Development of a Novel CT Tool to Identify Cholecystitis

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Abstract: Background: Cholecystitis is a frequent surgical problem presenting via the emergency department. While clinical signs and symptoms are suggestive of cholecystitis, imaging is usually used as a diagnostic adjunct. Ultrasound (US) has been the modality of choice for evaluating the gallbladder; however the use of computed tomography (CT) has been increasing, particularly in emergency departments (ER). Unfortunately, there is limited data elucidating which CT findings identify cholecystitis. This study sought to identify specific CT findings that were easily identified even by non-experts to aid in developing a checklist instrument to accurately diagnose acute cholecystitis using CT.

Methods: We utilized CT scans of patients admitted through the ER who underwent CT scan as well as US and surgical cholecystectomy during the same admission from June 2010-December 2011. Data recorded included details from imaging and pathology reports. Based on previous literature, we created a 23 point checklist of CT findings in acute cholecystitis. A surgeon, blinded to all patient data, used this checklist in yes/no fashion to interpret the CT scans for diagnosis of cholecystitis. Using the diagnosis of cholecystitis by pathology as gold standard, sensitivities for checklist-assisted CT, standard read CT and US, and individual imaging findings on CT scans were calculated.

Results: Ninety-two patients were included in the study. When evaluating both acute and chronic cholecystitis, the sensitivity for US was 32.9%; the standard CT was 27.0% and checklist-assisted CT was 60.7%. When evaluating only acute cholecystitis, sensitivities were 47.1% for US, 42.9% for standard CT and 76.2% for checklist-assisted CT. Most sensitive findings on the checklist included presence of gallbladder distention (46.1%), sub-serosal halo/wall edema (38.2%), gallstones (37.1%), sludge (37.1%) and irregular/absent wall (32.6%).

Conclusion: The use of a checklist improved detection of acute and chronic cholecystitis, even when used by a non-expert, suggesting that this is a useful tool in evaluation of the disease.

Keywords: Cholecystitis, gallbladder, CT, US.

1. INTRODUCTION

Acute cholecystitis is a common surgical problem with well-established treatment options. The diagnosis of cholecystitis is based on clinical symptoms and signs including fever, right upper quadrant abdominal pain, positive Murphy’s sign, and leukocytosis, with imaging used as a diagnostic adjunct in the setting of appropriate clinical findings. However, Shakespeare and colleagues report that no clinical or laboratory finding is sufficient to rule in or rule out cholecystitis without an associated imaging examination, and that patients presenting with clinical features of acute cholecystitis should undergo imaging to confirm the diagnosis [1].

The appropriate management of acute cholecystitis hinges on timely diagnosis. Without timely diagnosis and management, the risk for potential complications, including sepsis, peritonitis, cholecystoenteric fistulae, and death is substantially increased [2]. Thus the frequency of acute cholecystitis and the risk for serious morbidity and/or mortality mandate the need for efficient and functional diagnostic imaging tools.

A great deal of existing literature supports the use of ultrasound (US) as the gold standard for initial imaging evaluation in the setting of right upper quadrant pain. The preference for US is based on its wide availability, relatively low cost in comparison to other studies, and its absence of ionizing radiation, thus making it safe in pediatric and pregnant populations. Moreover, US has been reported to have a high sensitivity, specificity, and positive and negative predictive values for diagnosing cholecystitis [3]. Well-established US findings for cholecystitis include gallbladder wall thickening, gallbladder distention, pericholecystic fluid, cholelithiasis, and a positive sonographic Murphy’s sign [1].

Nationally, computed tomographic scan utilization has been steadily increasing in assessment of patients with abdominal pain, including cases of suspected biliary etiology [4, 5]. This trend is especially true in emergency departments, where CT scans are frequently ordered even prior to surgical consultation. Although CT features of cholecystitis have been described, these have not been well evaluated in clinical practice, and while CT has been reported to be highly specific for cholecystitis [3], there is insufficient data regarding the accuracy of CT alone in diagnosing cholecystitis. Further, many physicians opt for an US even if CT has already been performed, due to US
historically being the first-line investigation for biliary pathology.

The principles of sound resource stewardship and good patient care necessitate the appropriate utilization of diagnostic studies as well as thorough data extraction from these studies. Since it is apparent that the dependence on CT scans in evaluation of suspected biliary disease and abdominal pain is generally increasing, it is essential to elucidate how best to utilize the information provided. Thus, a systematic way to diagnose gallbladder disease by CT imaging would be of benefit to emergency room physicians, surgeons, and others who manage these patients in the acute setting, often before formal radiological reads are available.

The goals of this study were (1) To assess whether a checklist incorporating specific CT findings in cholecystitis could be accurately used by a non-radiologist to diagnose cholecystitis using CT alone and (2) to identify the most sensitive CT findings for cholecystitis in order to develop a simple and broadly applicable diagnostic tool utilizing an imaging modality that is already extensively applied in the evaluation of abdominal pain.

2. METHODS

The study was approved by the Institutional Review Board at the Texas Tech University Health Sciences Center.

A thorough literature search was completed to identify previously published research findings on CT suggestive of cholecystitis. A list of these findings was compiled to be used as a scoring tool on the basis of each finding being either present or absent (see Figure 1). In order to provide a cohort of images on which to test this checklist, a list of patients with a discharge diagnosis of cholecystitis was obtained. Images selected for the study were from those who were admitted through the emergency department, had subsequent abdominal CT scan for suspected abdominal pathology as well as gallbladder US, and underwent cholecystectomy during the same index admission. All patients with imaging performed prior to admission were excluded, as were patients admitted for other indications (i.e. trauma, proven myocardial infarction, detoxification, etc.).

A single general surgeon then interpreted the CT scans using the checklist, scoring each of the imaging findings as present or absent and made a subjective diagnosis of cholecystitis. The surgeon was blinded to all patient data including imaging and pathology reports and viewed only actual CT images for interpretation. This test was then repeated on a subset of 35 images to assess intra-rater reliability by calculating the Cohen’s Kappa (K) value for each of the 23 findings.

Radiology and pathology reports were recorded for each subject whose images were selected for review. Imaging reports were considered “positive” for cholecystitis if the radiology report included direct or indirect suggestion of cholecystitis as a possible diagnosis. However, “cannot rule out” phrasing was considered negative. The pathology report was reviewed for presence of acute cholecystitis, chronic cholecystitis, acute-on-chronic cholecystitis, cholecystitis (unspecified), cholelithiasis, necrotic

<table>
<thead>
<tr>
<th>CT Checklist [1-3, 7-8, 10-11, 14-18]</th>
<th>Gallstones</th>
<th>Intraluminal layering</th>
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<tbody>
<tr>
<td>Gallbladder distention</td>
<td>Intraluminal hemorrhage</td>
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<tr>
<td>Gallbladder wall thickening</td>
<td>Intramural hemorrhage</td>
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<tr>
<td>Pericholecystic fluid</td>
<td>Mucosal sloughing</td>
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<td>Biliary duct dilatation</td>
<td>Intramural gas</td>
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<td>Choledocolithiasis</td>
<td>Intraluminal gas</td>
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<tr>
<td>Inflammation</td>
<td>Gallbladder wall calcification</td>
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<tr>
<td>High attenuation of bile/sludge</td>
<td>Suberosal halo/wall edema</td>
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<td>Gallbladder mural/mucosal hyperenhancement</td>
<td>Irregular/absent wall</td>
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<td>Pericholecystic fat stranding</td>
<td>Gallbladder associated mass</td>
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<tr>
<td>Stone in gallbladder infundibulum</td>
<td>Pericholecystic abscess</td>
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<tr>
<td>Enhancement/blurring of hepatic parenchyma of gallbladder fossa</td>
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Figure 1: CT imaging findings for checklist.
cholecystitis, gangrenous cholecystitis, emphysematous cholecystitis and acalculous cholecystitis. Using the diagnosis of cholecystitis per the pathology report as the gold standard, we calculated the sensitivity of each item on the checklist as well as the overall determination of cholecystitis based on CT. Sensitivities for the pre-existing standard US and CT reads were also calculated.

3. RESULTS

92 patients fit study criteria and had CT images available for review. Forty percent were male. The majority were Hispanic or Caucasian, 48% and 40% respectively. The mean age was 48.5 years (range 16-88 years). The majority of patients were overweight or obese, with an average body mass index of 30.3, (range 19.9-51.3), representative of the local population.

Only three of the 92 patients had negative pathology. Of the pathology-proven cholecystitis patients, 11.2% had acute cholecystitis only, 76.4% had chronic cholecystitis only, and 12.4% had acute-on-chronic cholecystitis. Seventy percent of cholecystitis positive patients also had cholelithiasis. Four patients had necrotic cholecystitis and three patients had gangrenous cholecystitis, which were included in the acute cholecystitis category. No patients in this study were determined to have emphysematous or acalculous cholecystitis on pathology.

Sensitivities of each diagnostic imaging modality are shown in Table 1. When evaluating both acute and chronic cholecystitis, the sensitivity for standard read US was 32.9%; the standard read CT was 27.0% while checklist-assisted CT was 60.7%. When evaluating only acute cholecystitis (including necrotic and gangrenous) higher sensitivities were noted of 47.1% for standard read US, and 42.9% and 76.2% for standard and checklist-assisted CT respectively.

<table>
<thead>
<tr>
<th>Acute and/or Chronic Cholecystitis</th>
<th>Sensitivity</th>
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<tr>
<td>Checklist-assisted CT</td>
<td>60.7%</td>
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<tr>
<td>Standard read CT</td>
<td>27.0%</td>
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<tr>
<td>Standard read US</td>
<td>32.9%</td>
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<tr>
<td><strong>Acute Cholecystitis</strong></td>
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<tr>
<td>Checklist-assisted CT</td>
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</tr>
<tr>
<td>Standard read US</td>
<td>47.1%</td>
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Examples of the most sensitive findings on the checklist-assisted CT are shown in Figure 2. These include presence of gallbladder distention (46.1%, K 0.7), subserosal halo/wall edema (38.2%, K 0.72), gallstones (37.1%, K 0.9), sludge (37.1%, K 0.68) and irregular/absent wall (32.6%, K 0.73). Only eleven patients were interpreted as having both sludge and stones concurrently. A lack of imaging findings described on the standard CT reports precluded parallel analysis of this data.

4. DISCUSSION

Acute cholecystitis is a common presentation facing emergency room physicians and surgeons. Clinical and laboratory data suggest the diagnosis, but early imaging confirmation is essential as the definitive management includes surgical removal of the gallbladder, and early timing of laparoscopic cholecystectomy has been shown to reduce complications and rates of conversion to open cholecystectomy [6]. Moreover, a missed diagnosis substantially increases the risk for morbidity and mortality, thus good patient care requires diagnostic accuracy. Historically, sonography has been the imaging modality of choice in biliary evaluation for reasons previously mentioned, with computed tomography reserved for atypical presentations and suspected complications of acute cholecystitis [7].

Despite the preference for US, the use of CT scans has been steadily expanding in the evaluation of abdominal pain of all etiologies, including biliary assessment [10]. The suspected reasons for increased usage of CT imaging are likely multifactorial. Some groups have suggested medicolegal considerations such as avoidance of malpractice litigation. Other contributing factors include increased availability of CT compared to US, with US being more difficult to obtain after hours due to a paucity of US radiologists and technicians during these off times. In one series, the biggest predictor of CT use in gallstone disease was evening imaging [8]. Further plausible explanations include institution-specific principles, financial aspects, atypical disease presentations, and increased need for diagnostic accuracy and speed in general.

Regardless of the reason for increased CT scan utilization, the fact remains that these studies are being performed more frequently. In order to maximize medical resources it is essential that all potentially useful data be extracted from ordered studies. Therefore, since CT imaging is already being
Soledad et al. performed on a very frequent basis in American emergency departments, this analysis has attempted to open an evidenced-based dialogue regarding how best to utilize studies and data that are already available, rather than question the utility or appropriateness of CT compared to US. To that end we attempted to identify CT findings most sensitive for predicting cholecystitis and to evaluate image interpretation by point-of-care physicians—surgeons in this case.

While CT features of cholecystitis have been described, these have not been well evaluated in clinical practice. Some previously described CT features of cholecystitis include cholelithiasis, increased bile attenuation/biliary sludge, gallbladder distention, gallbladder wall thickening, pericholecystic inflammation and fluid, pericholecystic stranding, subserosal edema, and irregular or absent wall [7-8, 10-11]. The current study found that the most sensitive findings were gallbladder distention, subserosal halo/wall edema, choledolithiasis, biliary sludge and irregular/absent wall.

Gallbladder distention is defined in the literature as greater than 5cm in short axis diameter and/or greater than 8cm in long axis diameter [11]; however distention was subjectively interpreted in this study. Several of the cases may have represented a mucocele, a term used to describe hydrops—a clear or mucoid fluid filling the gallbladder—usually due to chronic cystic duct obstruction, and usually associated with chronic cholecystitis. Since there is not a specific level of distention of echogenicity of gallbladder contents that characterizes this entity, we chose not to sub-divide this category. Subserosal halo/wall edema is characterized by a sandwich-like mural thickening of the gallbladder wall with an inner layer of enhancing mucosa and an outer layer of enhancing serosa with a layer of hypodense edematous fluid in between. Wall edema can be differentiated from pericholecystic fluid by the presence of small enhancing punctuate structures within the edematous wall which are diffusely distributed in wall edema versus being focally distributed in pericholecystic fluid [12]. While choledolithiasis and biliary sludge were two of the more sensitive findings, it should be noted that the existing literature clearly supports sonography as superior to CT in detection of stones [9]. Irregular or absent gallbladder wall is a hallmark CT finding of acute

Figure 2: Examples of most sensitive CT findings.
gangrenous cholecystitis [8], and thus a future study might review the number of patients with irregular/absent wall who were determined pathologically to have gangrenous rather than non-gangrenous gallbladder disease.

While gallbladder distention, wall edema, gallstones, sludge, and irregular/absent wall were the most sensitive CT findings for cholecystitis in this series, their respective sensitivities were statistically low when considered individually, with distention being the most sensitive at 46.1%. Sensitivity values in the 30-50% range fall well short of those of a powerful screening tool; however, we did not examine sensitivities for any of these most sensitive findings in combination with each other. When considered in combinations of two or more findings together, the sensitivities may be higher.

In addition to identifying the most sensitive CT findings for cholecystitis, we opted to perform sensitivity analysis on checklist-assisted CT interpretation compared to the standard read in order to determine whether the checklist would aid a non-expert in accurately using CT as a diagnostic tool. The non-expert checklist-assisted read was compared to the formal read in order to better assess interpretations by point-of-care physicians since formal reads are not always immediately available, especially in many rural settings or even certain larger centers after normal business hours. The checklist-assisted CT interpretation was more than twice as sensitive as standard read for acute or chronic cholecystitis, with sensitivities being higher for both reads in acute cholecystitis. This suggests that it would be a useful tool for the point-of-care physician especially in settings where radiologist reads are not immediately available.

Sensitivities for standard read US were 32.9% and 47.1% for acute and chronic cholecystitis and acute cholecystitis respectively. This data was included for completeness and comparison to the existing literature. Interestingly, these values were lower than those reported in the current literature where the sensitivity of US for diagnosing acute cholecystitis ranges from 83% to 97% depending on the series [3, 9, 13] The criteria for determining report positivity in this study was relatively broad, as any suggestion of cholecystitis, including “suspected” or “possible” was considered positive. However, US sensitivities may have been lower than previously reported because some of the standard US reports may have noted various signs of cholecystitis without providing an official diagnosis.

Our approach is supported by the variability in statistical parameters between this series and previous papers, as well as the variability between those papers. For example, Harvey et al. reported that US was more sensitive and specific (83% and 95% respectively) than CT (39% and 93% respectively) and concluded that US should be the imaging modality of choice in cases in diagnosing acute cholecystitis, with CT being reserved for complicated or atypical presentations. In comparison, while not calculating sensitivity and specificity, McGilliguddy et al. found that in a population of 475 elderly patients diagnosed with acute cholecystitis, US detected biliary sludge and gallbladder inflammation more often, while CT was superior at detecting pericholecystic fluid. The same series found that in the sub-group who received both CT and US, 19% had inflammation that was only detected on CT, concluding that US and CT may be complementary in the diagnosis of acute cholecystitis. Additionally, in comparison of CT findings of acute gangrenous cholecystitis to acute non-gangrenous cholecystitis, the sensitivity, specificity, and accuracy of CT for acute cholecystitis were 91.7%, 99.1%, and 94.3% respectively. These findings support the authors’ conclusions that CT should be further investigated as a reliable imaging modality to establish a diagnosis of acute cholecystitis.

Therefore, based on the identification of the most sensitive CT features for acute cholecystitis from a list of previously described findings, along with moderately high sensitivity for checklist-assisted CT in this cohort of patients with acute cholecystitis, our data supports the potential for a checklist-based tool for CT as a sensitive method for diagnosing cholecystitis in patients presenting to the emergency department with abdominal pain. The findings for checklist-assisted CT scans were sensitive despite the surgeon being blinded to all clinical information at the time of interpretation. While the sensitivities of the most sensitive CT findings for cholecystitis in this study were relatively low, these could be evaluated in combinations of two or more and sensitivities determined for various combinations. It therefore seems feasible, based on our data, that a simple tool could be developed for predicting cholecystitis on CT by non-radiologist physicians. This tool could be further validated in a larger cohort of point-of-care physicians, with oversight by radiology experts, in order to determine its appropriateness for broad application.
This study was limited by the use of a single surgeon’s interpretation of the selected CT images. It is possible that different physicians may have different interpretations of the images for a variety of reasons. In addition, the analysis was limited by the subjective interpretation of selected CT findings (ex: gallbladder distention). Further, we were unable to perform specificity analysis since the inclusion screening and the image pool were biased toward few pathologically negative gallbladders, meaning that if cholecystitis is clinically suspected, and if imaging in any way supports the diagnosis, then the likelihood of removing a pathologically negative gallbladder is substantially reduced. The high proportion of chronic cholecystitis without acute inflammation was surprising in a population that was admitted for acute symptomatology rather than elective surgery; however this reflects local financial realities, where uninsured patients with biliary colic and/or recurrent cholecystitis are unable to have elective cholecystectomy unless this is categorized as an urgent procedure requiring in-hospital admission. As the local county hospital we see a high proportion of uninsured patients, many of whom present repeatedly to the emergency room until admitted for definitive surgery. As a result the study findings are more relevant to chronic rather than acute cholecystitis, which was not the authors’ original intention. Finally, this was a pilot study and thus the results cannot be generalized, but rather serve as a starting point for development of a broadly applicable scoring tool. The next steps in this series would include performing inter-rater reliability to confirm that these findings are reliable even after accounting for individual variability. We could subsequently develop a scoring system for trial in a cohort of surgeons and ER physicians in order to assess broader application.

In conclusion, checklist-assisted CT images had the highest sensitivity in both acute and chronic cholecystitis, suggesting that CT may yield useful information in diagnosing cholecystitis. Further, the most sensitive CT findings identified in this study may be used to develop a simple tool for predicting cholecystitis on CT. Further validation and inter-rater reliability of CT findings with a larger cohort of physicians and a larger sample group containing more negative pathology would be the next step in this series.

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