Quality initiative: institutional performance of diagnosing acute cholecystitis using multi-modality imaging

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Aims and objectives

In the United States about 10-15% of adults have gallstones. With the increasing use of imaging, this disease is being identified more often and at a younger age (1). The prevalence of acute cholecystitis is approximately 5% (1) and 90-95% is secondary to calculous obstruction of the cystic duct (2). Acute cholecystitis is associated with known clinical signs and symptoms, as well as specific imaging findings. The Tokyo guidelines attempted to combine both clinical and imaging findings to aid in more rapid and accurate diagnosis of acute cholecystitis (3). Early diagnosis of acute cholecystitis is important for management and to prevent complications. Laparoscopic surgery is the treatment of choice for acute cholecystitis, but is most successful when performed within 3 days of onset of symptoms (4).

Ultrasound is used as the initial means of diagnosing cholelithiasis and the complication of gallstones, specifically acute cholecystitis. Ultrasound is a quick, non-invasive, real time, and inexpensive way to evaluate for gallstones and/or acute cholecystitis. There have been studies that have determined the ultrasound findings that most accurately correlate with a diagnosis of acute cholecystitis. There has been a range of ultrasound sensitivities and specificites reported in the literature regarding diagnosis of acute cholecystitis. When ultrasound is equivocal or negative for this diagnosis but symptoms persist, further imaging modalities may be used for diagnosis. The other imaging modalities used include CT scan, HIDA scan, and MRCP. Studies have shown CT to be less or similar in sensitivity compared to US for detecting gallstones. HIDA scans and MRCP are timely and more expensive. (1,2,5)

At our facility, ultrasound is currently the initial modality for diagnosing acute cholecystitis in the acute setting. The purpose of this study is to retrospectively investigate our institutional accuracy of diagnosis of acute cholecystitis on ultrasound, CT, and MRCP in patients with positive pathology or discharge diagnosis of acute cholecystitis at Boston Medical Center.
Methods and materials

A retrospective review was performed identifying patients with a discharge diagnosis of acute cholecystitis or a MRCP performed from 1/1/2005 - 12/31/2011. If the patients were identified by the discharge diagnosis and did not receive imaging during the admission for the acute visit they were excluded from the study. In addition, the patients identified by MRCP billing code were excluded if the study was not performed during the acute visit or was performed for an indication other than suspected acute cholecystitis.

There were a 264 ultrasound, 82 CT, and 296 MRCP imaging studies included in the analysis, making a total of 642 examinations.

Additional clinical and demographic information was obtained on each patient via inpatient and outpatient clinic notes, admission history and physical, and discharge summaries. This information included gender, date of birth, age at time of cholecystectomy, pathology report, length of admission, time to diagnosis, date of emergency room visits for same problem, clinical symptoms, abnormal lab values, past medical history, and any complications.

Ultrasound, CT, and MRCP imaging were included in the study. Each exam was reviewed, independently and blindly, by two abdominal imaging fellowship trained radiologists. The studies were evaluated for predetermined imaging findings of acute cholecystitis, specific to each modality, and for the presence or absence of acute cholecystitis.

Pathology, if available, and/or discharge diagnosis were used for the reference standard. The imaging diagnosis was compared to the reference standard to determine concordance or discordance.

The sensitivity and specificity, as well as positive and negative predictive values (PPV and NPV) were calculated for each modality.
Results

The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for diagnosis of acute cholecystitis was calculated for each modality:

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasound</td>
<td>39%</td>
<td>83%</td>
<td>67%</td>
<td>61%</td>
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<tr>
<td>CT</td>
<td>28%</td>
<td>100%</td>
<td>100%</td>
<td>53%</td>
</tr>
<tr>
<td>MRCP</td>
<td>26%</td>
<td>97%</td>
<td>91%</td>
<td>52%</td>
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Imaging Results

True positive case: Acute cholecystitis diagnosed with ultrasound imaging and confirmed with positive pathology.
Fig. 1: A. Cholelithiasis, wall thickening, wall edema (white arrow) and (B) hypervascularity of the gallbladder wall seen on ultrasound. The study was read as positive for acute cholecystitis. The patient underwent cholecystectomy and pathology confirmed the diagnosis of acute cholecystitis.

References: Radiology, Boston medical Center, Boston Medical Center - Boston/US

The below ultrasound was read as positive for choledolithiasis and negative for acute cholecystitis. The CT was ordered due to persistent clinical concern and was called positive for acute cholecystitis because of the pericholecystic stranding (shown below the ultrasound images). The patient was discharged with a diagnosis of gallstone pancreatitis and never underwent a cholecystectomy. The ultrasound findings were correct, while the CT findings were misleading.

Fig. 2: The initial imaging performed was an ultrasound and read as negative for acute cholecystitis. A. No evidence of wall thickening or edema, or pericholecystic fluid. B. There is a gallstone in the gallbladder neck, positive for cholelithiasis.

References: Radiology, Boston medical Center, Boston Medical Center - Boston/US
Fig. 3: A. Coronal and (B) axial non contrast CT was performed for persistent clinical suspicion of acute cholecystitis after the US seen in Fig 2. The CT was read as positive for acute cholecystitis because it demonstrated pericholecystitis fat stranding and a small amount of perihepatic fluid. The patient did not have a cholecystectomy and had a discharge diagnosis of acute gallstone pancreatitis.

References: Radiology, Boston medical Center, Boston Medical Center - Boston/US

The below CT was read as positive for acute cholecystitis with findings of a distended gallbladder, pericholecystitic fluid, and areas of wall thickening. An MRCP was performed per request of the clinical team to assess the biliary system. The below MRCP images show the findings consistent with acute cholecystitis more prominently than the CT. The patient underwent cholecystectomy and positive pathology confirmed the diagnosis.
Fig. 5: A. Coronal CT with contrast showing a distended gallbladder with pericholecystitic fluid/submucosal wall edema in the gallbladder (black arrow). B. Coronal contrast enhanced CT with mild perihepatic hyperenhancement (black arrow head). C. Gallbladder wall thickening (white star) in a distended gallbladder. MRCP was performed after this examination and findings are showed in Fig 6.

References: Radiology, Boston medical Center, Boston Medical Center - Boston/US
Fig. 6: A. Coronal T2 single shot. Distended gallbladder with wall thickening and edema (black arrow). B. T2 STIR axial image. Layering T2 hypointensity within the gallbladder consistent with sludge (white star). C. Post gadolinium T1 fat saturated image shows hyperenhancing mucosa within the edematous gallbladder wall (black arrow head). Diagnosis of acute cholecystitis was made after the CT examination seen in Fig 6. MRCP was performed per request of the primary team to evaluate the biliary system. The MRCP was positive for acute cholecystitis and was confirmed with positive pathology from cholecystectomy.

References: Radiology, Boston medical Center, Boston Medical Center - Boston/US

The ultrasound images showed gallstones, but was read as negative for acute cholecystitis. Contrast enhanced CT also demonstrated stones and mild, non-specific, wall edema, read as negative for acute cholecystitis. The patient did not have an operation on this admission, but was discharged with a diagnosis of acute cholecystitis.
Fig. 10: The patient first had an ultrasound performed which showed gallstones (A, white arrow), distention of the gallbladder and mild hypervascularity (B) of the wall. The ultrasound was not suggestive of acute cholecystitis. A contrast enhanced CT was performed to further evaluate the clinical symptoms and again gallstones (D, white arrow) were visualized and mild gallbladder wall edema (C and D, white star). The CT was read as negative for acute cholecystitis. The patient did not undergo a cholecystectomy on this admission but was discharged with a diagnosis of acute cholecystitis.

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Findings of cholelithiasis and nonspecific wall thickening on ultrasound was equivocal for the diagnosis of acute cholecystitis and MRCP was performed. Besides cholelithiasis there were no findings to suggest acute cholecystitis. The patient had a cholecystectomy and the pathology was positive for acute cholecystitis.
Fig. 11: Ultrasound findings of gallstones and nonspecific mild wall thickening (A, B) were determined to be equivocal for the diagnosis of acute cholecystitis. MRCP was performed for further evaluation and cholelithiasis was seen. There was no significant wall thickening, pericholecystic fluid, or pericholecystic liver enhancement. C. Coronal T2 single shot image showing mild gallbladder distention. D. Axial T2 STIR image with gallstones and no pericholecystic fluid or wall edema. E. Axial T1 fat saturated post gadolinium imaging without significant gallbladder wall or surrounding liver enhancement.

References: Radiology, Boston medical Center, Boston Medical Center - Boston/US
Fig. 9: This study was called positive for acute cholecystitis and the patient underwent a cholecystectomy with pathology confirming the diagnosis of acute gangrenous cholecystitis. A. T2 single shot coronal image showing circumferential gallbladder wall thickening and increased hyperintensity. The gallbladder is distended. B. T2 STIR axial image shows a distended gallbladder, cholelithiasis, pericholecystic T2 hyperintense inflammation and (C) pericholecystic liver parenchymal hyperintensity. D. There is increased enhancement of the surrounding liver parenchyma on the T1 fat saturated post gadolinium imaging.

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**Fig. 8:** The ultrasound examination and MRCP were reported as positive for acute cholecystitis, however, the patient did not undergo a cholecystectomy or percutaneous cholecystostomy tube. Ultrasound demonstrates a distended gallbladder (A), wall thickening and sludge (B), and hypervascularity of the wall (C). The patient had a positive Murphy's sign on examination. D. Coronal T2 single shot shows a large gallstone in the gallbladder neck and gallbladder wall thickening and edema as T2 hyperintensity. E. Axial T2 STIR better illustrates the gallbladder wall edema and thickening as well as the T2 hyperintensity of the surrounding liver parenchyma (F). G. HIDA scan performed a month after the initial imaging and acute visit demonstrated delayed filling of the gallbladder, which can be seen in the setting of chronic cholecystitis.

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**Fig. 2:** The initial imaging performed was an ultrasound and read as negative for acute cholecysitis. A. No evidence of wall thickening or edema, or pericholecystic fluid. B. There is a gallstone in the gallbladder neck, positive for cholelithiasis.

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Fig. 3: A. Coronal and (B) axial non contrast CT was performed for persistent clinical suspicion of acute cholecystitis after the US seen in Fig 2. The CT was read as positive for acute cholecystitis because it demonstrated pericholecystitis fat stranding and a small amount of perihepatic fluid. The patient did not have a cholecystectomy and had a discharge diagnosis of acute gallstone pancreatitis.

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Fig. 4: A. Axial and (B) coronal contrast enhanced CT shows cholelithiasis but was read as negative for acute cholecystitis. The patient was clinically diagnosed with acute cholecystitis and underwent a cholecystectomy with positive pathology for acute cholecystitis.

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**Fig. 5:** A. Coronal CT with contrast showing a distended gallbladder with pericholecystitic fluid/submucosal wall edema in the gallbladder (black arrow). B. Coronal contrast enhanced CT with mild perihepatic hyperenhancement (black arrow head). C. Gallbladder wall thickening (white star) in a distended gallbladder. MRCP was performed after this examination and findings are showed in Fig 6.

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**Fig. 6:** A. Coronal T2 single shot. Distended gallbladder with wall thickening and edema (black arrow). B. T2 STIR axial image. Layering T2 hypointensity within the gallbladder consistent with sludge (white star). C. Post gadolinium T1 fat saturated image shows hyperenhancing mucosa within the edematous gallbladder wall (black arrow head). Diagnosis of acute cholecystitis was made after the CT examination seen in Fig 6. MRCP was performed per request of the primary team to evaluate the biliary system. The MRCP was positive for acute cholecystitis and was confirmed with positive pathology from cholecystectomy.

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Fig. 1: A. Cholelithiasis, wall thickening, wall edema (white arrow) and (B) hypervascularity of the gallbladder wall seen on ultrasound. The study was read as positive for acute cholecystitis. The patient underwent cholecystectomy and pathology confirmed the diagnosis of acute cholecystitis.

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Fig. 7: A. Technically limited ultrasound was performed. No gallstones, wall thickening, distention, or pericholecystitic fluid to suggest acute cholecystitis. B. MRCP was done for persistent clinical suspicion. Gallbladder wall thickening is seen on the T2 coronal single shot, (C) pericholecystic and perihepatic T2 hyperintense fluid and inflammation, and (D) hyperenhancement of the gallbladder wall are consistent with acute cholecystitis.

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Fig. 10: The patient first had an ultrasound performed which showed gallstones (A, white arrow), distention of the gallbladder and mild hypervasculartiy (B) of the wall. The ultrasound was not suggestive of acute cholecystitis. A contrast enhanced CT was performed to further evaluate the clinical symptoms and again gallstones (D, white arrow) were visualized and mild gallbladder wall edema (C and D, white star). The CT was read as negative for acute cholecystitis. The patient did not undergo a cholecystectomy on this admission but was discharged with a diagnosis of acute cholecystitis.

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**Fig. 11:** Ultrasound findings of gallstones and nonspecific mild wall thickening (A, B) were determined to be equivocal for the diagnosis of acute cholecystitis. MRCP was performed for further evaluation and cholelithiasis was seen. There was no significant wall thickening, pericholecystic fluid, or pericholecystic liver enhancement. C. Coronal T2 single shot image showing mild gallbladder distention. D. Axial T2 STIR image with gallstones and no pericholecystic fluid or wall edema. E. Axial T1 fat saturated post gadolinium imaging without significant gallbladder wall or surrounding liver enhancement.

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Fig. 12: The ultrasound images showed no hypervascularity of the wall (A), cholelithiasis and minimal wall thickening (B) and was not suggestive of acute cholelithiasis. MRCP was performed. C. Coronal T2 single shot image showing cholelithiasis. D. Axial T2 STIR showed mild pericholecystic hyperintense fluid and (E) axial T1 fat saturated post gadolinium image had mild enhancement of the gallbladder wall. The MRCP was read as negative for acute cholecystitis. The patient underwent cholecystectomy and pathology demonstrated findings consistent with acute cholecystitis.

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**Fig. 13:** A. Ultrasound was negative for acute cholecystitis and only showed gallstones (white arrow). B. Coronal contrast enhanced CT with nonspecific gallbladder wall edema (white arrow) and axial image (C) shows large gallstone (black star) and was read as negative for acute cholecystitis. MRCP was performed for further evaluation and showed similar findings of wall edema (D), gallstones (E), and mild wall enhancement (F). The MRCP was also determined to be negative for acute cholecystitis. The patient had a cholecystectomy and had positive pathology for acute cholecystitis.
Conclusion

In this study, we aimed to examine our own institutional accuracy of diagnosing acute cholecystitis on multiple modalities as a means of quality improvement. There have been many reported sensitivities and specificities in regards to each imaging modality, particularly for ultrasound. The least amount of information in the literature is regarding MRCP and CT diagnosis, specifically compared to ultrasound. The most recent meta analysis by Kiewiet et al. looks to analyze the reported differences for these modalities (1). We used this study as the most complete analysis to compare our own accuracy.

Similar to the reported literature, our demonstrated diagnostic accuracy of ultrasound is suboptimal. However, at our institution we had even lower sensitivity than found in the meta analysis (39 vs. 81%), while our reported specificity was similar (1). This suggests that we may be missing positive cases of acute cholecystitis on ultrasound and this could lead to additional and possibly unnecessary imaging.

There is less evidence in the literature reporting accurate sensitivity and specificity of CT and MRCP (1). One study reported the sensitivity of CT to be higher than US and the specificity to be similar, while another study states the sensitivities and specificities are too under evaluated to give accurate estimates (1,5). At our institution, we found that our sensitivity for diagnosis of acute cholecystitis using CT was slightly lower than that of US, but the specificity and positive predictive values were much higher. These findings supported the use of ultrasound as the initial imaging modality at our facility and suggests CT could aid in further workup with equivocal ultrasound findings. The benefit of CT allows us to exclude the diagnosis of acute cholecystitis and to evaluate other pathology in the abdomen that may be causing the clinical symptoms. Of note, the number of CT examinations included in our study is lower compared to both ultrasound and MRCPs, which is a limitation in our analysis, and increasing the number of studies may alter our findings.

MRCP sensitivity and specificities reported in the literature are similar to that of ultrasound (1), but there is limited data and head to head comparison with ultrasound and CT is not well evaluated at this point. Many studies of the studies had small numbers of MRCP examinations and since the time of these analyses there has been improvement in the MRCP imaging, which may alter the diagnostic accuracy. There are additional benefits of MRCP, however, which include: evaluation of the biliary system, which may alter management, evaluation for complications of acute cholecystitis, and lack of ionizing radiation. There has been a reported sensitivity of 97-99% and specificity of 95-99% for bile duct abnormalities(6).
Our results demonstrated a lower sensitivity than both ultrasound and CT (26%), but very high specificity and positive predictive values. The number of MRCP examinations included in our study was higher than that of CT, which provides a more accurate statistical analysis. These findings further support the use of ultrasound as the initial screening imaging modality for acute cholecystitis and the use of MRCP for further evaluation when ultrasound is equivocal or limited. In our institution, the finding of choledocholithiasis alters management and MRCP is being performed at a higher frequency to exclude this pathology. This may further support the decision to use MRCP as the second modality after ultrasound instead of CT imaging.

Our study was done retrospectively and if additional examinations are included we can provide more accurate statistical analyses. In addition, statistical head to head comparison should be performed to aid in developing an imaging algorithm. The next step in our analysis would be to look at the most sensitive and specific imaging findings with each modality to aid in increasing our own institutional accuracy and developing relevant imaging guidelines. Further research could be done regarding functional MR imaging with the use of hepatobiliary agents such as Eovist to increase the sensitivity of MRCP (7).

Given our findings, we determined that no modality was significantly more sensitive than ultrasound or was able to provide enough addition benefit to justify replacing ultrasound as the initial imaging modality. Both CT and MRCP have high specificities and positive predictive values suggesting that these modalities have the potential to be used to as problem solving tools when ultrasound is not diagnostic. MRCP may provide additional benefits over CT with evaluation of the biliary system, lack of ionizing radiation, and possibility of functional imaging.
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