Gallbladder Patterns in Acute Pancreatitis:

An MRI Study

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Rationale and Objectives: The aim of this study was to assess the gallbladder patterns on magnetic resonance imaging (MRI) associated with acute pancreatitis (AP).

Materials and Methods: There were 197 patients with AP, all of whom had undergone abdominal MRI. AP was categorized as either edematous or necrotizing according to its findings on MRI and graded as mild (0–3 points), moderate (4–6 points), or severe (7–10 points) according to the magnetic resonance severity index. The changes to the walls and dimensions of the gallbladder and common bile duct, in addition to the presence of biliary stones and pericholecystic fluid, were noted and compared with the severity of AP on the basis of the magnetic resonance severity index.

Results: Of the 197 patients with AP, 81% were classified as edematous and 19% as necrotizing on MRI. There were 35%, 59%, and 6% of patients with mild, moderate, and severe AP according to the magnetic resonance severity index, respectively. Seventy-six percent of patients had at least one gallbladder abnormality on MRI, including a thickened gallbladder wall (42%), pericholecystic fluid (38%), gallbladder stones (35%), an enlarged gallbladder (24%), dilatation of the common bile duct (16%), and subserosal edema (15%). Eighty-nine percent of patients (34 of 38) with necrotizing AP had gallbladder abnormalities, which was significantly higher than the 72% of patients (115 of 159) with edematous AP ($P < .05$). The prevalence of gallbladder abnormalities was 64% in patients with mild AP, 81% in those with moderate AP, and 91% in those with severe AP ($P < .05$ among the three groups).

Conclusions: Most patients with AP have gallbladder abnormalities on MRI, including a thickened gallbladder wall and pericholecystic fluid. The prevalence of gallbladder abnormalities has a positive correlation with the severity of AP on MRI.

Key Words: Pancreas; pancreatitis; magnetic resonance imaging; gallbladder.

Acute pancreatitis (AP) is a common cause of acute abdominal presentation in the clinic. Its median mortality is 10%, but it may reach 20% to 30% in necrotizing pancreatitis with multiple organ dysfunction syndrome (1,2). AP inflammation often spreads, and the surrounding organ tissues are often involved. The gallbladder is affected by a variety of pathologic conditions that are often associated with nonspecific conditions (3,4). Because the pancreas and gallbladder are connected anatomically and functionally, pancreatic diseases are closely related to gallbladder disorders (5,6).

Understanding gallbladder patterns on magnetic resonance imaging (MRI) can help with the diagnosis and management of AP. Laparoscopic cholecystectomy has become the gold standard to avoid the recurrence of gallstone pancreatitis with gallstone disease (7), while percutaneous transhepatic gallbladder cholangio-drainage is a useful method for severe acute obstructive gallstone pancreatitis (8,9).

Zhang et al (10) reported gallbladder abnormalities in carcinoma of the pancreatic head. Andersson et al (11) found that the gallbladder and the surrounding tissues had edema with different degrees of AP during surgery. There are also reports of acute biliary pancreatitis caused by biliary tract disease, such as cholelithiasis, cholangiocarcinoma, and biliary tract surgery (8,9,12).

With the development of new technology, MRI has become a very important tool in evaluating the pancreas and gallbladder. With the use of MR cholangiopancreatography, the gallbladder and its disorders can be depicted without using a contrast medium. MR cholangiopancreatography can display the pancreatic biliary system anatomy and pathologic changes. It uses three-dimensional imaging and provides a noninvasive, safe, simple, and accurate diagnosis (13,14). MRI is also a valuable tool used in the assessment of AP, including effectively detecting, diagnosing, and staging AP (15–17). MRI is recommended as a reliable and safe imaging method in AP when an enhanced computed tomographic scan is contraindicated (14). In biliary AP,

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MRI provides information concerning biliary stones as well as an assessment of severity (16).

In clinical practice, we have primarily found that AP is often associated with gallbladder abnormalities on MRI. We conducted this study to retrospectively investigate gallbladder patterns on MRI associated with AP. We studied the prevalence of gallbladder abnormalities in AP and gallbladder patterns and their correlation with the severity of AP on MRI.

MATERIALS AND METHODS

Patient Selection

The recruitment criteria for patients in this study were as follows: (1) acute onset of abdominal pain; (2) pancreatitis at initial onset; (3) an elevation of serum amylase at levels three times the upper normal values, excluding other causes of elevated enzymes; (4) AP confirmed by surgery; and (5) upper abdominal MR examinations within 3 days of the onset of pancreatitis. This retrospective study was in compliance with the Health Insurance Portability and Accountability Act and was approved by our institutional review board. Patient informed consent was waived.

The exclusion criteria in this study were as follows: (1) an inability to cooperate when MRI was performed, (2) a history of chronic pancreatitis, (3) AP due to pancreatic carcinoma, and (4) no gallbladder.

The recruitment criteria for patients with acute cholecystitis on MRI included the following: (1) gallbladder wall thickening, (2) mural or mucosal hyperenhancement, (3) pericholecystic fluid, (4) adjacent soft tissue inflammatory changes, (5) abnormally increased gallbladder distention, and (6) cholelithiasis (hypointense intraluminal foci on T2-weighted imaging sequences) (18,19).

Two hundred thirty-nine patients with AP were admitted to our institution between January 2010 and October 2011. Forty-two patients were excluded, including seven patients with severe motion artifacts during MRI scanning and 35 patients with no gallbladder. The final study group consisted of 197 consecutive patients.

MRI Technique

All MR examinations were performed during suspended respiration with a 1.5-T system and a phased-array coil (Signa; GE Medical Systems, Milwaukee, WI). The sequences included two-dimensional coronal and axial single-shot fast spin-echo (SSFSE) T2 weighted, axial fast-recovery fast spin-echo (FRFSE) T2 weighted with fat suppression, axial spoiled dual gradient-echo (GRE) T1 weighted in phase and out of phase, axial slab three-dimensional spoiled gradient-echo (SPGR) dynamic contrast enhanced with fat suppression, and SSFSE radial series slab MR cholangiopancreatography.

Coronal SSFSE T2-weighted MR images were obtained in two or more breath-holds. The parameters used were as follows: repetition time (TR), infinite; echo time (TE), 90 to 100 or 180 to 190 ms; section thickness, 7 mm; intersection gap, 0; matrix size, 256 × 192; signal acquired, 0.5; and field of view (FOV), 32 × 32 cm.

Axial SSFSE T2-weighted images were obtained in one or two breath-holds. The parameters used were as follows: TR, infinite; TE, 90 to 100 or 180 to 190 ms; section thickness, 5 mm; intersection gap, 0; matrix size, 256 × 160; signal acquired, 0.5; and FOV, 32 × 24 cm. Axial two-dimensional multisection SPGR T1-weighted images were obtained during breath-holding. The parameters used were as follows: TR, 120 ms; TE, 4.2 ms (in phase) and 2.1 ms (out of phase); flip angle, 90°; section thickness, 8 mm; intersection gap, 0; matrix size, 256 × 192; signal acquired, 1; and FOV, 32 × 24 cm.

SSFSE radial oblique slabs were obtained for MR cholangiopancreatography with the following parameters: TR, infinite; TE, 700 ms; fat saturation; section thickness, 40 mm; matrix size, 256 × 192; signal acquired, 0.5; and FOV, 24 × 24 cm.

Axial three-dimensional SPGR dynamic MR images were obtained with the following parameters: TR, 6.1 ms; TE, 2.1 ms; flip angle, 15° to 20°; matrix size, 256 × 128; signal acquired, 1; section thickness, 5 mm; overlap, 2.5 mm; and FOV, 32 × 24 cm.

Three-dimensional SPGR was obtained at 2.5-mm increments with zero-fill interpolation for dynamic enhancement.

Twenty milliliters of gadolinium (Magnevist; Schering Guangzhou Company, Guangzhou, China) was administered intravenously with a pressure injector (Spectris MR Injection System; Medrad, Inc, Warrendale, PA) at 2 to 3 mL/s. This was followed by a 20-mL saline solution flush. First-pass arterial enhancement was optimized with a timing bolus sequence (axial fast multiplanar spoiled gradient recalled). Dynamic imaging was performed during breath-holding before the injection (unenhanced), immediately after the injection (hepatic arterial phase), 30 seconds after the injection (early venous phase), and 1 minute after the injection (late venous phase). The delayed phases were acquired with axial fast spoiled gradient-echo and another three-dimensional SPGR T1-weighted sequence.

MR Image Analysis

The original MRI data were loaded onto a computer workstation (GE Advantage Workstation version 4.1; Sun Microsystems, Palo Alto, CA) for review. Two observers (with 4 and 6 years of experience in interpreting abdominal MRI examinations) were blinded to the laboratory data and clinical outcomes and reviewed the MR images. Any discrepancies between the two readers were settled by consensus.

AP was categorized as edematous or necrotizing according to the findings on MRI (20–22). The severity of AP on MRI was evaluated with the MR severity index (MRSI), which is derived from the computed tomographic severity index (16,23,24). AP was graded as mild (0–3 points), moderate (4–6 points), or severe (7–10 points), according to the MRSI (16,23,24).

TABLE 1. Number of Patients According to MRSI

	MRSI										
	1	2	3	4	5	6	7	8	9	10	Total
Patients	11	32	26	93	3	21	1	7	0	3	197

MRSI, magnetic resonance severity index.

TABLE 2. MRI Diagnosis of Cholecystitis

	Surgery and Pathology		
MRI	Positive	Negative	Total
Positive	46	0	46
Negative	2	1	3
Total	48	1	49

MRI, magnetic resonance imaging.

To describe gallbladder patterns on MRI, the measured dimensions and characteristics are outlined below. A thickened gallbladder wall was defined as being >3 mm (18,25). The measurement was taken in the mid portion to prevent measuring the partial volume expansion of the fundus or neck of the gallbladder. Subserosal edema of the gallbladder wall was considered to be present when a central area of low water signal (a "halo") was observed around the gallbladder (26). Increased dimensions of the gallbladder were defined as a short diameter > 40 mm and/or a long diameter > 80 mm (27). Gallbladder size was measured from the outer wall in the transverse diameter. Dilatation of the common bile duct (CBD) was defined as a short diameter of the CBD > 7 mm, which was measured on SSFSE T2-weighted or MR cholangiopancreatographic images (28). Gallstones and CBD stones were observed on T2-weighted or MR cholangiopancreatographic images, which showed hypointense areas or filling defects in the bright bile background. Pericholecystic fluid was defined as fluid surrounding the gallbladder, appearing as a hypointense signal on T1-weighted images and a hyperintense signal on T2-weighted images (25).

Statistical Analyses

All of the data derived from the MR images were averaged between the two observers. Any discrepancies for noncontinuous data were negotiated by the two observers until consensus was reached.

Kappa statistics were used to assess the interrater reliability of the final MR diagnoses between the two observers. The statistic is generally interpreted as follows: $\kappa \geq 0.81$ indicates very good agreement, $\kappa = 0.80$ to 0.61 indicates good agreement, $\kappa = 0.60$ to 0.41 indicates moderate agreement, and $\kappa < 0.41$ indicates poor agreement.

Continuous variables are expressed as mean ± standard deviation and range. Chi-square tests were used to analyze the patterns between patients with gallbladder edema; those with necrotic AP; and those with mild, moderate, and severe AP. Spearman's rank correlation coefficients were used to test the correlations of gallbladder abnormalities with the severity of AP by the MRSI.

Data analysis was performed using SPSS for Windows version 13.0 (SPSS, Inc, Chicago, IL). P values ≤ .05 were considered significant.

TABLE 3. Agreement of the Two Raters for Gallbladder Abnormalities on Magnetic Resonance Imaging (n = 197)

Abnormality	Rater 1	Rater 2	κ
Thickened gallbladder wall	87	70	0.57
Pericholecystic fluid	35	48	0.62
Gallbladder stone	65	70	0.72
Subserosal edema	38	30	0.68
Enlarged gallbladder	35	48	0.62
Dilatation of CBD	25	35	0.57
CBD stone	19	16	0.66
Dilatation of cystic duct	14	17	0.76
Cystic duct stone	3	5	0.75

CBD, common bile duct.

RESULTS

Among the 197 patients with AP, there were 100 men and 97 women, and the average age was 54 ± 16 years (range, 16–87 years). The etiology of AP was biliary in 62% (n = 122), alcoholic in 4% (n = 8), endoscopic retrograde cholangiopancreatography in 2% (n = 3), and trauma in 0.5% (n = 1) of the patients. Thirty-two percent of patients (n = 63) did not have specified etiologies.

Eighty-one percent of patients were classified as edematous and 19% of patients as necrotizing on MRI. Thirty-five percent, 59%, and 6% of patients had mild, moderate, and severe AP according to the MRSI, respectively (Table 1).

In the 197 patients with AP, 97 patients were diagnosed with cholecystitis by MRI, and 49 patients were confirmed by surgery and pathology. The sensitivity of the MRI diagnosis of cholecystitis was 96%, and the specificity was 100% (Table 2).

The agreement of the two raters was generally good, except for the dilatation of the CBD and thickened gallbladder wall (Table 3).

Of the 197 patients with AP, 76% (n = 149) had at least one gallbladder abnormality on MRI. The patterns of the abnormalities included a thickened gallbladder wall (Figs 1–3), gallbladder stones (Fig 4), dilatation of the CBD (Figs 1, 3, and 4), pericholecystic fluid (Figs 2, 4, and 5), and subserosal edema (Fig 6). The most common abnormalities were a thickened gallbladder wall (42%), pericholecystic fluid (38%), gallbladder stones (35%), and an enlarged gallbladder (24%) (Table 4).

Eighty-nine percent of patients with necrotizing AP (34 of 38) had gallbladder abnormalities, significantly higher than the 72% of patients with edematous AP (115 of 159) ($P < .05$).

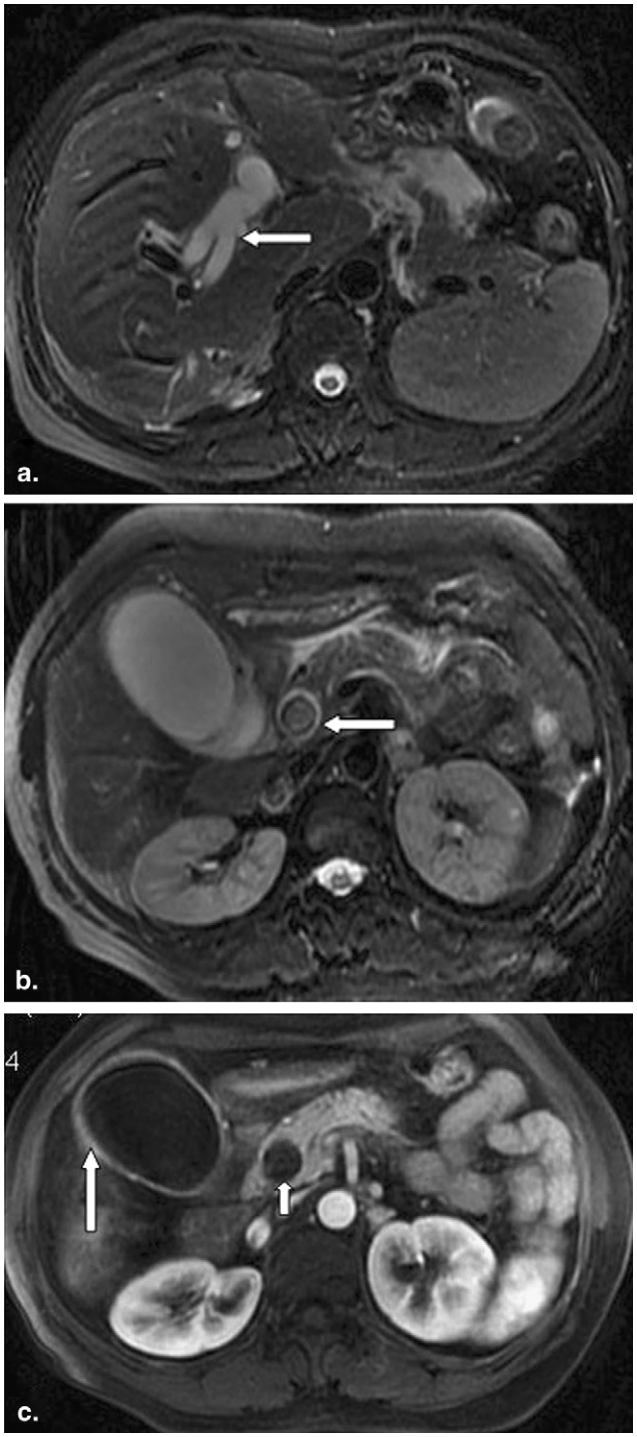

Figure 1. A 52-year-old woman with moderate acute pancreatitis. On fast-recovery fast spin-echo T2-weighted images, the intrahepatic duct (*arrow*) was dilated **(a)**. Stones can be observed in the distal end of the dilated common bile duct **(b)**. The gallbladder was enlarged with a thickened wall, which was enhanced on the arterial phase after intravenously injecting gadolinium diethylenetriamine penta-acetic acid **(c)**.

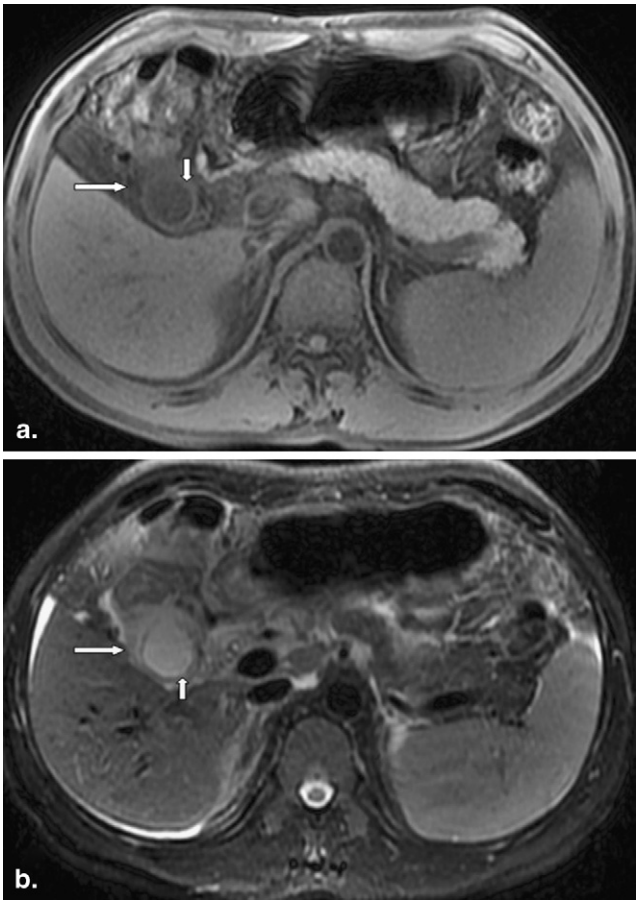

Figure 2. A 40-year-old man with moderate acute pancreatitis. The gallbladder wall was coarse and thickened with a thickness of 5 mm (*short arrows*). Pericholecystic fluid (*long arrows*) was seen as a hypointense signal on T1-weighted images **(a)** and a hyperintense signal on fast-recovery fast spin-echo T2-weighted images **(b)**.

The prevalence of gallbladder abnormalities was 64% in patients with mild AP, 81% in those with moderate AP, and 91% in those with severe AP (among the three groups, $P < .05$; between mild and moderate, $P < .05$; between moderate and severe, $P > .05$; and between mild and severe, $P > .05$). The prevalence of gallbladder abnormalities was weakly correlated with the severity of AP by the MRSI (Spearman's rank correlation coefficient $r = 0.21$, $P < .05$).

DISCUSSION

The gallbladder is affected by a variety of pathologic conditions. Although many of these conditions may cause significant morbidity and mortality if untreated, the prognosis is generally excellent when promptly diagnosed and managed. Imaging often plays an important role in the evaluation of patients with suspected gallbladder disease (18). Pancreatic diseases have a close relationship with gallbladder disorders, and imaging is a useful tool in determining the nature of the pathologic condition and in guiding the appropriate clinical therapy.

Previous studies have reported that sensitivity and specificity range from 64% to 98% for the detection of acute cholecystitis on MRI (19,28–30). Our results for sensitivity

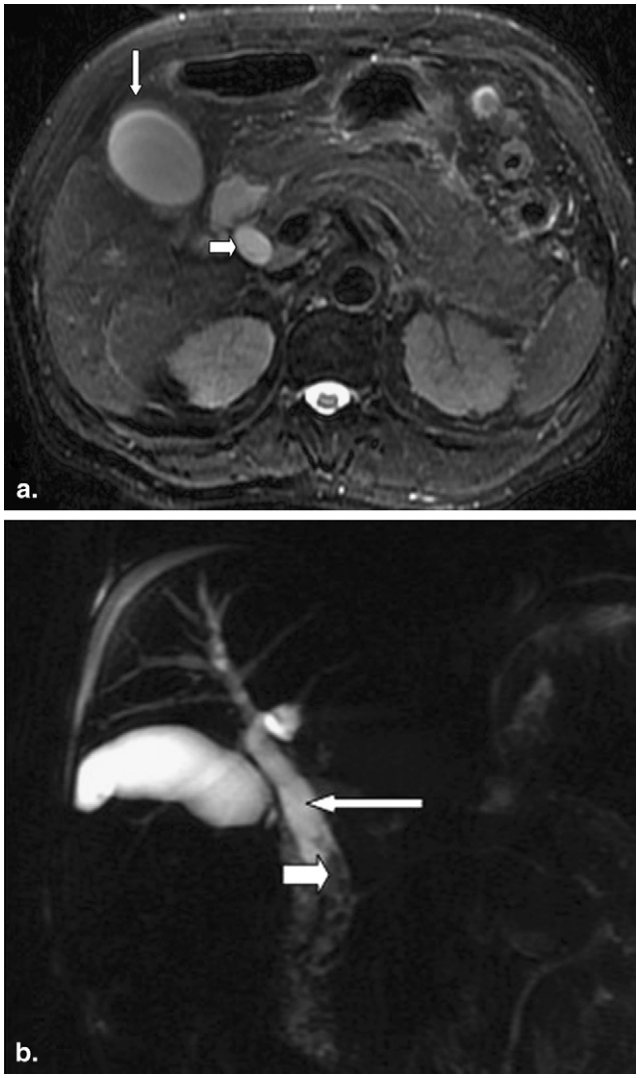

Figure 3. A 70-year-old man with mild acute pancreatitis. The gallbladder wall was thickened with a thickness of 4 mm (*long arrow*), and the common bile duct (CBD) (*short arrow*) was dilated with a diameter of 13 mm **(a)**. Magnetic resonance cholangiopancreatography **(b)** showed the enlarged gallbladder and stones (*short arrow*) in the distal end of the dilated CBD (*long arrow*).

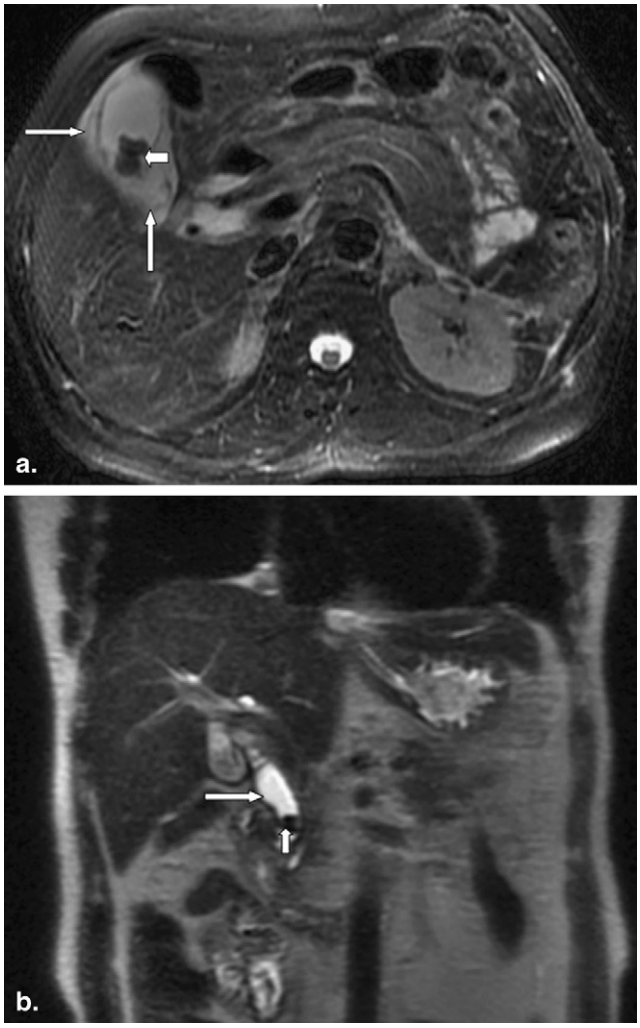

Figure 4. A 67-year-old woman with moderate acute pancreatitis. Stones can be observed in the gallbladder (*short arrow*) on fast-recovery fast spin-echo T2-weighted image **(a)**, and pericholecystic fluid can also be observed (*long arrow*). Single-shot fast spin-echo T2-weighted image **(b)** showed a dilated common bile duct (CBD) with a stone in the distal end of the CBD (*short arrow*).

and specificity were 96% and 100%, respectively, which were consonant with data reported elsewhere.

In this retrospective study, we found that 76% of patients had at least one gallbladder abnormality on MRI, including a thickened gallbladder wall (42%), pericholecystic fluid (38%), gallbladder stones (35%), and an enlarged gallbladder (24%).

Gallbladder wall thickening was the most common finding in patients with cholecystitis. However, gallbladder wall thickening is a nonspecific finding and may occur in both intrinsic and extrinsic gallbladder diseases, including cholecystitis, hepatitis, hypoproteinemia, heart failure, renal disease, myeloma, and other diseases with ascites (30). Gallbladder macerate in ascites can directly lead to gallbladder wall thickening. Furthermore, the normal gallbladder wall may appear spuriously thickened if the gallbladder is collapsed (26). In our study, 42% of patients had thickened walls, and most of the thickened walls were diffuse and uniform. It was the mucosal and submucosal diffuse hyperemia and the gallbladder edema confirmed by surgery that differed from gallbladder cancer, which presents with focal gallbladder wall thickening (31). Our results were similar to computed tomographic findings reported by Fidler et al (26). We presume that some patients with AP showed wall thickening similar to cholecystitis but did not actually have cholecystitis.

Pericholecystic fluid provides strong evidence for the presence of cholecystitis in clinical experience. Fidler et al (26) reported that pericholecystic fluid occurred in 31% of patients with acute cholecystitis, which represented a small gallbladder perforation or localized peritonitis. In our study, 38% of patients had pericholecystic fluid, which was slightly higher than reported. The first reason for this finding could

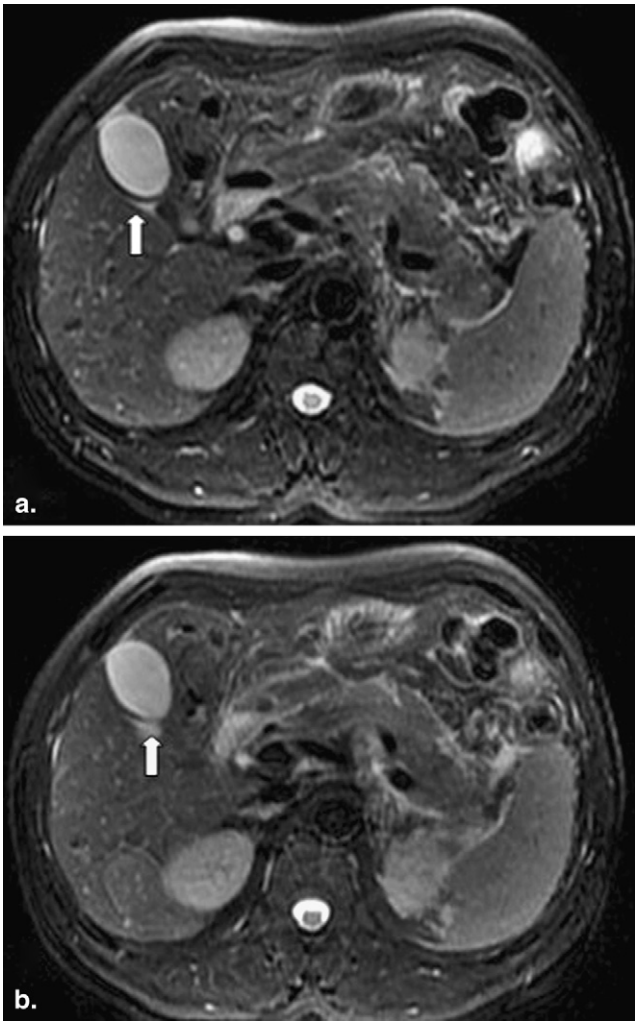

Figure 5. A 41-year-old man with moderate acute pancreatitis. Pericholecystic fluid was hyperintense (*arrows*) on fast-recovery fast spin-echo T2-weighted images **(a,b)**.

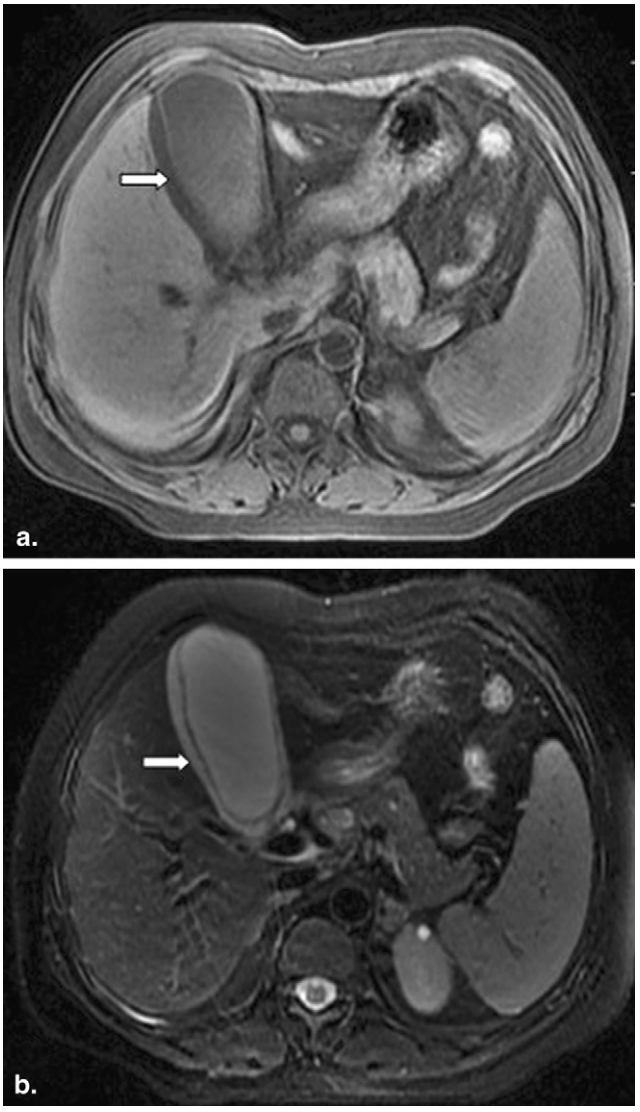

Figure 6. A 46-year-old woman with mild acute pancreatitis. The gallbladder was enlarged (long diameter, 8.5 cm) with subserosal edema that showed a hypointense signal on T1-weighted images **(a)** and a hyperintense signal on T2-weighted images **(b)** (*arrows*).

be that patients with AP have associated cholecystitis. The second reason may be the anatomic connection between gallbladder and pancreas; both the gallbladder and pancreas are located the same retroperitoneal space (5,6), and the inflammation of pancreas could spread to the gallbladder, thus causing pericholecystic fluid. The third reason may be that pancreatic juices reflux into the biliary tree when patients with AP have increased pancreatic duct pressure, and the upstream pancreatic juices lead to changes in the gallbladder (32,33). The pericholecystic fluid may reflect the degree of acute infection process spreading to the gallbladder to a certain extent.

In our study, patients with AP had associated gallbladder stones (35%), enlarged gallbladders (24%), dilatation of the CBD (16%), CBD stones (9%), dilatation of the cystic duct (8%), and cystic duct stones (3%). Indar and Beckingham (34) reported that 95% of people with acute cholecystitis have gallstones (calculous cholecystitis), 5% lack gallstones (acalculous cholecystitis), and biliary tract disease was the main etiology of severe AP in China (35). Gallstones are reported as a common finding in cholecystitis (19). However, gallstones and increased gallbladder diameter are frequently observed in both healthy individuals and patients with chronic cholecystitis. Thus, these findings have limited utility in the diagnosis of acute cholecystitis (25,26).

Staging AP is performed by grading both the degree of pancreatic and peripancreatic fluid and the extent of pancreatic necrosis. The sum of these two parameters led to the creation of the MRSI (23). Triantopoulou et al (1) initially documented disease severity according to the imaging parameters expressed by the Balthazar computed tomographic severity index score. Arvanitakis et al (17) considered MRI a reliable method for staging AP severity, because it has a higher predictive ability for local complications and the prognosis of the disease. In this study, we found that the

TABLE 4. Frequencies of Gallbladder Abnormalities in Acute Pancreatitis on Magnetic Resonance Imaging (*n* = 197)

Gallbladder Pattern	*n* (%)
Thickened gallbladder wall	83 (42)
Pericholecystic fluid	75 (38)
Gallbladder stone	69 (35)
Subserosal edema	29 (15)
Enlarged gallbladder	47 (24)
Dilatation of CBD	32 (16)
CBD stone	18 (9)
Dilatation of cystic duct	15 (8)
Cystic duct stone	5 (3)

CBD, common bile duct.

prevalence of gallbladder abnormalities in necrotizing AP was significantly higher than in edematous AP. The prevalence of gallbladder abnormalities was correlated with the severity of AP, as determined by the MRSI. The gallbladder abnormalities associated with AP may be caused by the spread of AP inflammation and may be a supplementary factor for grading the severity of AP.

Diseases of the gallbladder are often associated with the presence of gallstones; however, bile stasis, sepsis, ischemia, cholesterol, and bile acids have established effects on the gallbladder (3,4). Therefore, the pancreas and gallbladder have effects on each other. However, because of the close correlations of the anatomy and functions between the pancreas and gallbladder, both the gallbladder and pancreas are located the same retroperitoneal space (5,6), and the inflammation of the pancreas could spread to the gallbladder, thus causing pericholecystic fluid. It also may be that pancreatic juices reflux into the biliary tree when patients with AP have increased pancreatic duct pressure, and the upstream pancreatic juices lead to changes in the gallbladder (32,33). Therefore, biliary and pancreatic diseases influence each other and affect the progression of disorders, and it is difficult to differentiate the causes and effects of pancreatic and biliary disorders.

CONCLUSIONS

Seventy-four percent patients with AP had gallbladder abnormalities on MRI, including a thickened gallbladder wall, pericholecystic fluid, gallbladder stones, and an enlarged gallbladder. Being aware of these features can be valuable when assessing the severity and determining the management of AP. The prevalence of gallbladder abnormalities has a positive correlation with the severity of AP on MRI.

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