Acute Cholecystitis: MR Findings and Differentiation from Chronic Cholecystitis[1]

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Purpose: To retrospectively determine the sensitivity and specificity of magnetic resonance (MR) imaging for differentiation between acute and chronic cholecystitis, with histopathologic analysis as the reference standard.

Materials and Methods: Institutional review board approval with waived informed consent was obtained for this HIPAA-compliant study. Four reviewers blinded to the cholecystitis type but aware that cholecystitis was present retrospectively evaluated MR images for predetermined findings in 32 patients (15 male, 17 female; mean age ± standard deviation, 55 years ± 20) with histopathologically proved acute or chronic cholecystitis. The final MR diagnoses and MR findings in both groups were compared with each other and with the histopathologic diagnoses to determine the sensitivity and specificity of MR imaging. χ^2 tests were used to detect differences in MR findings between the acute and chronic cholecystitis groups.

Results: MR imaging sensitivity and specificity for detection of acute cholecystitis were 95% (18 of 19 patients) and 69% (nine of 13 patients), respectively. The sensitivities of increased gallbladder wall enhancement and increased transient pericholecystic hepatic enhancement were 74% (14 of 19 patients) and 62% (10 of 16 patients), respectively. Both findings had 92% (12 of 13 patients) specificity. Sensitivities of increased wall thickness, pericholecystic fluid, and adjacent fat signal intensity changes were 100% (19 of 19 patients), 95% (18 of 19 patients), and 95% (18 of 19 patients), respectively; specificities were 54% (seven of 13 patients), 38% (five of 13 patients), and 54% (seven of 13 patients), respectively. Pericholecystic abscess, intraluminal membranes, and wall irregularity or defect each had 100% (13 of 13 patients) specificity; sensitivities were 11% (two of 19 patients), 26% (five of 19 patients), and 21% (four of 19 patients), respectively. Increased gallbladder wall enhancement ($P < .001$) and increased transient pericholecystic hepatic enhancement ($P = .003$) were the most significantly different between acute and chronic cholecystitis.

Conclusion: Increased gallbladder wall enhancement and increased transient pericholecystic hepatic enhancement had the highest combination of sensitivity and specificity for the diagnosis and differentiation of acute and chronic cholecystitis.

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Ultrasonography (US) and cholescintigraphy are the imaging modalities most commonly used to diagnose acute cholecystitis (1–18). Owing to their varying sensitivity (40%–90%) and specificity (40%–95%), however, the results of these tests can be inconclusive in some patients (2,7,8). Computed tomography (CT) has been reported to have high sensitivity and specificity (95% for both) for the diagnosis of acute cholecystitis but important limitations, including limited soft-tissue contrast resolution, radiation exposure, and potential nephrotoxic effects from iodinated contrast media (2,7,8,16). Accordingly, magnetic resonance (MR) imaging may have a role in the diagnosis of acute cholecystitis given its inherent superior soft-tissue contrast resolution without risks of radiation exposure or nephrotoxicity.

Few reports describe the use of MR imaging in the diagnosis of acute cholecystitis (19–27). To our knowledge, there is no MR imaging report in which all of the findings of acute and chronic cholecystitis are compared. Thus, the purpose of our study was to retrospectively determine the sensitivity and specificity of MR imaging in the differentiation between acute and chronic cholecystitis, with histopathologic analysis as the reference standard.

Materials and Methods

Patient Selection

Institutional review board approval with waived informed patient consent was obtained for our Health Insurance Portability and Accountability Act–compliant study. Pathology and radiology department databases were searched for all patients with histopathologically proved cholecystitis who had undergone upper abdominal MR examinations within 1 month before surgery between January 2004 and February 2006. All MR examinations were performed for abdominal pain and problem solving. Patients who presented with predominantly findings of pancreatitis were excluded from the study. The final study group consisted of 32 patients: 19 with acute cholecystitis and 13 with chronic cholecystitis (Table 1).

MR Imaging Technique

MR imaging of the upper abdomen was performed with 1.5-T MR systems (Vision, Sonata, or Avanto; Siemens Medical Systems, Malvern, Pa) by using a phased-array torso coil. MR examinations were performed by using a breathing-dependent or breathing-independent patient protocol, depending on the patient's ability to suspend respiration (Table 2). The breathing-dependent protocol sequences required suspended respiration, whereas the breathing-independent protocol sequences were performed during respiration. In all patients, gadodiamide (Omniscan; GE Healthcare, Oakville, Ontario, Canada) was administered intravenously in a power-injected (Medrad, Pittsburgh, Pa) bolus of 0.1 mmol per kilogram of body weight at 2 mL/sec.

MR Image Interpretation

The upper-abdomen MR images obtained in all patients were independently and retrospectively evaluated by two radiologists (E.A., J.E.) who were blinded to the clinical information and the type of cholecystitis but aware that cholecystitis was present. These reviewers assessed all image studies on the basis of predetermined findings, and the final diagnoses made by the reviewers were recorded. The findings were as follows: gallstones, increased wall thickness (>3 mm [28]), mural striation (layered pattern of gallbladder wall with different alternating signal intensities [22]), increased gallbladder dimension (>40 mm in transverse plane [29]), increased contrast enhancement of the gallbladder wall, increased transient contrast enhancement of the liver parenchyma adjacent to the gallbladder, pericholecystic fluid, signal intensity changes in the fat planes surrounding the gallbladder (increased or decreased signal intensity in the pericholecystic fat on T2- and T1-weighted images, respectively [28]), pericholecystic abscess (encapsulated fluid collection adjacent to the gallbladder [28]), intraluminal membranes (irregular, intraluminal linear soft-tissue signal intensity [28]), wall irregularity or defect (irregularity or focal absence of the gallbladder wall [28]), and gas in the wall or lumen (signal void gas bubbles in the gallbladder wall or lumen and air-fluid level in the lumen on T1- or T2-weighted images [30]).

In the 28 patients with normal renal function, increased contrast enhancement of the gallbladder wall was evalu-

Advance in Knowledge

- Increased gallbladder wall enhancement and increased transient pericholecystic hepatic parenchymal enhancement were found to be the most discriminative MR findings for the diagnosis of acute cholecystitis and the differentiation between acute and chronic cholecystitis.

Implications for Patient Care

- Increased gallbladder wall enhancement and increased transient pericholecystic hepatic parenchymal enhancement, which were highly specific and relatively frequent MR findings of acute cholecystitis, may help discriminate this entity from chronic cholecystitis, and this distinction may affect the therapeutic approach.
- MR imaging may be especially useful for the diagnosis of acute acalculous cholecystitis in critically ill patients, who often have borderline renal function.

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Abbreviation:
AAC = acute acalculous cholecystitis

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Table 1

Characteristics of Study Population

Characteristic	Acute Cholecystitis Group ($n = 19$)	Chronic Cholecystitis Group ($n = 13$)
Age (y)*	65 ± 17	41 ± 15
Female patients	5 (26)	12 (92)
Chronic renal failure	2 (11)	2 (15)
Breathing-dependent protocol	15 (79)	13 (100)
Breathing-independent protocol	4 (21)	. . .
Chronic symptoms	0	9 (70)
Acute cholecystitis†	19 (100)	4 (30)
Time interval between MR imaging and surgery (d)*	5 ± 6	12 ± 11

Note.—Unless otherwise specified, data are numbers of patients and numbers in parentheses are percentages. Only four patients, who had acute cholecystitis, were examined with a breathing-independent protocol.

* Mean value ± standard deviation.

† Clinical diagnosis of acute cholecystitis at presentation.

ated on postcontrast delayed interstitial-phase images by means of comparison with the renal parenchymal enhancement (31). Increased gallbladder wall enhancement was accepted as positive for acute cholecystitis when it was equal to or greater than the renal parenchymal enhancement qualitatively. In the four patients with chronic renal failure, gallbladder wall enhancement was evaluated solely on the basis of the reviewers' experiences. Focally increased liver parenchymal enhancement adjacent to the gallbladder was assessed on immediate-postcontrast hepatic arterial-dominant phase images (32). On the basis of these findings, the reviewers were asked to evaluate the presence of acute or chronic cholecystitis.

Table 2

MR Imaging Sequences and Parameters

MR Sequence*	Imaging Plane(s)	Fat Suppression†	Intravenous Contrast Material Protocol	TR/TE‡	Flip Angle (Degrees)	Section Thickness (mm)	Matrix Size
Breathing-dependent protocol							
T1-weighted 2D GRE	Transverse, coronal	Not used	Pre- and postcontrast images assessed§	140/2.2–4.4	80	8–10	128 × 256
T1-weighted 3D GRE	Transverse	Used	Postcontrast images assessed§	4.3/1.7	10	3.5	144 × 320
T2-weighted half-Fourier RARE	Transverse, coronal	Used, not used	Precontrast images assessed	∞/90	180	8–10	192 × 256
Short-time inversion recovery	Transverse	Used	Precontrast images assessed	3830/64	150	8–10	118 × 256
Breathing-independent protocol							
T1-weighted magnetization-prepared rapid acquisition GRE	Transverse, coronal	Used, not used	Pre- and postcontrast images assessed§	2000/1.7	15	8–10	192 × 256
T2-weighted half-Fourier RARE	Transverse, coronal	Used, not used	Precontrast images assessed	∞/90	180	8–10	192 × 256
MR cholangiopancreatography							
T2-weighted half-Fourier RARE	Transverse, coronal oblique	Used	. . .	∞/99	150	4	240 × 256
T2-weighted fast spin-echo	Coronal, coronal oblique	Used	. . .	3100/1200	150	30–40	240 × 256

* The breathing-dependent protocol was used to examine 28 of the 32 patients; the breathing-independent protocol, to examine four patients; and MR cholangiopancreatography, to examine 24 patients. MR cholangiopancreatographic images were obtained to evaluate the gallbladder; neither the intrahepatic nor extrahepatic bile ducts were evaluated. GRE = gradient echo, RARE = rapid acquisition with relaxation enhancement, 3D = three-dimensional, 2D = two-dimensional.

† MR images were obtained with fat suppression (used), without fat suppression (not used), and both with and without fat suppression (used, not used).

‡ TE = echo time msec, TR = repetition time msec.

§ Non–fat-suppressed two-dimensional gradient-echo images were acquired at 18 seconds (hepatic arterial-dominant phase), and fat-suppressed two- or three-dimensional gradient-echo images were acquired at 45–60 seconds (portal venous phase) and 2 minutes (interstitial phase) after contrast material administration. Postcontrast images were acquired during the hepatic arterial-dominant and portal venous phases with the same injection protocol used for magnetization-prepared rapid acquisition gradient-echo imaging.

Figure 1

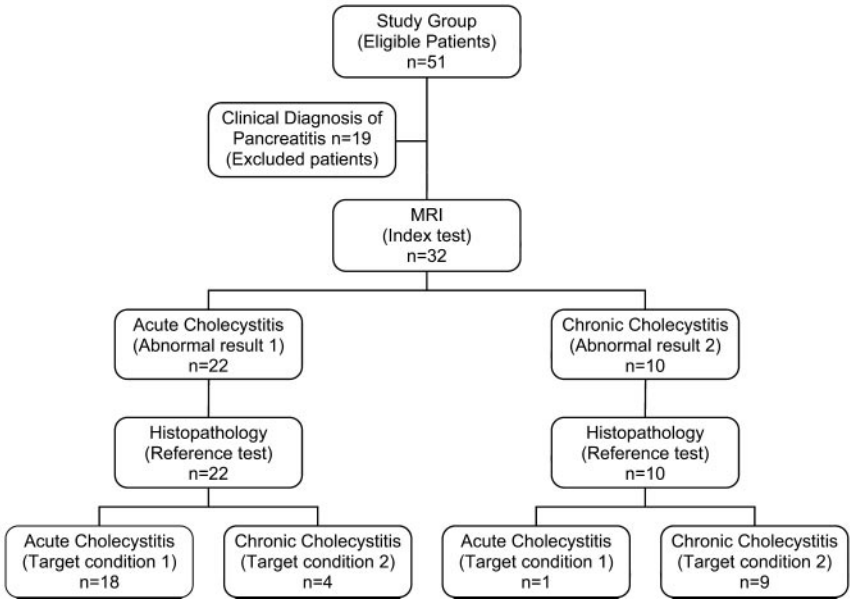


Figure 1: Flow diagram of the study group.

Table 3

Frequencies of MR Findings of Acute and Chronic Cholecystitis

MR Finding	Acute Cholecystitis ($n = 19$)			Chronic Cholecystitis ($n = 13$)
	AAC ($n = 5$)	ACC ($n = 14$)*	All ($n = 19$)†	
Gallstones	0	13 (93)	13 (68)	10 (77)
Increased wall thickening	5 (100)	14 (100)	19 (100)	6 (46)
Mural striation	5 (100)	9 (64)	14 (74)	4 (31)
Increased gallbladder dimension	4 (80)	10 (71)	14 (74)	5 (38)
Increased wall enhancement	4 (80)	10 (71)	14 (74)	1 (8)
Increased adjacent transient hepatic enhancement‡	4 (80)	6 (54)§	10 (62)‖	1 (8)
Pericholecystic fluid	5 (100)	13 (93)	18 (95)	8 (62)
Pericholecystic fat signal intensity changes	5 (100)	13 (93)	18 (95)	6 (46)
Pericholecystic abscess	1 (20)	1 (7)	2 (11)	0
Intraluminal membranes	2 (40)	3 (21)	5 (26)	0
Wall irregularity or defect	1 (20)	3 (21)	4 (21)	0

Note.—Data are numbers of patients, with percentages in parentheses.

* ACC = acute calculous cholecystitis.

† All patients with acute cholecystitis: those with AAC plus those with acute calculous cholecystitis.

‡ Adjacent transient hepatic enhancement was evaluated in 16 patients with acute cholecystitis.

§ Based on denominator of 11 patients.

‖ Based on denominator of 16 patients.

Two additional observers (R.C.S., L.B.) blinded to the diagnoses determined the frequencies and proportions of the findings (qualitative analysis), as well as the gallbladder wall thickness, gallbladder dimension, and signal intensities of the gallbladder wall and renal parenchyma (quantitative analysis). In all patients, gallbladder wall thickness and dimension were measured on the viewing station monitor from the sections showing the thickest part of the wall and the largest transverse gallbladder dimension. Measurements of the renal medulla parenchyma were performed. The signal intensities of the gallbladder wall and renal parenchyma on gadolinium-enhanced interstitial-phase images were determined by using standardized region-of-interest measurements in 26 (of the 32) patients (15 of 19 patients with acute and 11 of 13 with chronic cholecystitis) who were examined in a breathing-dependent protocol and had normal renal function. Region-of-interest sizes were similar for all measurements and patients and varied between 0.03 and 0.06 cm^2. These measurements were not performed in the patients who were examined in a breathing-independent protocol because the signal-to-noise ratio with the magnetization-prepared rapid acquisition gradient-echo sequence was lower than that with the two- and three-dimensional gradient-echo sequences (33), and, thus, including these measurements would have affected the statistical analysis adversely. Discordances between these observers were resolved by consensus.

Statistical Analyses

The qualitative and quantitative MR findings in the acute and chronic cholecystitis patient groups determined by two observers (R.C.S., L.B.) in consensus and the final MR diagnoses made by the two reviewers (E.A., J.E.) were compared with each other and with the histopathologic diagnoses. Analyses were performed by using the "Proc Freq" procedure in the Statistical Analysis System (SAS, version 8.02; SAS Institute, Cary, NC). The Mann-Whitney *U* test was used to evaluate differences in gallbladder wall

thicknesses, transverse gallbladder dimensions, gallbladder wall and renal parenchyma signal intensities, and MR imaging–surgery time intervals between the acute and chronic cholecystitis groups. χ^2 tests were used to detect differences in MR findings between the two groups. The consensus data of the two observers (R.C.S., L.B.) were used to perform the Mann-Whitney *U* and χ^2 tests. Kappa statistics were used to assess the interrater reliability of the final MR diagnoses between the two reviewers (E.A., J.E.). Associations were considered significant at two-tailed $P < .05$. The accuracy of MR imaging and of each MR finding in the diagnosis and differentiation between acute and chronic cholecystitis was calculated on the basis of the histopathologic diagnosis (reference standard).

Results

The average time intervals between MR imaging and surgery for acute or chronic cholecystitis were significant ($P = .005$) (Table 1).

MR Findings of Acute Cholecystitis in Both Groups

Acute cholecystitis group.—Acute cholecystitis was correctly identified at MR imaging in 18 of 19 patients (Fig 1). One patient, who had only two findings—increased gallbladder wall thickness and gallstones—represented a case of missed diagnosis. The other 18 patients had a combination of at least three findings (Figs 2, 3; Table 3) not including gallstones.

Focal transient liver enhancement adjacent to the gallbladder was not assessed in three of 19 patients, and two of these three patients were examined with a breathing-independent protocol. Immediate-postcontrast images were obtained in these three patients but not during the hepatic arterial-dominant phase. In 16 of the 19 patients with acute cholecystitis, hepatic arterial-dominant phase images were obtained. In the patients in whom the hepatic parenchyma showed increased enhancement during the hepatic arterial-dominant phase, the enhancement became isointense to the remaining liver tissue during the portal and interstitial phases of enhancement.

In the two patients with abscess at MR imaging, pericholecystic abscesses were not detected at surgery or histopathologic analysis. Of the five patients who had intraluminal membranes, four had gangrenous or necrotic gallbladder at surgery and histopathologic analysis. Of the four patients with wall irregularity or defect (Fig 4), three had histopathologically detected gangrenous or necrotic gallbladder, but perforation was not observed in any of these patients at surgery or histopathologic analysis.

Quantitatively, increased enhancement of the gallbladder wall was detected in 11 of 15 patients. In the remaining four patients, the gallbladder

Figure 2

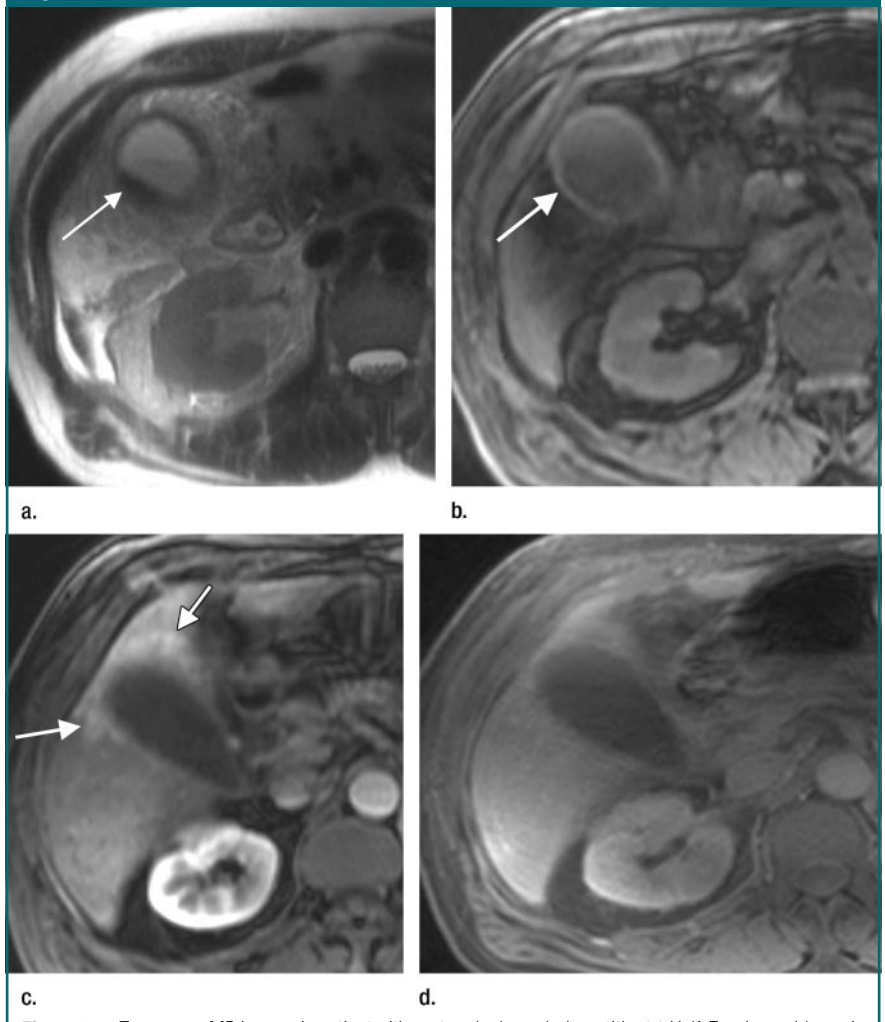


Figure 2: Transverse MR images in patient with acute calculous cholecystitis. **(a)** Half-Fourier rapid acquisition with relaxation enhancement image (∞/90, 180° flip angle) shows gallstones (arrow), pericholecystic fluid, and fat signal intensity changes surrounding the gallbladder. **(b)** Fat-suppressed three-dimensional gradient-echo image (4.3/1.7, 3.5° flip angle) shows thickened hyperintense gallbladder wall (arrow), indicating hemorrhage. **(c)** Contrast-enhanced hepatic arterial-dominant phase fat-suppressed three-dimensional gradient-echo image (4.3/1.7, 3.5°) shows patchy increased transient pericholecystic hepatic parenchymal enhancement (arrows). **(d)** Two-minutes-postcontrast interstitial-phase fat-suppressed spoiled gradient-echo image (140/4.4, 80° flip angle) shows the hepatic parenchyma that was enhancing in **c** is now isointense to the remaining liver parenchyma.

wall enhancement was less intense than the renal parenchymal enhancement. Increased gallbladder wall enhancement was detected qualitatively but not quantitatively in one patient with necrotic gallbladder wall. This discordance arose from the small quantitative signal intensity difference between the gallbladder wall and the renal parenchyma, which was not appreciated qualitatively. The mean signal intensities of the gallbladder wall and the renal parenchyma were not significantly different ($P = .20$) in the patients who had increased gallbladder wall enhancement quantitatively (Table 4).

Chronic cholecystitis group.—Thirteen patients had chronic cholecystitis at histopathologic analysis. At MR imaging, four of these patients were considered to have acute cholecystitis on the basis of the combination of at least five findings not including gallstones (Table 3). The remaining nine patients had a combination of at most three MR findings of gallbladder disease not including gallstones. At clinical examination, three of the four patients who received an incorrect diagnosis of acute cholecystitis at MR imaging were considered to have acute cholecystitis; the fourth patient had received an initial clinical diagnosis of symptomatic cholelithiasis, in keeping with the other patients in the chronic cholecystitis group.

Both the mean wall thickness ($P = .001$) and the mean gallbladder dimension ($P = .014$) for the chronic cholecystitis group were significantly lower than those for the acute cholecystitis group (Table 4). Increased gallbladder wall enhancement was not detected qualitatively in 12 of the 13 patients. In one patient, increased gallbladder wall enhancement and increased transient focal pericholecystic hepatic parenchymal enhancement were detected on the interstitial-phase and hepatic arterial-dominant phase images both qualitatively and quantitatively (Fig 5).

There was no discordance between the qualitative and quantitative analysis findings in any chronic cholecystitis group patients. There was no significant difference in mean signal intensity between the gallbladder wall and the renal parenchyma in those patients who did not have increased wall enhancement ($P = .28$). The mean signal intensity of the gallbladder wall for the acute cholecystitis group was higher than that for the chronic cholecystitis group but not significantly different ($P = .27$) (Table 4).

Figure 3

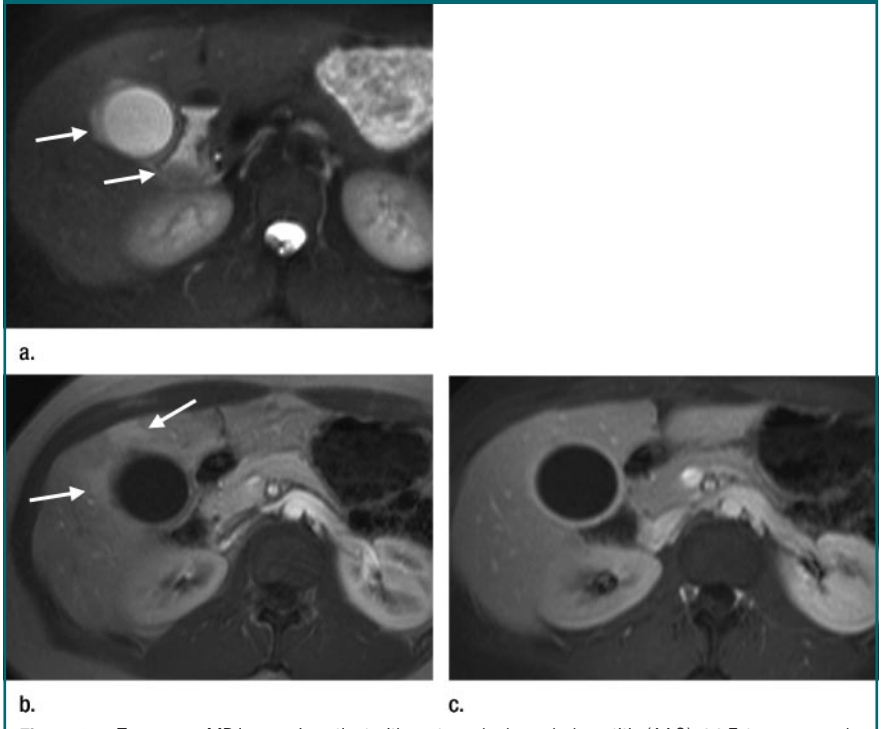


Figure 3: Transverse MR images in patient with acute acalculous cholecystitis (AAC). **(a)** Fat-suppressed half-Fourier rapid acquisition with relaxation enhancement image (∞/90, 180° flip angle) shows pericholecystic fluid (arrows). **(b)** Contrast-enhanced hepatic arterial-dominant phase spoiled gradient-echo image (140/4.4, 80° flip angle) shows patchy increased transient pericholecystic hepatic parenchymal enhancement (arrows). **(c)** Two-minutes-postcontrast interstitial-phase fat-suppressed spoiled gradient-echo image (140/4.4, 80° flip angle) shows the hepatic parenchyma that had increased enhancement in **b** is now isointense to the remaining liver parenchyma. Increased gallbladder wall thickness and enhancement are also noted.

Accuracy of MR Imaging and MR Findings for Diagnosis and Differentiation of Acute Cholecystitis

The sensitivity, specificity, and positive and negative predictive values of MR imaging for the diagnosis and differentiation of acute and chronic cholecystitis in the entire study population were 95% (18 of 19 patients), 69% (nine of 13 patients), 81% (18 of 22 patients), and 90% (nine of 10 patients), respectively (Table 5). MR imaging sensitivities for the diagnosis of acute calculous cholecystitis and AAC were 93% (13 of 14 patients) and 100% (five of five patients), respectively. Excellent interrater reliability (0.92) was demonstrated at κ analysis.

Increased wall thickness (100%), pericholecystic fluid (95%), and adjacent fat signal intensity changes (95%) had the highest sensitivities for the detection of acute cholecystitis (Table 6). However, the individual specificities of these three findings were low. Gallstones and increased gallbladder dimension had moderate sensitivity, and gallstones had the lowest specificity (23%) of all the findings. Mural striation had moderate sensitivity (74%) and specificity (69%). Increased gallbladder wall enhancement (74%) and increased transient pericholecystic hepatic parenchymal enhancement (62%) also had moderate sensitivity but high specificity (92% for both). Pericholecystic ab-

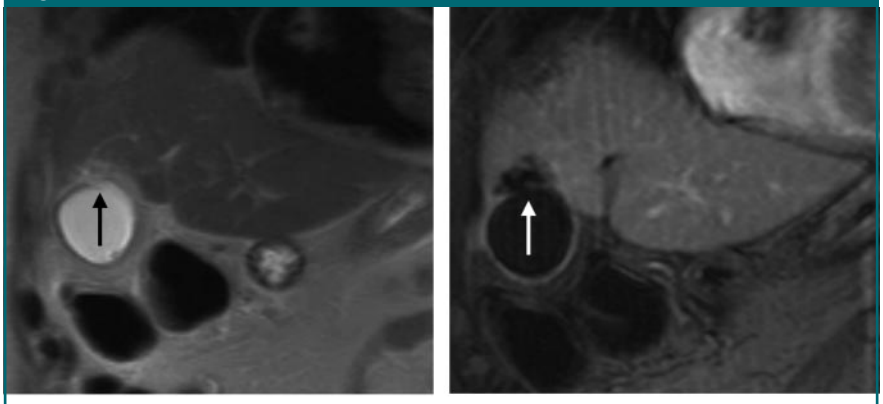
scess, intraluminal membranes, and wall irregularity or defect each had 100% specificity; however, their sensitivities were very low because these findings were rarely present and were observed only in association with complicated forms of acute cholecystitis. Intraluminal membranes and wall irregularity or defect enabled an accurate prediction of gangrenous or necrotic gallbladder in 80% (four of five) and 75% (three of four) of patients, respectively. Gas was not detected in the wall or lumen of the gallbladder in any patient; therefore, sensitivity and specificity values for this finding could not be determined. χ^2 Analysis revealed the most significant differences in increased gallbladder wall enhancement ($P < .001$) and increased transient pericholecystic hepatic enhancement ($P = .003$) between the acute and chronic cholecystitis groups.

Discussion

In our study, the sensitivity of MR imaging for the diagnosis and differentiation of acute cholecystitis was 95%, concurrent with similar findings in the literature (19,23–28,34). Acute calculous cholecystitis was missed in one patient, who had only two findings—increased wall thickness and gallstones; however, these two findings were not exclusive indicators of acute cholecystitis because of their low specificity.

The specificity of MR imaging for the diagnosis and differentiation of acute and chronic cholecystitis was 69%. This relatively low specificity was due to the four patients with discordant findings: They had chronic cholecystitis at histopathologic analysis but were considered to have acute cholecystitis at MR imaging. Three of these patients also presented with clinical findings of acute cholecystitis. In their cases, an explanation for the relatively low specificity may be that the histopathologic features and clinical findings clearly demonstrated a disease spectrum between acute and chronic cholecystitis (3,4,22). At times, the findings of acute and chronic cholecystitis may overlap radiologically, clinically, and even histopathologically (3,4,22). In the three patients with clinical acute findings, the acute inflammation seen at the time of the initial clinical diagnosis and MR imaging may have subsided by the time of histopathologic analysis owing to antibiotic therapy and/or the time interval between initial presentation and surgery. In the fourth patient, the reason for the discordance may have been simply overlapping clinical and radiologic findings between acute and chronic cholecystitis. If a healthy patient group had been compared with the acute cholecystitis group in our

Figure 4



a. b.

Figure 4: Coronal MR images in patient with necrotizing acute calculous cholecystitis. **(a)** Half-Fourier rapid acquisition with relaxation enhancement (∞/90, 180° flip angle) and **(b)** fat-suppressed magnetization-prepared rapid acquisition gradient-echo (2000/1.7, 15° flip angle) images show focal absence and irregularity at the superior aspect of the gallbladder wall (arrow).

Table 4

Quantitative Analyses of Patient Findings in the Two Cholecystitis Groups

Parameter	Acute Cholecystitis	Chronic Cholecystitis
Gallbladder wall thickness (mm)	6 ± 3 ($n = 19$)	3 ± 1 ($n = 13$)
Gallbladder dimension (mm)	44 ± 11 ($n = 19$)	33.6 ± 10.8 ($n = 13$)
Gallbladder wall signal intensity	453.7 ± 206.9 ($n = 11$)*	325.6 ± 195.7 ($n = 10$)†
Kidney signal intensity	376.4 ± 210.2 ($n = 11$)*	446.4 ± 254.6 ($n = 10$)†

Note.—Data are mean values ± standard deviations. The numbers of patients in whom the given parameter was measured are in parentheses. Signal intensity values are expressed in arbitrary units.

* Quantitative signal intensity analysis was performed in 15 patients with acute cholecystitis, 11 of whom had increased enhancement. Signal intensities were not measured in the remaining four patients: Two patients were examined with a breathing-independent protocol, and two others were examined with a breathing-independent protocol and had chronic renal failure. One patient had increased gallbladder wall enhancement at qualitative but not at quantitative analysis.

† Quantitative signal intensity analysis was performed in 11 patients with chronic cholecystitis, 10 of whom had increased enhancement. Signal intensities were not measured in the remaining three patients, including two who had chronic renal failure and one who had increased gallbladder wall enhancement.

Table 5

Distribution of Patients according to MR Results and Histopathologic Diagnoses of Acute Cholecystitis

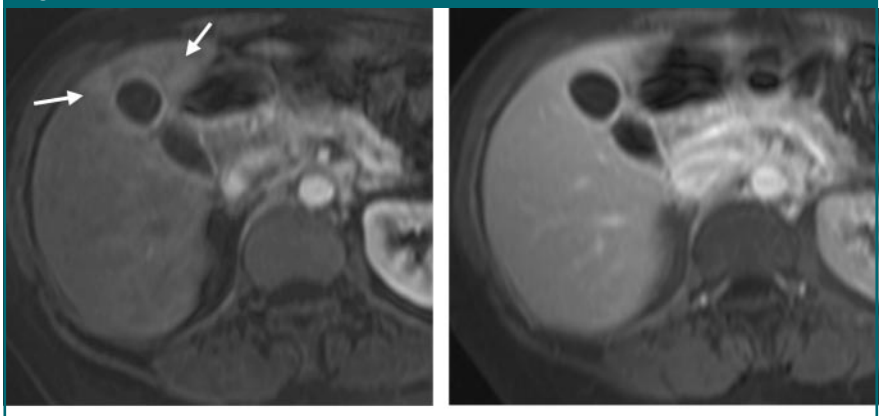
	Histopathologic Diagnosis		
MR Result	Positive	Negative	Total
Positive	18	4	22
Negative	1	9	10
Total	19	13	32

Note.—Data are the numbers of patients with MR results or a histopathologic diagnosis positive or negative for acute cholecystitis.

study, the specificity probably would have been much higher (19).

Highly specific and relatively frequent findings were increased gallbladder wall enhancement and increased transient pericholecystic hepatic enhancement; these were also the most discriminative and useful findings for the diagnosis of acute cholecystitis and the differentiation between acute and chronic cholecystitis—an observation that to our knowledge had not been previously reported. Statistical analysis results also supported these findings. The specificities of these two findings for the differentiation of acute cholecystitis would have been even higher if comparisons had been made with normal gallbladders (32,35). An important aspect in the detection of these two findings is the need for optimal timing of the postcontrast sequences (32,35). Ideally, pericholecystic transient hepatic enhancement should be evaluated during the hepatic arterial-dominant phase. During the portal venous and interstitial phases, the inflamed liver parenchyma adjacent to the gallbladder tends to rapidly become isointense to the remaining liver parenchyma (32,35). Therefore, if the immediate data acquisition is too early or too late, excluding the hepatic arterial-dominant phase, then pericholecystic transient hepatic parenchymal enhancement will not be appreciated. The gallbladder wall should be evaluated during the interstitial phase because it enhances maximally during this phase (28,34,35). In the setting of acute inflammation, gallbladder wall enhancement should be comparable to renal parenchymal enhancement (32). Increased enhancement is usually seen, at least in some part of the gallbladder wall, even in the setting of acute cholecystitis with necrosis (28), although it is a typical finding of acute cholecystitis without necrosis.

Figure 5



a. b.

Figure 5: Transverse fat-suppressed MR images in patient with chronic cholecystitis. **(a)** Hepatic arterial-dominant spoiled gradient-echo image (140/4.4, 80° flip angle) shows patchy transient pericholecystic hepatic parenchymal enhancement (arrows). **(b)** On 2-minutes-postcontrast interstitial-phase spoiled gradient-echo image (140/4.4, 80° flip angle), the hepatic parenchyma seen in **a** is now isointense to the remaining liver parenchyma. Increased gallbladder wall enhancement is also seen.

Table 6

Sensitivity and Specificity of MR Findings for Diagnosis and Differentiation of Acute Cholecystitis in Entire Study Population

MR Finding	Sensitivity	Specificity
Gallstones	68 (13/19)	23 (3/13)
Increased wall thickening	100 (19/19)	54 (7/13)
Mural striation	74 (14/19)	69 (9/13)
Increased gallbladder dimension	74 (14/19)	62 (8/13)
Increased wall enhancement	74 (14/19)	92 (12/13)
Increased adjacent transient hepatic enhancement	62 (10/16)*	92 (12/13)
Pericholecystic fluid	95 (18/19)	38 (5/13)
Pericholecystic fat signal intensity changes	95 (18/19)	54 (7/13)
Pericholecystic abscess	11 (2/19)	100 (13/13)
Intraluminal membranes	26 (5/19)	100 (13/13)
Wall irregularity or defect	21 (4/19)	100 (13/13)

Note.—Sensitivity and specificity values are percentages. The numbers of patients used to calculate the percentages are in parentheses.

* Adjacent transient hepatic enhancement was evaluated in only 16 of the 19 patients with acute cholecystitis.

The use of pericholecystic abscess, intraluminal membranes, and wall irregularity or defect for the diagnosis and differentiation of acute cholecystitis was limited because of their very low sensitivities (28,34). Pericholecystic abscesses were not detected at histopathologic analysis or surgery. We believe that because the abscesses were small, they had probably ruptured and drained unnoticeably at surgery owing to intense generalized acute inflammation. Intraluminal membranes and wall irregularity or defect enabled successful predictions of gangrenous or necrotic gallbladder. These findings concur with previous reports (28).

The use of increased wall thickness, pericholecystic fluid, and pericholecystic fat signal intensity changes for the diagnosis and differentiation of acute cholecystitis was limited owing to their low specificities. In our study, the sensitivities of these three findings were slightly higher and the specificities were slightly lower compared with values in previously reported studies (28,34). These findings probably had relatively low specificity because they were compared with findings in the chronic cholecystitis group. They may have had rela-

tively high sensitivity because of the reviewers' experiences and because the complex cases were referred for MR imaging.

Gallstones and increased transverse gallbladder dimension are frequent findings in both healthy individuals and patients with chronic cholecystitis (28,34). Mural striation, which may be seen with both acute and chronic cholecystitis, is difficult to detect without using thin sections and MR cholangiopancreatographic images (22,28,34). Thus, these findings had limited usefulness in the diagnosis of acute cholecystitis.

MR imaging has many advantages in the diagnosis of acute cholecystitis. In young patients, who are most susceptible to the harmful effects of radiation and have a relatively higher incidence of AAC, MR imaging should be considered the first imaging choice more often than radiation-generating modalities (9,10). Moreover, because AAC frequently develops in critically ill patients, who often have borderline renal function, the use of gadolinium chelates, as opposed to the iodinated contrast media used in CT, is advantageous for preserving renal function (8). In addition, MR imaging better reveals some of the complications and associated conditions of acute cholecystitis, such as choledocholithiasis (19,20).

There are a few disadvantages to using MR imaging to diagnose acute cholecystitis. AAC commonly develops in critically ill patients who are too unstable to be transported and/or are unable to be placed in or stay in the MR unit owing to their poor medical condition, metallic implants, or medical devices (7,8). However, many new MR examinations are fast and result in consistent image quality such that they can be tolerated by many severely ill patients. Despite the inability to elicit focal pain overlying the gallbladder with MR imaging, as can be done with US, our study results showed that acute cholecystitis can still be diagnosed successfully with MR imaging. In addition, because many critically ill patients are sedated, US may not demonstrate pain overlying the gallbladder for the diagnosis of AAC (7,8).

One limitation of our study was the small size of the patient population, which prevented us from obtaining significant quantitative signal intensity analysis results. Another limitation was the retrospective design of the study, which necessitated the use of three 1.5-T MR systems with potentially different magnetic field homogeneities. However, the magnetic field homogeneities of these systems were maximal and in the range of acceptable high-quality diagnostic standards. Therefore, we believe that the effect of magnetic field inhomogeneities on signal intensity measurements was negligible. The other limitation was the referral of patients with inconclusive findings for MR imaging, which probably skewed the population toward patients with more complex disease. We believe this may have contributed to the diminished specificity—rather than increased the accuracy—of MR imaging.

In conclusion, the results of our study show that MR imaging is accurate for the diagnosis of acute cholecystitis. Increased gallbladder wall enhancement and increased transient pericholecystic hepatic parenchymal enhancement are specific and frequent MR findings of acute cholecystitis. The clinical findings of acute cholecystitis and chronic cholecystitis may overlap, and MR imaging may be used for differentiation. MR imaging may be the most beneficial in the diagnosis of AAC, which is particularly difficult to detect with US. Our results showed MR imaging to have high sensitivity for this diagnosis.

References

1. Hanbidge AE, Buckler PM, O'Malley ME, Wilson SR. Imaging evaluation for acute pain in the right upper quadrant. RadioGraphics 2004;24:1117–1135.
2. Ko CW, Lee SP. Biliary sludge and cholecystitis. Best Pract Res Clin Gastroenterol 2003; 17:383–396.
3. Suter M, Meyer A. A 10-year experience with the use of laparoscopic cholecystectomy for acute cholecystitis: is it safe? Surg Endosc 2001;15:1187–1192.
4. Lillemoe KD, Lin JW, Talamini MA, Yeo CJ, Snyder DS, Parker SD. Laparoscopic cholecystectomy as a "true" outpatient procedure: initial experience in 130 consecutive patients. J Gastrointest Surg 1999;3:44–49.
5. Prevot N, Mariat G, Mahul P, et al. Contribution of cholescintigraphy to the early diagnosis of acute acalculous cholecystitis in intensive-care-unit patients. Eur J Nucl Med 1999;26:1317–1325.
6. Trowbridge RL, Rutkowski NK, Shojania KG. Does this patient have acute cholecystitis? JAMA 2003;289:80–86.
7. Mariat G, Mahul P, Prevot N, et al. Contribution of ultrasonography and cholescintigraphy to the diagnosis of acute acalculous cholecystitis in intensive care unit patients. Intensive Care Med 2000;26:1658–1663.
8. Menu Y, Vuillerme MP. Non-traumatic abdominal emergencies: imaging and intervention in acute biliary conditions. Eur Radiol 2002;12:2397–2406.
9. Parithivel VS, Gerst PH, Banerjee S, Parikh V, Albu E. Acute acalculous cholecystitis in young patients without predisposing factors. Am Surg 1999;65:366–368.
10. Chung SC. Acute acalculous cholecystitis: a reminder that this condition may appear in a primary care practice. Postgrad Med 1995; 98:199–204.
11. Bortoff GA, Chen MY, Ott DJ, Wofman NT, Routh WD. Gallbladder stones: imaging and intervention. RadioGraphics 2000;20:751–766.
12. Mirvis SE, Vainright JR, Nelson AW, et al. The diagnosis of acute acalculous cholecystitis: a comparison of sonography, scintigraphy, and CT. AJR Am J Roentgenol 1986;147:1171–1175.
13. Swayne LC. Acute acalculous cholecystitis: sensitivity in detection using technetium-99m iminodiacetic acid cholescintigraphy. Radiology 1986;160:33–38.
14. Flancbaum L, Choban PS, Sinha R, Jonasson O. Morphine cholescintigraphy in the evaluation of hospitalized patients with suspected acute cholecystitis. Ann Surg 1994;220:25–31.
15. Flancbaum L, Alden SM, Trooskin SZ. Use of cholescintigraphy with morphine in critically ill patients with suspected cholecystitis. Surgery 1989;106:668–673.
16. Cornwell EE 3rd, Rodriguez A, Mirvis SE, Shorr RM. Acute acalculous cholecystitis in critically injured patients: preoperative diagnostic imaging. Ann Surg 1989;210:52–55.
17. Ziessman HA. Acute cholecystitis, biliary obstruction, and biliary leakage. Semin Nucl Med 2003;33:279–296.
18. Puc MM, Tran HS, Wry PW, Ross SE. Ultrasound is not a useful screening tool for acute

acalculous cholecystitis in critically ill trauma patients. Am Surg 2002;68:65–69.

19. Loud PA, Semelka RC, Kettritz U, Brown JJ, Reinhold C. MRI of acute cholecystitis: comparison with the normal gallbladder and other entities. Magn Reson Imaging 1996;14:349–355.

20. Park MS, Yu JS, Kim YH, et al. Acute cholecystitis: comparison of MR cholangiography and US. Radiology 1998;209:781–785.

21. Sood B, Jain M, Khandelwal N, Singh P, Suri S. MRI of perforated gall bladder. Australas Radiol 2002;46:438–440.

22. Jung SE, Lee JM, Lee K, et al. Gallbladder wall thickening: MR imaging and pathologic correlation with emphasis on layered pattern. Eur Radiol 2005;15:694–701.

23. McCarthy S, Hricak H, Cohen M, et al. Cholecystitis: detection with MR imaging. Radiology 1986;158:333–336.

24. Pu Y, Yamamoto F, Igimi H, et al. A comparative study usefulness of magnetic resonance imaging in the diagnosis of acute cholecystitis. J Gastroenterol 1994;29:192–198.

25. Demachi H, Matsui O, Hoshiba K, et al. Dynamic MRI using a surface coil in chronic cholecystitis and gallbladder carcinoma: radiologic and histopathologic correlation. J Comput Assist Tomogr 1997;21:643–651.

26. Regan F, Schaefer DC, Smith DP, Petronis JP, Bohlman ME, Magnuson TH. The diagnostic utility of HASTE MRI in the evaluation of acute cholecystitis: half-Fourier acquisition single-shot turbo SE. J Comput Assist Tomogr 1998;22:638–642.

27. Pedrosa I, Guarise A, Goldsmith J, Procacci C, Rofsky NM. The interrupted rim sign in acute cholecystitis: a method to identify the gangrenous form with MRI. J Magn Reson Imaging 2003;18:360–363.

28. Bennett GL, Rusinek H, Lisi V, et al. CT findings in acute gangrenous cholecystitis. AJR Am J Roentgenol 2002;178:275–281.

29. Boland GW, Slater G, Lu DS, Eisenberg P, Lee MJ, Mueller PR. Prevalence and significance of gallbladder abnormalities seen on sonography in intensive care unit patients. AJR Am J Roentgenol 2000;174:973–977.

30. Maalouf EF, Faqbemi A, Duggan PJ, et al. Magnetic resonance imaging of intestinal necrosis in preterm infants. Pediatrics 2000;105:510–514.

31. Mirowitz SA, Gutierrez E, Lee JK, Brown JJ, Heiken JP. Normal abdominal enhancement patterns with dynamic gadolinium-enhanced MR imaging. Radiology 1991;180:637–640.

32. Yamashita K, Jin JM, Hirose Y, et al. CT finding of transient focal increased attenuation of the liver adjacent to the gallbladder in acute cholecystitis. AJR Am J Roentgenol 1995;164:343–346.

33. Brown MA, Semelka RC. MR imaging abbreviations, definitions, and descriptions: a review. Radiology 1999;213:647–662.

34. Fidler J, Paulson EK, Layfield L. CT evaluation of acute cholecystitis: findings and usefulness in diagnosis. AJR Am J Roentgenol 1996;166:1085–1088.

35. Choi SH, Lee MJ, Lee KH, Kim SH, Kim JY, An SK. Relationship between various patterns of transient increased hepatic attenuation on CT and portal vein thrombosis related to acute cholecystitis. AJR Am J Roentgenol 2004;183:437–442.