Diffusion-weighted MR Imaging (DWI) in the differentiation of benign from malignant lesions in the gallbladder

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Purpose

Imaging findings of focal or diffuse wall thickening type or mass replacing the gallbladder type may mimic the appearance of cholecystitis. DWI can be helpful in the diagnosis of gallbladder carcinoma and differentiation it from inflammatory conditions of the gallbladder. The purpose of our study was to investigate the value of DWI in the distinction of malignant from benign lesions of the gallbladder.
Methods and Materials

Patients

This study was approved by the institutional review board of our hospital, and the requirements for informed consent were waived because of the retrospective study.

By performing a computerized search of pathologic and MR imaging reports, we identified 133 patients who underwent MR examination combined with DW imaging before cholecystectomy or US-guided biopsy of the gallbladder mass between February 2009 and December 2010.

After a brief review of retrieved reports and MR images by one radiologist, 4 patients were excluded whose images showed poor image quality. Three patients were also excluded due to previous biliary interventional procedures. As a result, the remaining 126 patients were included in our study.

The study population consisted of 79 men and 47 women (age range: 19-80 years; mean age, 59.8 years). The mean interval from MRI to surgery or biopsy was 10.9 days (range, 0-27 days).

Histology results of all lesions were reviewed by an experienced gastrointestinal pathologist. Final diagnoses were adenoma (n=2), cholesterol polyp (n=2), xanthogranulomatous cholecystitis (n=5), acute cholecystitis (n=17), adenomyomatosis (n=3), chronic cholecystitis (n=62), and gallbladder cancer (n=35).

MR technique

In our institution, MR imaging was performed with a superconductive 1.5-T imaging unit (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany) for 67 patients and a 3.0-T imaging unit (Magnetom Trio, Siemens Medical Solutions) for 59 patients by using a phased-array multcoil.

For DWI, respiratory-triggered, fat-suppressed, single-shot echo planar imaging was performed in the transverse plane with parallel imaging (generalized autocalibrating, partially parallel acquisition) acceleration factor of 2. Each acquisition was obtained using three b-values (0, 500, and 800 s/mm²). The imaging parameters of DWI in the 1.5-T
unit were as follows: 5000/103 (repetition time ms/echo time ms), 90° flip angle, 4-mm section thickness, 1-mm intersection gap, 964-Hz/pixel bandwidth, 20 slices, 230-mm field of view, 192×192 matrix, and 85-s acquisition time. Imaging parameters in the 3.0-T unit were as follows: 3900/92 (repetition time ms/echo time ms), 90° flip angle, 5-mm section thickness, 0.5-mm intersection gap, 1184-Hz/pixel bandwidth, 24 slices, 230-mm field of view, 192×192 matrix, and 85-s acquisition time. The ADC map was generated automatically with the built-in software of the MRI unit.

Thick single-slice turbo spin-echo MRCP was obtained in the coronal plane. The imaging parameters of MRCP was 4500/789 (repetition time ms/echo time ms), 180° flip angle, 40-mm section thickness with no gap, 350 mm field of view, 384×384 matrix, and 4.5 s acquisition time in the 1.5-T unit and 4500/461 (repetition time ms/echo time ms), 180° flip angle, 80 mm section thickness with no gap, 350×350 mm field of view, 384×384 matrix, and 4.5 s acquisition time in the 3.0-T unit.

**Image Evaluation**

Two gastrointestinal radiologists, who were blinded to information obtained the pathologic results, retrospectively reviewed the two images set; the T2-weighted image (T2WI) set and combined set of T2WI and diffusion-weighted image (DWI).

First, the observers independently reviewed the T2WI alone. To minimize any learning bias, these radiologists evaluated the combined T2WI and DWI 4 weeks after the analysis of T2WI alone.

They recorded the pattern according to extent of wall thickening, presence or absence of layered pattern, and extent of the mass on the basis of imaging finding (Fig. 1).

- The layered pattern was determined when each layer of gallbladder wall could be distinguished into inner and outer layer.
- A thick gallbladder wall was defined as thicknesses more than 3 mm.
- The polypoid mass was defined as more than 15 mm in largest diameter.

Disagreements were resolved by consensus. Also, these radiologists quantitatively analyzed the ADC value of gallbladder lesion.

**(1) T2WI analysis.**

The gallbladder lesions were classified into one of seven patterns on T2WI.
• Type 1 was defined as a thin gallbladder wall without layered pattern.
• Type 2 was defined as two layers with a thin hypointense inner layer and thick hyperintense outer layer.
• Type 3 was defined as a segmental or focal wall thickening without layered pattern.
• Type 4 was defined as a diffuse wall thickening without layered pattern.
• Type 5 was defined as a mass replacing the gallbladder.
• Type 6 was defined as a polypoid mass in the gallbladder.
• Type 7 was defined as multiple hyperintense cystic spaces in the wall.

Additionally, we classified these types broadly into two main groups, benign lesion (type 1, 2, and 7) and malignant lesion (type 3, 4, 5, and 6).

(2) Combined T2WI and DWI

After detecting the location of gallbladder lesion through T2WI analysis, the radiologists analyzed DWI with b factors of 0, 50, 500, 800 and 1000 s/mm² including the ADC map.

The gallbladder lesions were classified into one of seven patterns on high b-value DWI on basis of same criteria as applied on T2WI.

• Type 1 defined as a thin gallbladder wall without increased signal intensity.
• Type 2 defined as two layers with a thin hypointense inner layer and thick hyperintense outer layer.
• Type 3 defined as a segmental or focal hyperintense wall thickening without layered pattern.
• Type 4 defined as a diffuse hyperintense wall thickening without layered pattern.
• Type 5 defined as a hyperintense mass replacing the gallbladder.
• Type 6 defined as a hyperintense polypoid mass in the gallbladder.
• Type 7 defined as a focal or segmental hyperintense gallbladder lesion on the high B-value DWI and ADC map.

When gallbladder lesions were difficult to evaluate because signal intensity of the bile was not suppressed due to T2 shine-through effect, the observers were referred to the ADC map.

Also, like analysis of T2WI, we classified these types broadly into two main groups, benign lesion (type 1, 2, and 7) and malignant lesion (type 3, 4, 5, and 6).

(3) Quantitative analysis.
ADC values were calculated by placement of regions of interest (ROIs) within the gallbladder lesions. ADC was measured by an observer who had not preformed T2WI and DWI analysis. The radiologist drew ROIs as large as possible within the lesion and measured twice, after which the averaged ROI values were obtained as the mean signal intensity of the lesions. For lesions (Type 1) that were too small to receive an ROI, ADC values were not measured.

ADC values were recorded separately for the 1.5T and 3.0T MRI scans. Another observer who knew the pathologic diagnosis recorded ADC values separately for benign and malignant lesions.

**Statistical analysis**

The sensitivity, specificity, PPV, and NPV of pattern analysis on T2WI alone and combined T2WI and DWI in the diagnosis of gallbladder cancer were calculated respectively.

Diagnostic performance of each imaging set for all gallbladder lesions was calculated with receiver operating characteristic (ROC) curve analysis. The area under the ROC curve (AUC) was evaluated for models of malignant gallbladder lesion prediction on the basis of the T2WI alone and combined T2WI and DWI.

In addition, we attempted to compare the ADC values of the benign and malignant gallbladder lesions separately for 1.5T and 3.0T MRI by using the Mann-Whitney U test.

For all tests, differences were considered to be statistically significant when $P$ values were less than .05.

Statistical analyses were performed by using SPSS software package (version 11.0) and MedCalc for Windows (version 9.6.4.0).
**Fig. 1:** This schematic image shows different types of gallbladder disease include thin gallbladder wall, two layers, focal, diffuse wall thickening, mass replacing, polypoid mass and multiple cystic space in the wall.

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Results

T2WI analysis

1. 47 patients were classified as malignant lesions (type 3, 4, 5, and 6).
2. 79 patients were classified as benign lesions (type 1, 2, and 7).
3. The sensitivity, specificity, PPV, and NPV of pattern analysis on T2WI for the diagnosis of gallbladder cancer were 97.1%, 85.7%, 72.3% and 98.7% respectively.

Combined T2WI and DWI

1. 43 patients were classified as malignant lesions (type 3, 4, 5, and 6).
2. 83 patients were classified as benign lesions (type 1, 2, and 7).
3. The sensitivity, specificity, positive predictive values and negative predictive values on combined T2WI and DWI for diagnosis of gallbladder cancer were 97.1%, 90.1%, 79.1% and 98.8% respectively.

Comparison of T2WI alone and combined T2WI and DWI

1. The sensitivity for the diagnosis of gallbladder cancer between T2WI and combined T2WI and DWI equal.
2. The specificity, positive predictive value and negative predictive value were higher on combined combined T2WI and DWI than T2WI alone (Figs. 1-3).
3. The histologic results in the nine false-positive lesions on T2WI alone and combined T2WI and DWI simultaneously included chronic cholecystitis in four case and xanthogranumatois cholecystitis in five cases (Figs. 1, 4). Four lesions which were false positive with T2WI correctly characterized with the addition of DWI: adenoma (n=2), chronic cholecystitis (n=2) (Fig. 1).
4. The AUC for the DWI plus T2WI(0.936, 95% confidence interval [CI]: 0.878-0.972) was significantly larger than the AUC for the T2WI alone (0.914, 95% CI: 0.851-0.957) (Z=2.034, P < .05) (Table 1).

Analysis of the ADC value of the gallbladder

Mean ADCs for malignant lesions were significantly lower than those for benign gallbladder lesions (Table 2)(Figs 1- 4).

1. At 1.5T, mean ADC of malignant and benign lesions was $1.00 \times 10^{-3}$ and $1.61 \times 10^{-3} \text{ mm}^2/\text{sec}$, respectively (P <.005).
2. At 3.0 T, mean ADC of malignant and benign lesions was $1.06 \times 10^{-3}$ and $1.94 \times 10^{-3}$ mm$^2$/sec, respectively ($P < .005$).
Table 1: The area under curve for the DWI plus T2WI (0.936, 95% confidence interval [CI]: 0.878-0.972) was significantly larger than the AUC for the T2WI alone (0.914, 95% confidence interval [CI]: 0.851-0.957) ($Z=2.034$, $P < .05$).

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Table 2: Analysis of the ADC value of the gallbladder lesions revealed that the mean ADCs for malignant lesions were significantly lower than those for benign gallbladder lesions.

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Fig. 3: Cholecystitis with intramural abscess in a 52-year-old man. (a) CT shows focal wall thickening in the body of the gallbladder (b) T2-weighted image shows focal wall thickening without layered pattern at the gallbladder body that we classified as type 3 malignant gallbladder lesion (c) DWI at b=50, 500, 1000 s/mm² shows focal iso signal intensity in the body of the gallbladder (arrow). (c) ADC value is measured as 1.61 × 10⁻³ mm²/sec.

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Fig. 2: Gallbladder carcinoma (Type 3) in a 77-year-old woman. (a) T2-weighted MR images shows focal wall thickening (arrow) in the gallbladder. (b) DWI at b=800 s/mm² shows focal asymmetric high signal intensity in the fundic portion of the gallbladder (arrow). (c) ADC value is measured as 0.97 × 10⁻³ mm²/sec.

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Fig. 4: Gallbladder carcinoma (Type 3) in a 61-year-old woman. (a) T2-weighted MR images shows focal wall thickening (arrow) in the body of gallbladder. (b) DWI at b=800 s/mm² shows focal asymmetric high signal intensity in the body portion of the gallbladder (arrow). Purulent bile shows high signal intensity on high b-value DWI. Metastatic lymph node in the portocaval space (arrowhead) is more evident on high b-value DWI. (c) By contrast, non-purulent bile in the non-dependent portion of the gallbladder returns low signal.
signal intensity with bright on ADC map. ADC value is measured as 1.17 × 10⁻³ mm²/sec.

Fig. 5: Xanthogranulomatous cholecystitis in a 74-year-old man. (a) T2-weighted MR images shows focal wall thickening (arrow) in the fundic portion of gallbladder (Type 3). (b) DWI at b=800 s/mm² shows focal asymmetric high signal intensity in the fundic portion of the gallbladder (arrow). Therefore we classified as malignant gallbladder lesion (Type 3). Purulent bile shows high signal intensity on high b-value DWI. (c) By contrast, non-purulent bile in the non-dependent portion of the gallbladder returns low signal intensity with bright on ADC map. ADC value is measured as 1.30 × 10⁻³ mm²/sec.

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Conclusion

The mean ADC value of malignant gallbladder lesions was significantly higher than that of benign gallbladder lesions.

In conclusion, adding interpretation of the diffusion-weighted image to the T2-weighted image was useful for differentiating malignant gallbladder lesion.

Diffusion-weighted image can be useful for assessment of benign or malignant gallbladder lesions in patients with renal impairment, because contrast-enhanced CT or MR scans should be avoided.
References


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