 51.3%. There was no reported significant decrease in the negative appendicitis rate over this period of time, however, ultrasound and HCT were both used in this patient population. Furthermore, the time period studied spanned only 3 years, 1998–2001, and HCT was used throughout the study period, albeit with increasing frequency in the latter years. McDonald and associates reported their experience at the University of Tennessee Medical Center (19). They retrospectively looked at patients before and after 1998 who went to the operating room with a diagnosis of appendicitis. They found a small decrease in the rate of negative appendicitis, from 15.1% to 13.3%, that did not reach statistical significance despite a 400% rise in the use of HCT. This study did not directly compare HCT use in the specific patients taken to the operating room during the two time periods, but rather compared more general HCT utilization during the two time periods and then separately analyzed the outcomes of the patients taken to surgery for presumed appendicitis. When they compared patients taken to surgery with pre-operative HCT to those without HCT, there was a significant decrease in negative appendicitis rate. A report from the University of California, Davis

suggested that HCT was not associated with any decrease in rate of negative appendectomy (20). In this retrospective study, patients undergoing HCT were compared to those who did not receive this imaging technique, and only 6% of patients undergoing appendectomy had HCT. Despite this, the rate of negative appendicitis in the HCT group was 12.9% vs. 15.5% in the non-HCT group.

Although the present study reflects the experience at a single institution, the rate of negative appendicitis, 15.5% in the pre-HCT group, is remarkably similar to the baseline rates reported in numerous other studies that demonstrated a decrease, as well as those with no reduction. This would suggest some similarity between study institutions with respect to overall accuracy of evaluation before or without the common use of HCT.

A sub-analysis of Group B patients found a negative appendicitis rate of 11.7% in the patients not imaged, as compared to 7.2% in the group imaged with HCT ($p = 0.19$). However, there may be significant differences in the patient population between these two groups and this limits the utility of this comparison. Patients selected for imaging are likely different with respect to clinical presentation from those taken directly to the operating room. Nevertheless, the reduction in group B patients imaged with HCT to 7.2%, and the overall negative appendicitis rate of 7.9% does suggest that it was the common use of this imaging modality and not some other unidentified change in the management of patients with suspected appendicitis that was associated with the statistically significant overall decrease in the rate of negative appendicitis.

LIMITATIONS

This was a retrospective study and, as such, is at risk for incomplete data acquisition. In this particular circumstance, the key data elements were all readily available and no patients had to be excluded for incomplete data collection. Although just short of pre-defined statistical significance, patients in Period B were slightly older and there was a slightly larger percentage of women. Considering that other studies suggest that increasing age and female gender are risk factors for negative appendicitis, it was not felt that these demographic differences would mitigate the finding of a significant decrease in negative appendicitis rate identified in this investigation (10,11,24,25).

The greatest concern in this type of before-and-after study relates to other co-variables that may have been introduced over the relatively large time period considered. One major change that is known to have occurred during this interval was the increased use of laparoscopic appendectomy. Although the use of this intervention was not measured in this study, it was apparent that many more patients were managed with laparoscopic approach during Period B than Period A. Thoughtful consideration of the consequences of this surgical approach does not suggest it would lead to a reduction in negative appendicitis rates, as this less invasive approach should lower, not raise, the threshold for surgical intervention. This impression is endorsed by the findings in a study by Nguyen and colleagues that failed to identify any decrease in the rate of negative appendicitis in association with the increased use of laparoscopic appendectomy (4). Data were not available to assess differences in other potential covariables that might have affected outcome, such as consideration of alternate diagnoses, consultation of other specialists such as Obstetrics and Gynecology for female patients, administration of empiric antibiotics, and other imaging studies (i.e., ultrasound or plain radiography).

The study design did not allow for the determination of missed appendicitis rates. Therefore, it remains a possibility that the use of HCT may have resulted in a change in the rate of missed appendicitis. It should also be noted that the study design is consistent with an association between common use of HCT and a decrease in the negative appendicitis rate in period B, but does not allow for a causal relationship to be defined.

Finally, although the decrease in the negative appendicitis rate is dramatic, time from presentation to operation was not measured. It is possible that the decrease in negative appendicitis rate in the HCT era occurred at the expense of delay to operative intervention. The most serious consequence of operative delay could be an increase in the rate of perforated appendicitis. Although the rate did tend to increase during the HCT era, this increase was not statistically significant. Although operative delay cannot be excluded as a consequence of common use of HCT, there is no evidence that it led to a meaningful increase in the most common complication of appendicitis, perforation.

CONCLUSION

At the study institution, there was an absolute decrease of 7.6% or a relative decrease of 48% in the rate of negative appendicitis in association with the common use of HCT. During the same time interval, there was a non-statistically significant increase in the rate of perforated appendicitis. The decrease in the negative appendicitis rate is compatible with other studies and is disparate from those that suggest that common use of HCT does not favorably impact the rate of negative appendicitis. Although the current study does support the liberal but selective use of

HCT as an adjunct in the assessment of patients with suspected appendicitis, it does not prove that doing so will reduce the rate of negative appendicitis at the time of surgery. Our findings are consistent with an association between common use of HCT and a decrease in the negative appendicitis rate at our institution, however, study design precludes a true causal relationship to be defined. Trends in perforated appendicitis rates should be monitored to assure this complication does not emerge as an unintended consequence of liberal HCT use.

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