Changing roles of computed tomography in diagnosing acute appendicitis in emergency rooms

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Summary

Background: We used the Taiwan National Health Insurance Database for analysis and statistics to investigate the role of computed tomography (CT) in diagnosing acute appendicitis.

Materials and Methods: All 10 046 patients with acute appendicitis were selected and categorized into two groups based on those who did and did not receive CT 3 days before acute appendicitis diagnosis: non-CT and CT groups. A noteworthy outcome was the incidence of peritonitis within 90 days after diagnosis of acute appendicitis.

Results: The rate of using CT for patients with acute appendicitis increased considerably from 7.9% to 52.9% from 2000 to 2010. The peritonitis incidence rates were 3.54% and 10.7% in the non-CT and CT groups, respectively. Patients who received CT on the same day exhibited a 3.8-fold higher risk of peritonitis than did those in the non-CT group. Those who underwent CT before diagnosis of acute appendicitis exhibited no significant difference of peritonitis risk when compared with those in the non-CT group. The CT group patients were hospitalized 2.19 days longer than the non-CT group patients. Patients who received CT before and on the same day were hospitalized 1.31 and 2.43 days longer than those who did not undergo CT.

Conclusion: Patients who underwent CT exhibited higher risks of peritonitis and longer hospital stays compared with those who did not. Moreover, patients who received CT on the same day of operation exhibited a higher risk of peritonitis than those who underwent CT 1 or 2 days before operation.

Introduction

Acute appendicitis is among the most common diseases accompanied by acute abdominal pain. Traditionally, diagnosing acute appendicitis has relied on clinical symptoms, case history, physical examinations and laboratory tests. Typical clinical symptoms start with periumbilical pain, with accompanying anorexia, nausea or vomiting, followed by migration of pain to the right lower abdominal region within a few hours; the pain then becomes fixed in this region, with tenderness detected on palpation by a physician. The body temperature of appendicitis patients can increase, and hematologic examination can show an increased white blood cell count. Although the
aforementioned presentations are typical, some patients present with atypical clinical symptoms. The Alvarado score system, developed to facilitate the clinical diagnosis of acute appendicitis, has been adopted by some institutions. It contains the following elements or symptoms, with a total score of 10 and one point each for migratory right iliac fossa pain, anorexia, nausea or vomiting, rebound tenderness and fever; leukocytosis and right iliac fossa tenderness are more crucial and receive 2 points; regarding the white blood cell count, a shift to the left (segmented neutrophils) receives one point. Thus, acute appendicitis is unlikely when a patient scores <5 points, whereas patients scoring ≥7 points are likely to have acute appendicitis. However, when a patient scores 5 or 6 points, diagnosis becomes challenging.

Some patients with acute appendicitis require appendectomy as a definitive treatment, either through laparotomy or laparoscopy. Otherwise, patients can develop subsequent complications such as peritonitis and sepsis from a ruptured appendix, which are associated with higher mortality rates. When clinical diagnosis is inaccurate, operation may reveal a normal appendix, or operation may be omitted or delayed, thereby increasing the risks of the aforementioned complications.

Various acute abdominal diseases can mimic the clinical signs and symptoms of acute appendicitis, which may confuse the physician, thereby hindering accurate diagnosis: urinary tract infection, renal colic, gastroenteritis, colonic diverticulitis, epiploic appendagitis, colitis, mesenteric adenitis, Meckel’s diverticulum, colon cancer, ischemic bowel syndrome, intestinal adhesion band, volvulus, Crohn’s disease, ulcerative colitis, pancreatitis, acute cholecystitis and intussusception. In addition, female patients are more prone to additional acute abdominal diseases such as tuboovarian abscess, endometritis, pelvic inflammatory disease, ovarian torsion, dysmenorrhea and ectopic pregnancy. Therefore, accurately diagnosing all such diseases merely based on clinical symptoms, case history, and physical and hematologic examinations is considerably challenging.

Sonography and computed tomography (CT) are the most crucial imaging diagnostic tools. Sonography can identify any lesion exhibiting free fluid collection in the right iliac fossa as well as a dilated appendix. However, ~15% of acute appendicitis lesions cannot be diagnosed using sonography alone. In particular, in patients with excessive bowel gas (with the lesion covered by bowel gas) or in those with thick subcutaneous and intraabdominal fat, sonographic diagnosis is extremely difficult. Occasionally, an inflamed appendix may be present at locations other than the right iliac fossa and can be located in the middle of the abdomen. Furthermore, the inaccurate diagnosis rate can be >15% when the physician or technician performing sonography is inadequately experienced.

The accurate diagnosis rate of CT is higher than that of ultrasound and is less affected by the operator’s experience or technique. According to a study, using CT in diagnosis can decrease the negative appendectomy rate (when the operation reveals a normal appendix during laparotomy or laparoscopy) from 23% to 2%. In recent decades, CT equipment has demonstrated several improvements, such as higher speed to reduce motion artifacts and higher resolution to enhance image quality. Currently, multidetector CT scans can produce high-resolution images within a short duration and provide coronal reconstruction images, thus proving it a useful tool in diagnosing acute appendicitis.

We used the Taiwan National Health Insurance Database for analysis and statistics to investigate the role of CT in diagnosing acute appendicitis. We analysed data recorded from 2000 to 2010 regarding the clinical use of CT for patients diagnosed with acute appendicitis. We evaluated the relationships between CT and peritonitis and between CT and length of hospital stay. Based on observing the clinical use of CT and the relationships among various data, we predict future developments in CT for accurately diagnosing acute appendicitis and offer suggestions.

Materials and methods

Data source
The Taiwan Bureau of National Health Insurance (TBNHI) established a single-payer national health insurance program on 1 March 1995. This program covers over 99% of the population in Taiwan (http://www.nhi.gov.tw). In addition, the TBNHI has established a National Health Insurance Research Database (NHIRD) for research purposes. The Longitudinal Health Insurance Database used in this study is a part of the NHIRD, containing 1 million insured, who were randomly selected from the 2000 registry, and including all medical records and information on the insured from 1996 to 2011. The insurant identification numbers were recorded using a computer and then sent to the researcher according to the Personal Information Protection Act. This study was approved by the Institutional Review Board of China Medical
University and Hospital in Taiwan (CMU-REC-101-012). The NHIRD uses the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) to identify diseases and related operations.

Study subjects and outcomes

Figure 1 was presented as a flowchart for study subjects. Patients with acute appendicitis (ICD-9-CM 540) at admission (2000–2010) were enrolled in this study (N=10,231). Patients with a history of peritonitis (ICD-9-CM 567, 567.0, 567.2, 567.8 and 567.9) before diagnosis of acute appendicitis (N=185) were excluded. All 10,046 patients with acute appendicitis were selected and categorized into two groups (CT and non-CT groups) based on those who did and did not receive CT within 3 days before acute appendicitis diagnosis. A noteworthy outcome was the incidence of peritonitis within 90 days after acute appendicitis diagnosis.

Taiwan launched the national health insurance in 1995, operated by a single-buyer, the government. Medical reimbursement specialists and peer review should scrutinize all insurance claims. The diagnoses of appendicitis and peritonitis were based on the ICD-9 codes, which were judged and determined by related specialists and physicians according to the standard clinical criteria such as imaging findings, laboratory data and operation results. Therefore, the diagnoses and codes for appendicitis and peritonitis used in this study should be correct and reliable.

Statistical analysis

The chi-square test and t-test were used to assess the differences between the categorical and continuous variables of both groups. We estimated the odds ratios (ORs) and 95% confidence intervals (CIs) for peritonitis in both CT and non-CT groups. The same linear regression was applied to assess and compare the lengths of hospital stay because of acute appendicitis between the CT and the non-CT groups. All statistical analyses were performed using the Statistical Analysis System software (Version 9.3; SAS Institute Inc., Carey, NC), and a significance level of 5% was applied for the two-tailed test.

Results

We selected 2504 patients with acute appendicitis who received CT within 3 days before acute appendicitis diagnosis (CT group) and 7542 patients with acute appendicitis who did not receive CT (non-CT group). Compared with the non-CT group patients, the CT group patients were older (mean age: 45.0 vs. 32.0 years) and included fewer male patients (51.5% vs. 55.8%, Table 1). The rate of using CT for patients with acute appendicitis markedly

<table>
<thead>
<tr>
<th>CT (N=2504)</th>
<th>Non-CT (N=7542)</th>
<th>P-value</th>
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<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Age, year (SD)</td>
<td>45.0</td>
<td>20.7</td>
</tr>
<tr>
<td>Men</td>
<td>1289</td>
<td>51.5</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>86</td>
<td>3.43</td>
</tr>
<tr>
<td>2001</td>
<td>90</td>
<td>3.58</td>
</tr>
<tr>
<td>2002</td>
<td>103</td>
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<td>2003</td>
<td>141</td>
<td>5.63</td>
</tr>
<tr>
<td>2004</td>
<td>177</td>
<td>7.07</td>
</tr>
<tr>
<td>2005</td>
<td>198</td>
<td>7.91</td>
</tr>
<tr>
<td>2006</td>
<td>229</td>
<td>9.15</td>
</tr>
<tr>
<td>2007</td>
<td>310</td>
<td>12.4</td>
</tr>
<tr>
<td>2008</td>
<td>342</td>
<td>13.7</td>
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<td>2009</td>
<td>369</td>
<td>14.7</td>
</tr>
<tr>
<td>2010</td>
<td>459</td>
<td>18.3</td>
</tr>
</tbody>
</table>

CT, computed tomography; SD, standard deviation. Chi-square test and t-test.
increased from 7.9% to 52.9% during 2000–2010; however, no significant differences were observed in the risk of peritonitis among the patients from both groups during 2000–2010 (Figure 2).

The peritonitis incidence rates were 3.54% and 10.7% in the non-CT and CT groups, respectively (Table 2). Multivariate logistic regression, controlled for age, sex and the year of acute appendicitis diagnosis, revealed that the CT-group patients exhibited a 3.54-fold risk (95% CI = 2.62–3.93) compared with the non-CT group patients. Based on the CT examination date, the CT group was classified into two groups: before diagnosis (N = 532, 21.2%) and on the same day (N = 1972, 78.8%). Patients who were diagnosed with acute appendicitis and underwent CT on the same day exhibited a 3.80-fold higher risk of peritonitis compared with the non-CT group patients (95% CI = 3.09–4.68). Those who underwent CT before diagnosis of acute appendicitis exhibited no significant difference of peritonitis risk when compared with those in the non-CT group.

The average lengths of hospital stay because of acute appendicitis were 4.36 and 6.73 (standard deviation [SD] = 4.05 and 6.90, respectively) in the non-CT and CT groups, respectively (Table 3). Multivariate linear regression, adjusted for age, sex and the year of acute appendicitis diagnosis, revealed that the CT group patients were hospitalized 2.19 days longer than the non-CT group patients (95% CI = 1.95–2.43). Patients who underwent CT before diagnosis and on the same day were hospitalized 1.31 and 2.43 days longer than the non-CT group patients, respectively (95% CI = 0.88–1.75 and 2.16–2.69, respectively).

Discussion
For over a decade, the role of CT in diagnosing patients with suspected acute appendicitis has remained controversial. Some emergency department physicians and surgeons discourage using CT in such cases. Combining a robust case history with physical examinations and laboratory tests is sufficient for confidently diagnosing acute appendicitis, particularly when pediatric patients have an additional risk of ionizing radiation exposure from CT.5,12,13 Another obvious consideration involves the financial costs of CT. Furthermore, using CT on a large scale may result in wasting the limited medical resources in Taiwan.

Nevertheless, some clinicians consider using CT essential in diagnosing acute appendicitis. Considering the high diagnostic accuracy of CT, forgoing its use may be unjustified. Not using CT can result in misdiagnosis or delay diagnosis and operation. In addition, because of subsequent complications, postoperative sequelae and increased costs of hospital care, refraining from CT may be unwarranted.14–19 Thus, both sides of the controversy appear valid.

This study revealed three facts. First, patients who received CT exhibited higher risks of peritonitis and longer hospital stays than did patients who did not undergo CT. This may be because patients who underwent CT exhibited more severe clinical symptoms; thus, clinicians deemed CT necessary for diagnosis. By contrast, for patients with less severe clinical symptoms, clinicians may consider CT unnecessary. This may have been an acceptable clinical practice in emergency departments in earlier years before CT became liberally used. Raptopoulos et al.20 compared the proportion of patients who underwent CT before appendectomy in 1997 and 2000, reporting that CT was performed in 33% of patients who received appendectomy in 1997 compared with 59% in 2000. When the use of CT increased in 2000, the proportion of severe imaging findings decreased, including the absence of periappendiceal stranding, accompanied by a
significant decrease in the surgical–pathological severity of appendiceal diseases and length of hospital stay. In our study, only 15.3% of patients underwent CT from 2000 to 2006. In the final few years (2007–2010), the use of CT increased markedly (52% in 2010). These data indicate that, in earlier years (2000–2006), emergency department physicians reserved using CT for patients with severe clinical symptoms.

Second, a higher risk of peritonitis was observed in patients who received CT on the same day of operation compared with those who underwent CT 1 or 2 days before operation. A reasonable speculation is that performing CT on the same day of operation implied that the operation was emergent. The clinical condition of these patients was likely already critical, or the treatment was delayed.

Therefore, such patients required emergent CT and operation. By contrast, the scenario for the other group of patients was different; they received CT with a clear diagnosis, stayed in the hospital for 1 day, and then underwent a scheduled operation. This group exhibited a lower risk of peritonitis. These findings lead to the speculation that CT should be used as early as possible to reduce the incidence of postoperative complications. Although, theoretically, an emergent appendectomy may avoid perforation in non-perforated appendicitis, and because of the higher morbidity and mortality rates of perforated appendicitis, some surgeons prefer to initiate antibiotic and intravenous fluid therapy and then schedule the appendectomy according to their ‘normal business hours’. Stahlfeld et al.\textsuperscript{21} compared the outcomes of emergent and scheduled appendectomies by including operation time, length of hospital stay, wound infection and antibiotic use at discharge. They reported that delaying operation for acute appendicitis to accommodate a surgeon’s preference or to maximize a hospital’s efficiency did not pose a significant risk to patient outcomes.

Third, during the 11 years of focus from 2000 to 2010, CT was getting more frequently used in diagnosing acute appendicitis. In 2010, more patients with acute appendicitis underwent CT than did those who did not (52%) compared with only 7.9% of patients with acute appendicitis who received CT scan 11 years previously.

### Table 2  Risk for peritonitis in CT group compared with non-CT group in logistic regression

<table>
<thead>
<tr>
<th></th>
<th>Peritonitis</th>
<th>OR (95% CI)</th>
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<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>Crude</td>
<td>Adjusted</td>
</tr>
<tr>
<td>Non-CT (N=7542)</td>
<td>267</td>
<td>3.54</td>
<td>1.00</td>
<td>Ref.</td>
</tr>
<tr>
<td>CT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall (N=2504)</td>
<td>267</td>
<td>10.7</td>
<td>3.25</td>
<td>(2.73–3.88)*</td>
</tr>
<tr>
<td>Before (N=532)</td>
<td>24</td>
<td>4.51</td>
<td>1.29</td>
<td>(0.84–1.97)</td>
</tr>
<tr>
<td>At the same day (N=1972)</td>
<td>243</td>
<td>12.3</td>
<td>3.83</td>
<td>(3.19–4.59)*</td>
</tr>
</tbody>
</table>

Adjusted for age, gender and appendicitis year. *p < 0.001.
CT, computed tomography; OR, odds ratio; CI, confidence interval.

### Table 3  Length of stay due to acute appendicitis in CT group compared with non-CT group in linear regression

<table>
<thead>
<tr>
<th></th>
<th>Length of stay</th>
<th>Crude</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Parameter Estimate (95% Cl)</td>
</tr>
<tr>
<td>Non-CT (N=7542)</td>
<td>4.36</td>
<td>4.05</td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall (N=2504)</td>
<td>6.73</td>
<td>6.90</td>
<td>2.37</td>
</tr>
<tr>
<td>Before (N=532)</td>
<td>5.80</td>
<td>6.66</td>
<td>1.44</td>
</tr>
<tr>
<td>The same day (N=1972)</td>
<td>6.98</td>
<td>6.80</td>
<td>2.62</td>
</tr>
</tbody>
</table>

Adjusted for age, gender and appendicitis year. *p < 0.001.
CT, computed tomography; SD, standard deviation; CI, confidence interval.
Concurrently, a minimal increase was observed in the incidence of peritonitis complicated by acute appendicitis. This may be attributed to the increased availability of CT in Taiwan; currently, even the regional primary hospitals have effective CT equipment, and more clinicians agree that CT is a reliable tool for diagnosing acute appendicitis accurately. Therefore, more clinicians advise their patients to undergo CT. Moreover, no significant increase in the incidence of peritonitis indicated that the disease pattern of acute appendicitis did not change during the 11 examined years. The increased use of CT for acute appendicitis revealed no correlation with the changes in the disease pattern. Terasawa et al. studied the negative appendectomy rate. Seethal et al. conducted a systematic review to compare CT and ultrasonography in diagnosing acute appendicitis. They reported an overall sensitivity of 94% and a specificity of 95% for CT compared with an overall sensitivity of 86% and specificity of 81% for ultrasonography. In addition, CT may decrease the negative appendectomy rate. Seethal et al. studied the negative appendectomy rate in a 10-year review. Their data revealed a consistent decline in the negative appendectomy rate from 14.7% in 1998 to 8.5% in 2007; this trend was attributed to superior diagnostic tools including CT.

This study has obvious limitations. First, we used the ICD-9-CM disease codes to collect patient data. The day of disease coding generally coincided with the day of operation because operation alone enables definitive diagnosis of both acute appendicitis and peritonitis. No data were available on the tentative clinical diagnoses at presentation in the emergency room before CT and operation, or on the proportions of patients who presented with severe clinical symptoms and those who did not. In this study, the proportion of patients whose treatment plans were changed based on CT diagnosis remained unknown.

Second, no data were available on whether patients who underwent CT were operated on at a tertiary medical center or a regional primary hospital. Clinicians at tertiary medical centers may possess more experience in using CT for acute appendicitis diagnosis, but those at regional primary hospitals may refrain from using CT because of the possible difficulties in health insurance reimbursement. In addition, the difference in the rates of using CT at regional primary hospitals or tertiary medical centers remained unknown. Furthermore, this study does not answer the following question: Is peritonitis encountered less often in tertiary medical centers because of the availability of higher-quality medical care and staff with superior training and clinical skills? Several limitations inherent to our database need to be mentioned. There were lack of individual patient’s laboratory data, imaging report, pathologic finding and received treatment in NHIRD.

Despite the aforementioned limitations, this study indicates the following facts: CT has gained particular importance in the diagnosis of acute appendicitis. CT has been widely accepted and trusted by clinicians. In particular, for patients with severe clinical symptoms, CT should be used to achieve accurate diagnosis. Furthermore, when CT is considered necessary, clinicians should use it as early as possible to decrease the incidence of peritonitis. In conclusion, we suggest using CT in diagnosing most, if not all, patients with suspected acute appendicitis.

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References


