Diagnosis of complications associated with acute cholecystitis using computed tomography and diffusion-weighted imaging with background body signal suppression/T2 image fusion

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Abstract. In a clinical setting, it is important to diagnose complications of acute cholecystitis accurately. Diffusion-weighted whole body imaging with background body signal suppression/T2-weighted image fusion (DWIBS/T2) provides high signal intensity with a strong contrast against surrounding tissues in anatomical settings. In the present study, patients who were being treated for acute cholecystitis and underwent DWIBS/T2 in the National Hospital Organization Shimoshizu Hospital between December 2012 and August 2015 were enrolled. A total of 10 men and 4 women underwent DWIBS/T2. Records, including DWIBS/T2 and computed tomography (CT) imaging, were retrospectively analyzed for patients with acute cholecystitis. CT images revealed thickened gallbladder walls in patients with acute cholecystitis, and high signal intensity was observed in DWIBS/T2 images for the thickened gallbladder wall. Inflammation of the pericholecystic space and the liver resulted in high intensity signals with DWIBS/T2 imaging, whereas CT imaging revealed a low-density area in the cholecystic space. Plain CT scanning identified a low-density area in the liver, which became more obvious with contrast-enhanced CT. DWIBS/T2 imaging showed the inflammation of the liver and pericholesyctic space as an area of high signal intensity. Detectability of inflammation of the pericholecystic space and the liver was the same for DWIBS/T2 and CT, which suggests that DWIBS/T2 has the same sensitivity as CT scanning for the diagnosis of complicated acute cholecystitis. However, the strong contrast shown by DWIBS/T2 allows for easier evaluation of acute cholecystitis than CT scanning.

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Introduction

Acute cholecystitis is an inflammation of the gallbladder caused by gallstones packed in its neck or the cystic duct (1). Perforations of the gallbladder into the liver or the pericholecystic space may lead to the development of liver abscesses or peritonitis, respectively (2-4). In order to effectively manage acute cholecystitis, an accurate diagnosis must be made before the disease worsens (5). Acute cholecystitis is diagnosed based on a combination of signs indicating local and systemic inflammation (6). Local inflammation presents as right upper quadrant pain. Murphy's sign, which is a pain on taking a deep breath in the right upper quadrant when the examiner's finger is on the location of the gallbladder, is considered to be the most useful indicator for the diagnosis of local inflammation in patients with acute cholecystitis (7). Systemic inflammation is confirmed based on the findings of blood tests, with leukocytosis and elevated levels of C-reactive protein (CRP) indicating systemic inflammation (8). To confirm the diagnosis of cholecystitis, diagnostic imaging is useful; computed tomography (CT) scanning typically reveals thickened walls of the gallbladder, pericholecystic inflammation, and the presence of liver abscesses (9).

Diffusion-weighted imaging (DWI) utilizes the random movement of water molecules to construct images (10). Based on DWI, diffusion-weighted whole body imaging with background body signal suppression (DWIBS) has been developed (11,12). DWIBS images are formed with the suppression of fat signals and the application of heavy diffusion weighting during free breathing (13). DWIBS shows a strong contrast between r tissue with high signal intensity and the surrounding tissues (14). One limitation of DWIBS in some cases is the difficulty of evaluating high signal intensities in anatomical settings (15,16). To overcome this disadvantage, DWIBS images are overlapped with T2-weighted images to create DWIBS T2-weighted image

Table I. Pulse sequences used in the present study.

Variable	T1-weighted image	T2-weighted image	DWI (DWIBS)
	GRE	Single-shot SE	EPI SE
TR, msec	Shortest	1,000	11,250
TE, msec	First: 2.3 (out of phase), second: 4.6 (in phase)	90	83
Flip angle, ˚	75	90	90
NSA	1	1	4
Slice thickness, mm	8	8	5
Slice gap	1	1	0
Fat saturation	No	No	SPAIR
Phase encoding direction	Posterior-anterior	Posterior-anterior	Posterior-anterior

TR, repetition time; TE, echo time; DWI, diffusion-weighted imaging; DWIBS, diffusion-weighted whole body imaging with background body signal suppression/T2 image fusion; GRE, gradient echo; SE, spin echo; EPI, echo planar imaging; SPAIR, spectral attenuated inversion recovery; NSA, mean number of signal.

fusion (DWIBS/T2) (14,17,18). DWIBS/T2 enables the evaluation of tissues with high signal and strong contrast in fusion with T2-weighted images (19).

In the present study, the use of DWIBS/T2 and CT scanning for patients with acute cholecystitis was evaluated.

Materials and methods

Ethical statement. The Ethics Committee of the National Hospital Organization, Shimoshizu Hospital (Yotsukaidu, Japan) approved the present study. Patient records were anonymous and retrospectively analyzed. Written informed consent was obtained from all the patients prior to DWIBS/T2 and CT, with or without contrast enhancement, being performed.

Patients. Patients who were treated for acute cholecystitis and underwent DWIBS/T2 in the National Hospital Organization, Shimoshizu Hospital between December 2012 and August 2015, and for whom DWIBS/T2 and CT results were available, were enrolled in the present study. Ten men (aged 67.7±7.6 years) and 4 women (aged 70.8±13.2 years) were enrolled in the present study. No patients were treated for acute cholecystitis prior to DWIBS/T2 and CT.

Diagnosis of acute cholecystitis. Diagnosis of acute cholecystitis was based on Tokyo Guideline 13 (6). Patients were suspected of acute cholecystitis when they presented with upper abdominal pain or right upper quadrant abdominal pain accompanied by leukocytosis or elevated CRP levels. Patients were subjected to abdominal ultrasonography or CT scanning, with or without contrast enhancement. Abdominal ultrasonography and CT have previously been demonstrated to detect an enlarged gallbladder, thickened walls, and fluid collection between the liver and gallbladder or pericholecystic space (20). A positive sonographic for Murphy's sign was a reliable test for the diagnosis of acute cholecystitis (21).

Magnetic resonance imaging (MRI) techniques. The MRI studies were performed using a 1.5 Tesla scanner with Achieva software version 3.2.2 (Philips Healthcare, DA Best, The Netherlands). Patients were placed in a supine headfirst position on an extended table platform that allowed for coverage of the body from the head to the lower legs. The DWIBS/T2 imaging protocol consisted of unenhanced T1-weighted, T2-weighted, DWI, and DWIBS imaging. The MRI pulse sequences are presented in Table I. DWIBS images were acquired axially by a Q-body coil, under free breathing conditions, using an echo-planar imaging single-shot pulse sequence. DWI gradients were applied along the X, Y, and Z axes prior to and following a 180˚ inversion pre-pulse to obtain fat-saturated isotropic images with DWI sensitivity. The following parameters were used for a single stack: B-value, 0 and 800 mm^2/sec; repetition time, 6,960 msec; echo time, 7 msec; inversion recovery, 150 msec; acquisition matrix, 176x115; reconstruction matrix, 256; right/left field of view, 530 mm; anterior/posterior field of view, 349 mm; feet/head field of view, 226 mm; slice thickness, 6 mm; and size of reconstructed voxels, 2.07x2.08x6 mm^3. Fused DWIBS/T2 images were constructed using an Extended MR WorkSpace workstation (Phillips Healthcare). For all patients, five stacks were acquired consecutively to obtain images from the head to the middle of the tibia, with each stack consisting of 45slices. Overall, the average required imaging time was 13.31 min. To rule out T2 shine-through effects and to differentiate malignant lesions from non-malignant causes of restricted diffusion, a decreased signal on the apparent diffusion coefficient (ADC) was used with ADC reduction, to determine a 'positive ADC map' (22).

CT scanning. CT scanning was performed using a 16-detector row CT scanner (SOMATOM Emotion 16; Siemens AG, Munich, Germany). Imaging parameters for three-phase contrast-enhanced images were as follows: Tube voltage, 130 kVp; gantry rotation speed, 0.6 rotations/sec; maximum allowable tube current, 120 mA. For some patients, contrast medium (100 ml of iopamidol; 3 ml/sec; Konica Minolta, Inc., Tokyo, Japan) was administered intravenously. CT images were acquired prior to and at 30, 70, and 180 sec following injection of contrast medium.

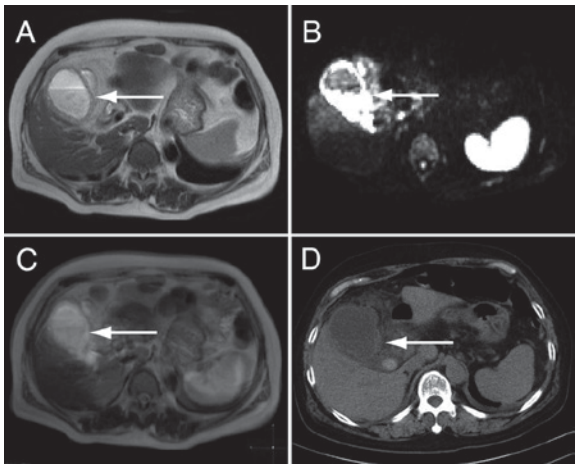

Figure 1. Thickening and high signal intensity in the gallbladder wall of a patient with acute cholecystitis. A 70-year-old woman presented with upper abdominal pain. (A) T2-weighted imaging revealed a thickened gallbladder wall. (B) High signal intensity in the gallbladder wall was observed with DWIBS. (C) The fusion image of T2-weighted imaging and DWIBS showed high signal intensity in the wall of the gallbladder. The high signal intensity with DWIBS indicated inflammation. (D) A thickened gallbladder wall was also observed in computed tomography images. Arrows indicate the gallbladder wall. All the figures were representative of the participants in the present study. DWIBS, diffusion-weighted whole body imaging with background body signal suppression.

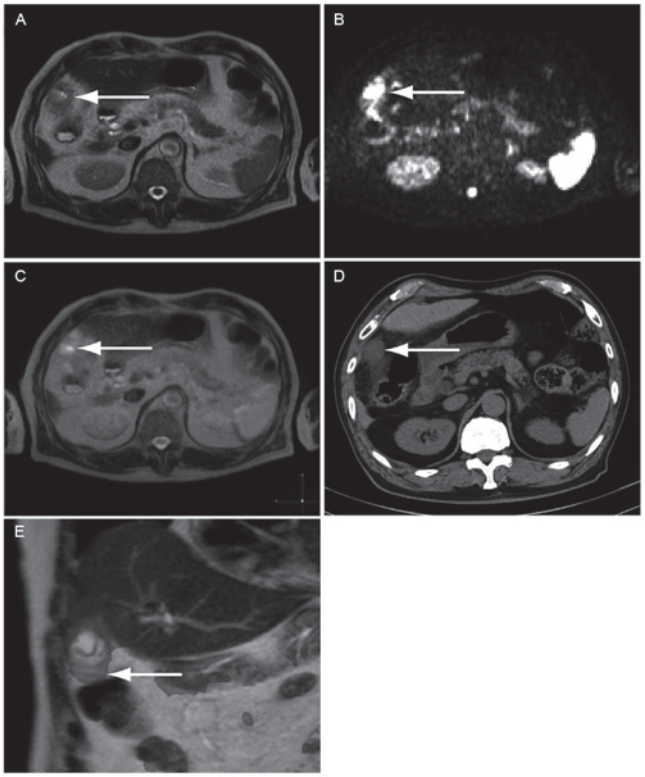

Figure 2. Pericholecystic inflammation. An 86-year-old man presented with upper abdominal pain. (A) T2-weighted imaging revealed a pericholecystic space. (B) DWIBS showed an area of high signal intensity in the pericholecystic space. (C) Anatomical analysis of the area of high signal intensity was conducted using DWIBS/T2. (D) Computed tomography images contained a low-density area in the pericholecystic space. (E) A cross section of DWIBS/T2 revealed pericholecystic inflammation. Arrows indicate the area of pericholecystic inflammation. All the figures were representative of the participants in the present study. DWIBS, diffusion-weighted whole body imaging with background body signal suppression; DWIBS/T2, DWIBS and T2 image fusion.

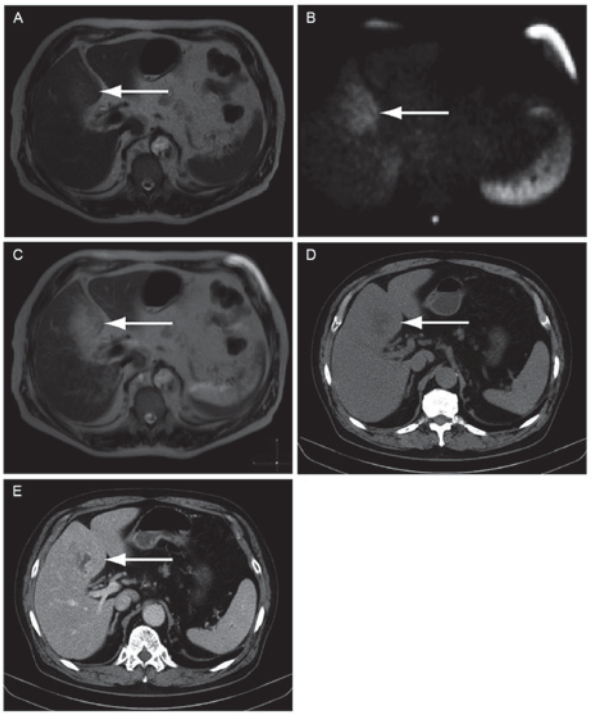

Figure 3. Liver inflammation due to acute cholecystitis. (A) A T2-weighed image of a 70-year-old man with acute cholecystitis found a weak high signal intensity in the liver. (B) High signal intensity was observed in the liver with DWIBS. (C) The fusion image of T2-weighted images and DWIBS clearly showed the high signal intensity in the liver. (D) Plain CT scanning identified an irregularly shaped, low-density area in the liver. (E) The low-density area became more obvious with contrast-enhanced CT. Arrows indicate the area of liver inflammation. All the figures were representative of the participants in the present study. DWIBS, diffusion-weighted whole body imaging with background body signal suppression; CT, computed tomography.

Results

The thickness of the gallbladder wall in DWIBS/T2 and CT images was compared. T2-weighted imaging revealed a thickened wall (Fig. 1A), and the signal intensity of the thickened wall was high with DWIBS (Fig. 1B). Fusion images of DWIBS and T2-weighted images showed high signal intensity of the gallbladder wall and allowed for anatomical analysis (Fig. 1C), which was not possible from the DWIBS image alone. The high signal intensity with DWIBS indicated inflammation. A thickened gallbladder wall was also observed in the CT images (Fig. 1D). These results suggest that gallbladder wall thickening is easily detectable using both DWIBS/T2 and CT imaging.

Pericholecystic inflammation is one of the complications of acute cholecystitis (9). T2-weighted imaging revealed a space around the gallbladder (Fig. 2A), which gave a high signal intensity with DWIBS (Fig. 2B). DWIBS/T2 showed high signal intensity for the gallbladder wall (Fig. 2C). The pericholecystic inflammation appeared as a low-density area in the CT images (Fig. 2D). The high signal intensity with DWIBS/T2 enabled easier detection than with CT, indicating that DWIBS/T2 shows pericholecystic inflammation more clearly than CT (Fig. 2E).

Liver abscess and liver inflammation are additional complications of acute cholecystitis (9). A weak high intensity signal was observed in the T2-weighted images for the liver (Fig. 3A).

Table II. Patient characteristics.

			Liver inflammation		Pericholecystic changes		Wall thickening	
Patient no.	Age, years	Sex	DWIBS/T2	CT	DWIBS/T2	CT	DWIBS/T2	CT
1	69	M	(-)	(-)	(-)	(-)	(+)	(+)
2	70	M	(-)	(-)	(-)	(-)	(+)	(+)
3	68	M	(-)	(-)	(-)	(-)	(+)	(+)
4	69	M	(-)	(-)	(-)	(-)	(+)	(+)
5	79	M	(+)	(-)	(+)	(+)	(+)	(+)
6	65	M	(-)	(-)	(+)	(+)	(+)	(+)
7	69	M	(-)	(-)	(+)	(+)	(+)	(+)
8	70	F	(-)	(-)	(+)	(+)	(+)	(+)
9	76	F	(+)[a]	(+)[a]	(-)	(-)	(+)	(+)
10	70	M	(+)	(-)	(-)	(-)	(+)	(+)
11	72	F	(-)	(-)	(-)	(-)	(-)	(-)[b]
12	88	M	(-)	(-)	(+)	(+)	(+)	(+)
13	50	F	(-)	(-)	(+)	(+)	(+)	(+)
14	50	F	(-)	(-)	(-)	(-)	(+)	(+)

M, male; F, female; DWIBS/T2, diffusion-weighted whole body imaging with background body signal suppression/T2 image fusion; CT, computed tomography, (+), present; (-), absent. [a]Indicates liver abscess and [b]indicates wall thickened after three days.

Table III. Laboratory test variables.

	Liver inflammation			Pericholecystic changes		
Parameter	(+), n=3	(-), n=11	P-value	(+), n=6	(-), n=8	P-value
WBC, x10^3/ml	17.4±11.2	9.8±4.3	0.08	11.0±4.3	12.0±8.3	0.76
CRP, mg/dl	15.5±5.6	6.2±2.4	0.09	8.4±10.6	8.1±7.2	0.95
ALP, IU/l	645±204	462±106	0.44	367±257	602±389	0.25
AST, IU/l	63±20	123±75	0.69	36±25	168±284	0.28
ALT, IU/l	77±20	85±183	0.94	37±30	119±210	0.37
γ-GTP, IU/l	226±70	232±273	0.97	126±83	320±313	0.17
LDH, IU/l	214±40	300±154	0.37	228±62	305±162	0.40
BUN, mg/dl	16±6	17±2	0.78	14±5	17±6	0.35
Cre, mg/dl	0.75±0.25	0.82±0.16	0.59	0.82±0.14	0.79±0.20	0.78

Data are presented as the mean ± standard deviation. (+), detected; (-), not detected; WBC, white blood cell count; Hb, hemoglobin; CRP, C-reactive protein; ALP, alkaline phosphatase; AST, aspartate aminotransferase: ALT, alanine aminotransferase; γ-GTP gamma-glutamyl transpeptidase; LDH, lactate dehydrogenase; BUN, blood urea nitrogen; Cre, creatinine.

An area with high signal intensity was observed for the liver with DWIBS (Fig. 3B). DWIBS/T2 images, however, clearly showed high signal intensity in the liver (Fig. 3C). The high intensity with DWIBS/T2 shown in Fig. 3C was less obvious than Figs. 1C and 2C. The possible reason was that the intensity of the inflammation was less severe in that shown in Fig. 3C compared with Figs. 1C and 2C. A low-density area was observed in liver when plain CT was used (Fig. 3D), and contrast-enhanced CT made this low-density area more obvious (Fig. 3E).

Detectability of inflammation of the pericholecystic space and the liver were compared between DWIBS/T2 and CT images (Table II). There was no obvious difference in detectability for either condition between DWIBS/T2 and CT.

The correlation between positive DWIBS/T2 results and laboratory test variables was also investigated (Table III). White blood count and CRP levels tended to be higher in patients whose DWIBS/T2 images indicated inflammation or liver abscesses; however, this difference was not statistically significant. These results suggested that acute cholecystitis is more severe in patients for whom there is a high signal density on the DWIBS/T2 image. DWIBS/T2 may therefore be more useful for the detection of severe acute cholecystitis.

Discussion

MRI imaging typically reveals gallbladder wall thickening and pericholecystic fluid in patients with acute cholecystitis (23), and is reported to be superior to CT for the diagnosis of acute cholecystitis (24). In the present study, DWIBS/T2 was as successful as CT imaging in identifying wall thickening and pericholecystic inflammation. Furthermore, compared with CT, DWIBS/T2 showed positive results more clearly due to the strong contrast between the target and surrounding tissues.

Liver abscesses typically appear as an irregularly shaped, low-density area, with slight signal enhancement in surrounding tissues (25). One patient in the present study had a liver abscess, and this was easily diagnosed via DWIBS/T2 or CT scanning. For this patient, a small liver abscess was observed in a contrast-enhanced CT image. DWIBS/T2 revealed an area of high signal intensity around the abscess. These results indicate that, in this case, DWIBS/T2 was able to reveal an area of inflammation in the liver that was developing into a liver abscess. The high signal intensity area observed with DWIBS/T2 appeared as a slight enhancement in the CT image, and was easy to detect. However, DWIBS/T2 indicated the area more clearly as the high signal intensity was strongly contrasted against the surrounding tissues. These results suggested that DWIBS/T2 enables easier evaluation of liver abscesses and the surrounding inflammation compared with CT.

One limitation of the present study was the small number of patients. Furthermore, the other complications that typically occur with cholecystitis, such as gallbladder perforation, emphysema, and gangrene, were not investigated. In future studies, a greater number of patients should be included to evaluate a broader set of complications.

In conclusion, the results of the present study suggest that DWIBS/T2 has the same sensitivity as CT for the diagnosis of complicated acute cholecystitis. However, the strong contrast shown by DWIBS/T2 allows for easier evaluation of acute cholecystitis than CT scanning. These findings may be beneficial in a clinical setting as they allow doctors to select the most effective diagnostic imaging technique for patients with suspected cholecystitis.

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