The effectiveness of diffusion-weighted magnetic resonance imaging in diagnosis of acute cholecystitis

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Aims and objectives

Acute cholecystitis is described as acute inflammation in the gallbladder wall, regardless of reason (1). Ultrasonography is primarily used for the visualization of acute cholecystitis; however, both computerized tomography and magnetic resonance imaging also contribute to imaging of the gallbladder. The characteristic imaging findings of acute cholecystitis are thickened gallbladder wall, enlarged gallbladder, and pericholecystic fluid accumulation (2). Systemic diseases, such as liver cirrhosis, heart failure, and kidney failure, may lead to diffuse gallbladder thickening accompanied by pericholecystic fluid (3). It is not always possible to make the differential diagnosis using conventional imaging methods.

There are studies in the literature about the visualization of inflammatory diseases of the gastrointestinal tract including acute appendicitis, inflammatory bowel diseases, and pancreatitis using diffusion weighted imaging (DWI) (4-7). Additionally, there are studies in the literature concerning the use of DWI in differential and preliminary diagnosis of benign and malignant lesions (8, 9). However, according to our research, there is no study in the literature about the use of DWI and apparent diffusion coefficient (ADC) value quantification in the diagnosis of acute cholecystitis.

The aim of this study was to evaluate the efficiency of DWI and ADC value quantification in the diagnosis of acute cholecystitis, as well as in the differentiation of acute cholecystitis from gallbladder wall thickening caused by ascites in the abdomen, with histopathological confirmation.

Methods and materials

Patient Selection

This prospective study was performed between March 2012 and September 2013. A total of 39 consecutive patients (17 male, 22 female; mean age: 52±14.6 years; age range, 27-89 years) who were admitted with the preliminary diagnosis of cholecystitis according to their clinical and laboratory findings and subsequently diagnosed with cholecystitis by ultrasonographic examination were included in this study. The initial diagnoses were eventually confirmed with the histopathological examination of resected specimens. The control group consisted of 18 individuals (13 male, 5 female; mean age: 58.5±12.9 years, age range: 30-80 years) without any symptoms of gallstones and cholecystitis but whose gallbladder walls revealed three millimeters or more thickening due to fluid in abdomen.
during ultrasonographic examination. Approval by the ethics committee and informed consent from all patients were obtained for the study.

**Imaging**

Abdominal MRI examinations of the study and control groups were performed with Magnetom Symphony 1.5 Tesla (Siemens AG Medical Solutions, Erlangen, Germany) using body coil. The gradient force of the superconductive (niobium-titanium) magnet was 30 mT/m, and the maximum field-of-view (FOV) width was 400 mm. Before the single shot echo-planar DWI examination of the all patients in the study and control groups, a T2-weighted Truefast imaging with steady state precession (True-FISP) sequence in the axial plane (TR, 4.4 s; TE, 2.2 s; average, 2; flip angle, 80°; matrix, 256×256; slice number, 25; slice thickness, 5 mm; slice gap, 15%) with breath hold were obtained. The diffusion-weighted single shot echo-planar sequence and chemical shift selective fat suppression were obtained without breath hold and without contrast medium (TR/TE, 300/94 sec; matrix, 128×128; slice number, 25; slice gap, 15%; slice thickness, 5 mm; FOV, 350-380 mm; time, 2.26 min; PAT factor, 2; PAT mode, generalized autocalibrating partially parallel acquisitions [GRAPPA]). The protocol used in our clinic for echo-planar DWI was as follows: 50 sec/mm$^2$, 400 sec/mm$^2$, 800 sec/mm$^2$, and ADC map.

**Image analysis**

Once obtained, the True-FISP and DWI sequences were transferred to an independent workstation (Leonardo Syngo 2002B, Siemens AG Medical Solutions) to evaluate the DWI data and remodel the ADC maps. One radiologist assessed the data. True-FISP images were assessed in terms of existence of gallbladder wall thickening, gallstones, and pericholecystic fluid. DWI examinations were evaluated, and the mean ADC values were calculated from ADC maps. For each group, three measurements were performed from the thickened gallbladder wall and the mean ADC values were calculated.

In the case group cholecystitis was defined as hyperintensity of gallbladder wall compared to gallbladder content on b:800 sec/mm$^2$ DWI, and hypointensity of gallbladder wall compared to gallbladder content on ADC maps (Fig. 1, 2). ROI areas were defined between 12 and 49 mm$^2$ according to the application area.

On b:800 sec/mm$^2$ DWI gallbladder wall could not be distinguished from the control group; however, it was able to be distinguished as slightly hypointense compared to gallbladder content on ADC maps (Fig. 3). ROI areas on ADC maps of the control group were between 20-49 mm$^2$. ADC values of study and control group were compared. The same observer calculated all ADC measurements in the study and control groups.
Statistical analysis

Descriptive statistics for studied variables (characteristics) were presented as mean, standard deviation, minimum and maximum values. Student t-test was used to compare control and study group means for the studied variables. In addition, one-way ANOVA test was used to compare subgroups of the study group. For determination of linear relationships among the variables, Pearson correlation analysis was carried out. The cut-off value of ADC was determined by ROC curve analysis. Statistical significance levels were considered as 5%. The SPSS (Statistical Package for Social Sciences, version 13.0, SPSS Inc., Chicago, Illinois, USA) statistical program was used for all statistical computations.

Images for this section:

**Fig. 1:** Acute cholecystitis in a 80-year-old woman. The gallbladder wall shows restricted diffusion on DWI (A) and is hypointense on ADC map (B). The mean ADC value is 1.68x10-3 mm2/s.
Fig. 2: Acute cholecystitis in a 27-year-old woman. The gallbladder wall shows restricted diffusion on DWI (A) and is hypointense on ADC map (B). The mean ADC value is $1.54 \times 10^{-3}$ mm$^2$/s.

Fig. 3: 57 years old man patient with cirrhosis. (A) On T2-weighted sequence in the axial plane, gallbladder wall thickening is demonstrated. On DWI, restricted diffusion isn't detected on gallbladder wall (B). The mean ADC value is $2.70 \times 10^{-3}$ mm$^2$/s (C).
Results

In 32 of 39 patients, the gallbladder wall was visualized in varying degrees of hyperintensity compared to gallbladder content on DWI with a b value of 800 sec/mm\(^2\) and hypointensity compared to gallbladder content on ADC map. The diagnosis of these 32 patients were confirmed with postoperative histopathological assessment. Surgical treatment was performed within 24 hours after DWI. Seven of the 39 patients whose diagnosis could not be made upon histopathological examination were excluded from the study.

Histopathological examination revealed that 24 of the patients had acute cholecystitis, five had chronic cholecystitis, and three had eosinophilic cholecystitis. The mean ADC value of patients with acute cholecystitis was 1.58±0.29x10\(^{-3}\) mm\(^2\)/sec (range: 1.06-2.09x10\(^{-3}\) mm\(^2\)/sec), the mean ADC value of patients with chronic cholecystitis was 1.92±0.13x10\(^{-3}\) mm\(^2\)/sec (range: 1.77-2.13x10\(^{-3}\) mm\(^2\)/sec) and the mean ADC value of patients with eosinophilic cholecystitis was 1.56±0.09x10\(^{-3}\) mm\(^2\)/sec (range, 1.45-1.64x10\(^{-3}\) mm\(^2\)/sec). There was not a statistically significant difference between mean ADC values of these subgroups (p>0.05).

The mean ADC value of patients histopathologically diagnosed with cholecystitis was 1.64±0.30X10\(^{-3}\) mm\(^2\)/sec (range: 1.06-2.13x10\(^{-3}\) mm\(^2\)/sec) and the mean ADC value of the control group was 2.35±0.24x10\(^{-3}\) mm\(^2\)/sec (range: 1.94-2.76x10\(^{-3}\) mm\(^2\)/sec). Mean ADC values of patients diagnosed with cholecystitis were significantly lower than the mean ADC values of the control group (p<0.05).

On receiver operator characteristics (ROC) curve analysis based on ADC values of the study and control groups, the cut-off value for the diagnosis of cholecystitis was 2.04x10\(^{-3}\) mm\(^2\)/sec, with a sensitivity of 94% and a specificity of 89.7% (Fig. 4).

Images for this section:
Fig. 3: 57 years old man patient with cirrhosis. (A) On T2-weighted sequence in the axial plane, gallbladder wall thickening is demonstrated. On DWI, restricted diffusion isn't detected on gallbladder wall (B). The mean ADC value is 2.70x10^{-3} \text{ mm}^2/\text{s} (C).
**Fig. 4:** On receiver operator characteristics (ROC) curve analysis based on ADC values of the study and control groups, the cut-off value for the diagnosis of cholecystitis was 2.04x10-3 mm²/sec, with a sensitivity of 94% and a specificity of 89.7%.
Conclusion

DWI is a noninvasive imaging method which reflects the motion of water protons in vivo. The motion of water protons in tissue is affected by factors such as organization of tissue, structure of extracellular distance, and cellular intensity of tissue (10, 11). Initially, DWI was used for the visualization of cerebral infarctions (12). The apparent decrease in diffusion in cerebral infarction is attributed to fluid balance changes in intracellular and extracellular compartments due to massive ion and water influx, so called cytotoxic edema (13).

Many studies conducted on the use of DWI in the differential diagnosis of benign and malignant lesions have been reported in the literature (12, 13, 14). The main reasons for the decrease in diffusion in malignant lesions are cell density, high nucleus/cytoplasm ratio and tissue disorganization (10, 11, 14).

The major limitations of DWI are low signal-to-noise ratio and sensitivity to artifacts (14). Its use in abdominal examinations was restricted due especially to its sensitivity to movement artifacts. Thanks to improvements in ultrafast magnetic resonance imaging techniques, at present it is widely used in abdominal examinations (4-9, 12).

The b value used in DWI is important. ADC values tend to become higher when low b values are used due to the contribution of perfusion. Therefore, the maximum b value should be kept higher in order to obtain more correct data on molecular diffusion of water. Signal-to-noise ratio decreases as b value increases and it requires maximum b value to be at an acceptable value. Another way to decrease the perfusion contribution of low maximum b value to ADC is to keep the minimum b value as a slightly higher from the 0 sec/mm² (14). In our study, we used b values of 50, 400, and 800 sec/mm², and these b values provided us sufficient quality of image.

DWI is used for the differential diagnosis of benign and malignant lesions in many organs, and many studies exist in the literature about the diagnostic contribution of DWI in inflammatory diseases of the gastrointestinal tract including acute appendicitis, inflammatory bowel diseases, and acute pancreatitis. Two studies conducted on the diagnosis of acute appendicitis via DWI demonstrated that an inflamed appendix showed high signal intensity on DWI and low values on ADC map. Both studies reported that DWI use in acute appendicitis had high sensitivity and specificity (4, 15). A study conducted by Kılıçkesmez et al. (16) on patients with ulcerative colitis identified that rectal ADC values of patients with distal colitis were lower than ADC values of patients who were in remission. Another study emphasized that inflamed bowel segments in Crohn's disease were able to be detected with DWI (6). The reasons for diffusion restriction in inflamed
bowel segments on DWI and low ADC values may be increased inflammatory cell density in the intestinal wall, fibrosis, or dilated lymphatic channels. Moreover, intracellular changes in epithelial and lymphoid cells may contribute to these changes (4, 6, 16).

To the best of our knowledge, there are fewer than ten studies in the literature about examination of gallbladder lesions with DWI. Most of these studies are retrospective and are based on the differentiation of benign and malignant lesions. Sugita R et al (9) reported a study that consisted of 15 patients with gallbladder carcinoma and 14 patients with cholecystitis, gallbladder polyps, or adenomyomatosis; the mean ADC values of two groups differed significantly. They reported that the mean ADC value of patients with gallbladder carcinoma was \((1.28\pm0.41) \times 10^{-3}\) mm\(^2\) /sec while the mean ADC value of patients in the control group was \((1.92\pm0.21) \times 10^{-3}\) mm\(^2\) /sec. Irie H et al. (17) identified in their study that the mean ADC values of malignant polypoid gallbladder lesions consisting of carcinomas \((1.34\pm0.50 \times 10^{-3}\) mm\(^2\) /sec) were significantly lower than mean ADC values of benign polypoid gallbladder lesions consisting of hyperplastic polyps and adenomas \((2.26\pm0.44 \times 10^{-3}\) mm\(^2\) /sec). Kang et al. (18) retrospectively assessed DWI and conventional magnetic resonance images of 14 patients with xanthogranulomatous cholecystitis and 19 patients with gallbladder cancer. Only one of 14 patients with xanthogranulomatous cholecystitis and 13 of 19 patients with gallbladder cancer exhibited diffusion restriction in this study. Mean ADC values of patients with xanthogranulomatous cholecystitis \((1.637\times10^{-3}\) mm\(^2\) /sec) were significantly higher than mean ADC values of patients with gallbladder cancer \((1.076\times10^{-3}\) mm\(^2\) /sec). Kim SJ et al. (19) reported a retrospective study of 75 patients with gallbladder lesions and, similar to other studies, they observed that ADC values of benign and malignant lesions differed significantly. Thirty-six patients who were enrolled in that study had benign gallbladder lesions; 28 of those were chronic cholecystitis, four were acute cholecystitis and four were xanthogranulomatous cholecystitis. A comparison between their ADC values was not performed. Yoshiako M. et al. (20) retrospectively investigated DWI and MRI images from 40 patients consisting of 22 gallbladder cancer, 7 adenoma, and 11 inflammatory gallbladder lesions. They found that the mean ADC value of gallbladder cancer was \((1.31\pm0.57\times10^{-3}\) mm\(^2\) /sec), mean ADC value of inflammatory gallbladder lesion was \((1.97\pm0.54\times10^{-3}\) mm\(^2\) /sec), and mean ADC value of inflammatory adenoma was \((2.66\pm0.43\times10^{-3}\) mm\(^2\) /sec). They observed a significant difference between groups. Mean ADC value of inflammatory gallbladder lesions was lower than mean ADC value of gallbladder adenoma and was higher than mean ADC value of gallbladder carcinoma in this study. Ogawa T. et al. (8) evaluated 153 patients with gallbladder wall thickening or polypoid lesion in gallbladder using DWI. Thirty-six of these patients were diagnosed with gallbladder cancer and 117 were diagnosed with benign gallbladder lesion. Among the group of patients with benign lesions, 67 were diagnosed with chronic cholecystitis, 44 were diagnosed with adenomyomatosis, four were diagnosed with cholesterol polyp, one was diagnosed with gallbladder adenoma, and one was diagnosed
with xanthogranulomatous cholecystitis. Positive signal intensity on DWI was 78% in
gallbladder cancer and 22% in benign gallbladder lesions according to the results of
this study. Among benign lesions, positive signal intensity on DWI was 22% in patients
with chronic cholecystitis, 100% in patients with xanthogranulomatous cholecystitis,
and 11% in patients with adenomyomatosis, while this value was 0% in patients with
other benign lesions. The mean ADC value of gallbladder cancer (1.83±0.69x10⁻³
mm²/sec) was significantly lower than the mean ADC value of gallbladder benign
lesions (2.60±0.55x10⁻³ mm²/sec) in this study. In addition, it was reported that the
mean ADC value of benign gallbladder disease with acute cholecystitis or a history of
acute cholecystitis was significantly lower (2.47±0.53x10⁻³ mm²/sec) than that of benign
gallbladder diseases not related with acute cholecystitis (2.71±0.51x10⁻³ mm²/sec).

Mean ADC values of patients diagnosed with cholecystitis (1.64±0.30X10⁻³ mm²/sec)
were significantly lower than mean ADC values of control group (2.35±0.24X10⁻³ mm²/
sec) in our study (p<0.05). Mean ADC values of patients with chronic cholecystitis in
histopathological examination were higher (1.92±0.13X10⁻³ mm²/sec) than mean ADC
values of patients with acute and eosinophilic cholecystitis (1.58±0.29x10⁻³ mm²/sec and
1.56±0.09x10⁻³ mm²/sec, respectively) in our study group, but this difference was not
statistically significant.

There were some limitations in our study. The study population did not include all
histopathological subgroups of cholecystitis such as xanthogranulomatous cholecystitis.
The number of individuals in the subgroups presented in this study was relatively
low (Chronic cholecystitis: 5, eosinophilic cholecystitis: 3). Further studies with a large
number of patients are required to make differential diagnosis of subgroups.

In conclusion, DWI is a fast, noninvasive method without the risk of radiation or
requirement for contrast injection, and can be used in conjunction with other imaging
modalities in the diagnosis of cholecystitis, as well as in the differentiation of cholecystitis
from other benign gallbladder wall thickenings caused by extrinsic factors such as ascites
in the abdomen.

Personal information

References


