Computed Tomography and Ultrasonography in the Diagnosis of Appendicitis

When Are They Indicated?

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Hypothesis: Relative merits and indications exist for ultrasonography (US) and computed tomography (CT) in the diagnosis of appendicitis.

Design: Prospective study.

Setting: General community and tertiary care hospital.

Methods: Ninety-nine patients (50 males and 49 females) were studied. Following consent, the initial disposition was recorded, designating the patient for operation, observation, or discharge from the hospital. Each patient was studied by CT and US. Studies were independently evaluated by 2 radiologists, and the results were designated as positive, negative, or equivocal. The surgeon reevaluated patients before and after learning the results of US and CT, recording whether the CT scan, US, or reexamination influenced the final disposition.

Results: Fifty patients had appendicitis; 6 appendixes were perforated. The initial clinical impression called for 44 operations, 49 observations, and 6 discharges. Thirty-four patients had their treatment plan changed from the initial disposition. Ultrasonography did not affect the initial impression. In contrast, 18 patients were rediagnosed solely on CT scan findings. Seven patients were rediagnosed by reexamination. Of 44 patients initially designated for operation, the CT scan and reexamination spared 6 females from surgery; the negative appendectomy rate potentially decreased from 50% to 17% ($P=.03$). The CT scan, US, or reexamination failed to spare 2 males from exploration with negative results. Of the 49 patients initially designated for observation, 23 were rediagnosed after reevaluation, 13 were discharged from the hospital, and 10 underwent expedient operation. One patient was spared from inappropriate discharge from the hospital. The reliability of the CT scan was good, with high sensitivities and specificities. Equivocal scan results lowered the diagnostic value.

Conclusions: Selective use of a CT scan with a second examination can improve the diagnostic accuracy and management of suspected cases of appendicitis by (a) reducing the negative appendectomy rate in females, (b) moving patients from observation to earlier operation or discharge from the hospital, and (c) preventing inappropriate discharge of patients with appendicitis.

PATIENTS AND METHODS

The research protocol and pathway were approved by the institutional review board (Figure 1). All patients receiving a surgery consultation for acute appendicitis were included in the prospective study. Patients were excluded if they refused consent; had diffuse peritonitis; were physiologically compromised, requiring immediate operation; were pregnant; or were nursing. All patients were evaluated by the surgical team, including an initial clinical history, a physical examination, and a routine laboratory workup.

One hundred four patients were evaluated for study enrollment, with 99 patients (or their guardians) (50 males and 49 females) providing consent and becoming enrolled. The mean age of the 99 patients was 27 years (range, 4–81 years). Six percent of the cases were perforated. The negative appendectomy rate was 10%. Patients designated for operation underwent laparoscopic or open appendectomy according to the surgeon’s preference. Operative and pathologic findings were recorded and compared with the previous clinical impression, the surgeon recorded which tests changed the diagnosis: the CT scan, US, and a second physical examination via the study pathway averaged 161 minutes (range, 42–365 minutes).

A senior resident who was managing the case was responsible for having the initial clinical impression recorded, designating the patient for operation, observation, or discharge from the hospital. All patients then underwent limited pelvic CT with rectal contrast and right lower quadrant US. The results of these 2 studies were independently evaluated by an experienced resident or staff radiologist. When recording the results of each test, the radiologist was blinded to the results of either test. The radiologist designated the test results as follows: appendicitis, equivocal test, or not appendicitis. These results were sealed in separate envelopes and returned to the surgical management team.

The surgical management team then rerecorded a clinical evaluation before opening the CT and US results to determine if the diagnosis had changed during the time taken to perform the 2 tests. The results of both studies were then revealed and the surgical team reevaluated the patient, using the test results to determine if the diagnosis had changed. If the pathway disposition changed from the previous clinical impression, the surgeon recorded which test or tests changed the diagnosis: the CT scan, US, or the second examination.

Patients designated for observation were followed up clinically during admission to the hospital and operated on or discharged from the hospital when deemed appropriate by the surgical team. Patients discharged from the hospital were followed up for correctness of diagnosis by telephone contact at 1 and 7 days. Statistical comparisons were made using the McNemar test for correlated proportions.

Patients from observation to either operation or discharge from the hospital (4 underwent operation and 12 were discharged). Thus, the study pathway of a CT scan, US, and a second examination resulted in a significant improvement from the initial clinical impression to the final disposition.

In total, the initial impression to operate on, observe, or discharge the patient was changed in 34 of the 99 study patients. The results were reviewed to determine which studies were responsible for changing the initial impression. The results of the CT scan alone affecting the diagnosis in 26 (76%) of these 34 patients, with the CT scan alone changing the diagnosis in 18 (53%) patients. In comparison, the second examination rediagnosed 12 (35%) of the 34 redesigned patients, with the second examination alone changing the diagnosis in 7 (21%) patients. In contrast, US rediagnosed 5 (15%) of the 34 patients but did not change the diagnosis independently in any patients. The combination of a CT scan and a second examination changed the diagnosis in 4 (12%) patients, and a CT scan and US together changed the diagnosis in another 4 (12%). A second examination and US results redesignated 1 patient (3%). Thus, the CT scan and the second examination were the most important arms of the pathway that affected the final disposition.

Table 2 compares the limited pelvic CT scan and US test results of the study population. A CT scan failed to diagnose 2 cases of appendicitis (false negatives) and overdiagnosed 3 patients (false positives). The results of the CT scan identified an alternate diagnosis in 8 (8%) patients. Six females had tubo-ovarian disease, such as ruptured ovarian cysts or pelvic inflammatory disease. Two males had diverticulitis. There were 28 equivocal scans. The positive predictive value of CT was 92%, and the negative predictive value was 94%. In contrast, the use of US resulted in 75 equivocal tests, with no negative test results. Seven false-positive examinations were
Table 1. The Effect of the CT Scan, US, and a Second Examination on the Initial Impression to Pathway Disposition*

<table>
<thead>
<tr>
<th>Patients</th>
<th>Operate</th>
<th>Observe</th>
<th>Discharge</th>
<th>Operate</th>
<th>Observe</th>
<th>Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (N = 99)</td>
<td>44</td>
<td>49</td>
<td>6</td>
<td>48</td>
<td>33</td>
<td>18</td>
</tr>
<tr>
<td>Those with appendicitis (n = 50)</td>
<td>33</td>
<td>16</td>
<td>1</td>
<td>43</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Those without appendicitis (n = 49)</td>
<td>11</td>
<td>33</td>
<td>5</td>
<td>5</td>
<td>26</td>
<td>18</td>
</tr>
</tbody>
</table>

*Data are given as the number of patients. CT indicates computed tomographic; US, ultrasonography.

Table 2. Sensitivities, Specificities, and Equivocal Results of CT and US*

<table>
<thead>
<tr>
<th>Patients</th>
<th>CT Results</th>
<th>US Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive Scan</td>
<td>Equivocal</td>
</tr>
<tr>
<td>Total (N = 99)</td>
<td>36 (36)</td>
<td>28 (28)</td>
</tr>
<tr>
<td>Those with appendicitis (n = 50)</td>
<td>33 (66)</td>
<td>15 (30)</td>
</tr>
<tr>
<td>Those without appendicitis (n = 49)</td>
<td>3 (6)</td>
<td>13 (27)</td>
</tr>
</tbody>
</table>

*Data are given as the number (percentage) of patients. Percentages may not total 100 because of rounding. The sensitivity and specificity of the computed tomography (CT) results were 94% and 92%, respectively (when equivocal results were included, 66% and 67%, respectively). The sensitivity and specificity of the ultrasonography (US) results were 100% and 0% (when equivocal results were included, 34% and 0%, respectively).

declared by the radiologists. Therefore, the sensitivity was 100% when equivocal tests are excluded from the calculation. The positive predictive value of US was 71%, and the negative predictive value was not calculable because of a lack of negative test results.

Of the 44 patients who were initially designated for operation, only 33 (75%) actually had appendicitis. The CT scan and the second examination moved 8 patients (18%) from operation; the final pathway disposition reassigned 7 patients to observation and 1 to discharge from the hospital. Thirty-eight patients (86%) underwent operation; 2 redesigned patients to observation were eventually operated on. Of the patients operated on, 33 had appendicitis and 5 did not, which is 11% of the original 44 patients. Thus, the negative appendectomy rate decreased from a potential of 25% to 11%, which was statistically significant ($P = .03$). The pathway spared 6 patients from unnecessary surgery.

Of the 26 males initially designated for operation, 24 (92%) had appendicitis and 2 (8%) did not. One male with appendicitis was moved from operation to observation because of an equivocal CT scan but then was operated on after observation. Therefore, all 26 males underwent operation despite the CT scan and a second examination. The pathway did not change the surgeon's mind in this group. The negative appendectomy rate remained at 8%. This is in striking contrast to 18 females who were initially designated for surgery. Nine (50%) of these females had appendicitis and 9 (50%) did not. Seven females (39%) who did not have appendicitis were moved from an initial plan to operate. The final pathway disposition called for 6 females to be observed and for 1 to be discharged from the hospital. One observed female eventually underwent an exploration (which had negative results). Six (86%) of these 7 rediagnosed females were spared unnecessary surgery. Twelve females (67%) went to the operating room; 9 had appendicitis and 3 did not (17% of the original 18 females). Thus, in females, a CT scan and a second examination reduced the negative appendectomy rate from a potential of 50% to 17%, which was statistically significant ($P = .03$).

Of 49 patients initially designated for observation, 16 (33%) had appendicitis and 33 (67%) did not. Twenty-four patients (49%) were redesignated from observation to either operation or discharge from the hospital. This was because of a CT scan in 16 patients, a second examination in 1, and a CT scan and a reexamination in 7. Of these 24 patients, 23 experienced an improvement in the diagnosis as a result of the study pathway. Ten patients with appendicitis were redesignated to operation. Thirteen patients without appendicitis were appropriately discharged from the hospital and spared unnecessary prolonged hospital observation. Twenty-one patients (43%) underwent surgery: 16 had appendicitis and 5 had a negative exploration.

There were 21 males initially designated for observation: 8 (38%) had appendicitis and 13 (62%) did not. Twelve males (57%) were redesignated from observation by the study pathway. 7 with appendicitis went to the operating room and 5 without appendicitis were discharged from the hospital. Eleven males (52%) underwent an operation: 8 had appendicitis and 3 did not. In comparison, 28 females were initially designated for observation: 7 (25%) had appendicitis and 21 (75%) did not. Twelve females (43%) were reassigned from observation. Three of these females with appendicitis were operated on, and 8 without appendicitis were discharged early from the hospital. One female without appendicitis received surgery owing to a false-positive CT scan. Ten females (36%) underwent surgery: 8 had appendicitis and 2 did not.

Only 6 of 99 patients initially were designated for discharge from the hospital. One patient (17%) had appendicitis. Two patients (33%) were redesignated from discharge from the hospital by the pathway to observation or operation. One patient without appendicitis was
observed in the hospital and then discharged. One male with appendicitis was redesignated to operation by a positive CT scan result and spared from inappropriate discharge from the hospital with perforated appendicitis.

**COMMENT**

The diagnostic accuracy of US has been reported to range from 71% to 97%, while that of a CT scan has been reported to range from 93% to 98%. Wade et al, in a prospective study, compared US with the surgeon's clinical impression. Ultrasonography was deemed to be statistically superior to clinical evaluation even though false-negative test results were observed. The researchers concluded that US could not replace clinical evaluation. Ramachandran et al reported similar findings in children. They noted an accuracy of 95% and concluded that US was a useful adjunct.

A recent prospective study by Rao et al of limited pelvic CT with rectal contrast concluded that routine use of CT improves patient care and reduces the use of hospital resources. Computed tomographic markers noted in appendicitis are associated with varying degrees of sensitivity and specificity. Rao et al showed that finding an enlarged (>6-mm) unopacified appendix was 93% sensitive and 100% specific for appendicitis. In comparison, fat stranding was 100% sensitive and 80% specific. Other findings, such as appendicoliths, dependent fluid, abscesses, extraluminal air, or phlegmon, were all specific but not sensitive. One prospective study compared the accuracy of CT with that of US directly, and found CT to have an accuracy of 94% compared with 83% for US. All of the previously reported prospective studies appear to have introduced a selection bias by enrolling patients only at the determination of the consulted surgeon.

Despite supporting evidence advocating the use of US and CT in the diagnosis for appendicitis, the routine use of these tests is not well established. Concern exists that the overuse or reliance of radiographic tests may distract from careful and timely clinical evaluation and not add significantly to establishing the diagnosis. This healthy skepticism stems from a lack of prospective studies that identify the indications for use, relative merits, and cost-effectiveness of these tests. This prospective trial establishes how these tests should be used in a clinical pathway to improve the diagnostic accuracy and cost-effective treatment in all cases of suspected appendicitis.

Computed tomography combined with clinical re-examination can assist in the diagnosis of acute appendicitis; however, the routine use of a CT scan, as suggested by some researchers, cannot be supported by this study. In fact, the results indicate that, to the contrary, males evaluated by a surgeon who determines that the patient needs an operation should not undergo a CT scan. In contrast, the negative appendectomy rate in females is significantly improved by the addition of a CT scan in conjunction with clinical reevaluation. In this study, the negative appendectomy rate declined from a potential of 50% to 17%, strongly suggesting the use of a CT scan in females before operation. In males and females who are designated for observation, a CT scan and a second examination can expedite the care in nearly half of these patients, reassigning them to either the operating room or discharge from the hospital. Moreover, a CT scan is of benefit in preventing the inappropriate discharge of patients with acute appendicitis.

It is significant to recognize that by obtaining these radiographic tests, a short period elapsed (mean, 2.7 hours), which allowed for clinical reexamination in association with the test results. This period was not detrimental to the patient and in some cases actually resulted in a more accurate diagnosis. In 7 patients, a second examination alone changed the surgeon's mind. In comparison, a CT scan helped rediagnose 26 patients, and the surgeon's mind was changed based solely on the CT scan results in 18 patients. However, US only helped rediagnose 5 patients and did not change the surgeon's diagnosis in any cases.

The sensitivities and specificities of CT and US in this study are lower than those reported, since equivocal test results were considered in the statistical comparison. It appears that previous studies may have excluded equivocal tests from the results to increase the sensitivity and specificity rates of the tests. Moreover, retrospective studies appear to have an inherent selection bias, which tends to affect the accuracy of the test. Of the few prospective studies published, most are difficult to apply to the average community hospital setting since the tests are evaluated by a CT or US radiology specialist. The strength of this study is the fact that the results were evaluated by radiologists with a broad range of experience. This more closely represents the common clinical setting. It is probable that the disappointing US results in this study more closely reflect the methods used to perform this test in the average hospital. In our hospital, US was performed by a US technician without a radiologist being present. The radiologist's impression is based solely on interpretation of the printed films. Other studies suggesting better diagnostic results more than likely represent direct involvement of the radiologist in performing the US examination.

The cost-effectiveness of the study pathway was compared with that of standard observation of patients in the hospital. The average length of observation was 1.6 days in patients without appendicitis. The direct costs of observed patients in the hospital during the study period was $1095 per patient or $695 per day. The approximate direct cost of a CT scan was $200, while the cost of a normal appendectomy was $2250. When comparing the costs related to 18 females initially designated for surgery and considering the fact that a CT scan spared 6 from unnecessary surgery, there was a cost savings of $9900 ($13500 in surgery costs vs the cost of the CT scans at $3600). Of the 23 patients rediagnosed from initial observation, 10 were taken straight to the operating room, which saved at least $6950 in observation costs. Thirteen patients were sent home, which saved at least $9035. This sum is offset by $9800 in CT scans in 49 patients and $2250 for 1 false-negative test result. Moreover, the hospital saved at least $6950 in observation costs. Thirteen patients were sent home, which saved at least $9035. This sum is offset by $9800 in CT scans in 49 patients and $2250 for 1 false-negative test result leading a patient to have surgery. Thus, the net savings of $3935 was experienced in those originally planned for observation. In these groups, at least $13835 was saved in 67 patients, or $206 per patient. Of those initially designated for discharge from the hospital,
1 patient was spared inappropriate discharge—the savings to that patient are incalculable.

In summary, despite the advances in radiographic imaging and reports advocating the routine use of CT in the diagnosis of appendicitis, appendicitis remains a disease requiring surgical expertise. All patients should undergo a complete surgical evaluation before any radiographic studies are ordered.

The protocol used at our hospital is based on the results of the present study (Figure 2). After surgical evaluation, if the patient is male and believed to have appendicitis, he is taken to the operative suite without further study. If the patient is female, a CT scan with a second examination is used. Patients with findings warranting observation are sent for a CT scan. Patients believed not to have appendicitis are discharged from the hospital if the patient lives close to the hospital and is compliant enough to return if symptoms progress. Otherwise, the patient may undergo CT scanning with a second examination before discharge from the hospital to avoid a delay or misdiagnosis. Ultrasonography in our experience is not helpful. Neither US nor CT replaces a physical examination and a second examination, which is always indicated. This study does not support the routine use of CT or US, but suggests that a safe cost-effective pathway requires early participation by the surgeon, clinical re-evaluation of the patient, and, in selected cases, the adjunctive use of a CT scan.

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REFERENCES

self not that I should have ordered one more preoperative test, but rather that I should have not so quickly read Cope's *Early Diagnosis of Acute Abdomen*.

This quote is atypical on one hand for Pickleman and typical for Pickleman on another. It's atypical because it implies a bit of humility. It's typical for another, and that is Pickleman doesn't quite have the facts straight. Jack thinks that his problem is a deficiency in clinical skills. I would contend that he is a superb clinician. There are probably none better. He could read Cope every night and he would still occasionally be fooled by the beast. I contend that it is not a sign of weakness for Jack to order a CT scan in many patients with suspected appendicitis. If he does, he'll be a more complete physician and he'll achieve better outcomes.

In preparing this discussion, I reviewed 6 prospective studies addressing the use of CT scans in patients with appendicitis. Virtually all report a negative appendectomy rate of about 7%. I think this number is better than most of us could achieve armed with only good judgment and a copy of Cope in our pocket.

I have a few simple questions for the authors. Their methods suggest that the “most experienced” radiologist or radiology resident read their CT scans. Do they know what the breakdown was of radiologists vs residents, and were they able to detect any difference in the rate of false-negative or false-positive CT scan reads in these 2 categories? My second question comes from my bias against laparoscopic appendectomy. Laparoscopic appendectomy costs more than open appendectomy, does not significantly improve the length of stay, and is no safer. Its only advantage is its ability to inspect the entire abdomen. Young women with gynecologic problems, fat people with sigmoid diverticulitis or cecal diverticulitis, or people with Crohn's disease are not helped by an appendectomy via right lower quadrant incision. Laparoscopy might obviate that circumstance. However, so will an abdominal CT scan. I believe the availability of abdominal CT scans by clarifying the true pathology eliminates the one possible reason to advocate laparoscopic appendectomy. Do the authors have any opinions regarding the role of laparoscopy in patients with normal CT scans?

Finally, I have a question about the technique of CT scan. Our radiologists insist on performing CT scans with oral and IV [intravenous] contrast, an ordeal that adds an hour to the exam. Do you have any experience or opinion regarding the relative merits of the technique you use vs the technique I am burdened with?

Terry M. Gilliland, MD, Denver, Colo: I want to congratulate the authors on a great job with a difficult question: should we use CT scan to improve our diagnosis and treatment of presumed appendicitis? Having conducted a prospective randomized trial using CT scan for appendicitis, I’ve come to the conclusion that the problem with CT scan for appendicitis is not its sensitivity or specificity; it’s the equivocal CT scan, which occurred 28% of the time in this study. I was wondering if the authors can comment about why their equivocal CT scan rate is several times what’s generally reported in the literature.

The second question I have is how those equivocal CT scans were represented in the 3 different groups, that is, did the patients who were observed have a higher tendency to have equivocal scans? If they were, we are left with the uncomfortable conclusion that CT scan provides less diagnosis benefit in patients who would seem to benefit the most from a definitive CT scan.

**James E. Goodnight, Jr, MD, PhD, Sacramento, Calif:** I certainly admire the authors’ utilization of a clinical pathway to try to evaluate the efficacy of this modality. And I may not have fully understood the pathway. Are the patients moved to observation or admission essentially at the same time irrespective of the pathway or are there differing times in the ER? Meaning that if there are different amounts of time in the ER, then those ER costs should be included in the cost-effectiveness.

**David R. Farley, MD, Rochester, Minn:** I would like to ask the authors if the radiologists were blinded by the patient scenarios? Meaning, did they know that the patient was febrile, ill, or was there a hungry surgical intern looking for an appendectomy later that night telling the radiologist about the patient and affecting their interpretation?

**Hung Ho, MD, Sacramento:** I certainly agree with the authors that ultrasound is no match for CT scan as a diagnostic modality in the patient with suspected acute appendicitis. In a test when 75% of the time ultrasound can’t even tell us what the problem is, and the specificity is practically zero, when would you still consider using it, or is it time that we should make a recommendation not to even bother with ultrasound?

**Dr Smith:** Answering the audience’s questions first, our equivocal rate for CT interpretation was higher than in some of the other studies. I think there are 2 reasons for this. One is that there is a learning curve for the radiologists in terms of interpreting the CT scan. Additionally, we didn’t give the radiologists a choice to have more than 3 diagnostic categories. If you look at Dr Rao’s study from Massachusetts General Hospital, they had different diagnostic categories that the radiologists could place the CT scan results in. The equivocal CTs were more prevalent in the observation group as expected. The radiologists were blinded to the clinical situation of the patient completely. In terms of the ultrasound, our ultrasound results were not as good as some previously published reports. As you might predict, the ultrasounds were done by technicians without the radiology resident or staff person being present. We would suggest that ultrasound may play a role if it were surgeon directed and we could become more proficient at ultrasound. I wouldn’t give up on it completely.

With regard to Dr Thirlby’s questions, again, as you might predict, at night the radiology residents read the ultrasound and CT. During the day, it was read by both of them concomitantly. I can’t give you an answer in terms of which radiologist interpreted the false negatives and positives. We only had 5 false scans out of 99, so the numbers are low. The CT scans were thin cut 5-mm pelvic CTs done only with rectal contrast. It doesn’t take very long, about 15 minutes, and there’s good support in the literature that this technique is just as accurate as oral, IV, and rectal contrast. In terms of laparoscopy for diagnosis, that’s not part of our practice. The technique of appendectomy was done at the discretion of the operating surgeon.

In conclusion, CT scans are being performed in emergency rooms without surgical input. Surgeons should be pivotal in the initial clinical evaluation of patients with suspected appendicitis. The surgeon should decide if CT scan is needed. This is the first study to establish a clinical pathway for evaluation of appendicitis utilizing CT scan with repeat exam. We will continue to evaluate our pathway prospectively.