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Abdominal apparent diffusion coefficient measurements: effect of diffusion-weighted image quality and usefulness of anisotropic images

Takeshi Yoshikawa[a,*], Yoshiharu Ohno[a], Hideaki Kawamitsu[b], Yonson Ku[c], Yasushi Seo[d], Carlos A. Zamora[e], Nobukazu Aoyama[b], Kazuro Sugimura[a]

[a]*Department of Radiology, Kobe University Graduate School of Medicine, Kobe, Hyogo 650-0017, Japan*
[b]*Division of Radiology, Kobe University Hospital, Kobe, Hyogo 650-0017, Japan*
[c]*Division of Hepato-Biliary-Pancreatic Surgery, Department of Surgery, Kobe University Graduate School of Medicine, Kobe, Hyogo 650-0017, Japan*
[d]*Division of Gastrenterology, Department of Internal Medicine, Kobe University Graduate School of Medicine, Kobe, Hyogo 650-0017, Japan*
[e]*Department of Radiology, San Juan de Dios General Hospital, Guatemala City 01001, Guatemala*

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Abstract

This study aimed to assess the effect of diffusion-weighted image (DWI) quality on abdominal apparent diffusion coefficient (ADC) measurements and the usefulness of anisotropic images. Twenty-six patients (10 men and 16 women; mean, 58.1 years) who underwent DW imaging and were diagnosed not to have any abdominal diseases were analyzed. Single-shot spin-echo echo-planar DW imaging was performed, and one isotropic and three orthogonal anisotropic images were created. ADCs were calculated for liver (four segments), spleen, pancreas (head, body, tail) and renal parenchyma. Image quality for each organ part was scored visually. We estimated the correlation between ADC and image quality and evaluated the feasibility of using anisotropic images. ADCs and image quality were affected by motion probing gradient directions in the liver and pancreas. A significant inverse correlation was found between ADC and image quality. The *r* values for isotropic images were −.46, −.48, −.70 and −.28 for the liver, spleen, pancreas and renal parenchyma, respectively. Anisotropic images had the best quality and lowest ADC in at least one organ part in 17 patients. DWIs with the best quality among isotropic and anisotropic images should be used in the liver and pancreas.

Keywords: Abdomen; Apparent diffusion coefficient; Diffusion weighted; Image quality; Magnetic resonance imaging

1. Introduction

Recently, diffusion-weighted (DW) magnetic resonance (MR) imaging and measurement of apparent diffusion coefficients (ADCs) have been applied to the abdomen. The results suggest that measuring ADCs can be useful in the evaluation of diffuse liver [1–3], pancreatic [4] and renal diseases [5,6], as well as in the characterization of focal hepatic [2,7–9], pancreatic [10] and renal lesions [11].

However, image quality has suffered from blurring due to the long readout interval and from artifacts because of a high susceptibility to resonance offsets. In addition, various artifacts caused by cardiac motion and air in the lung and intestines were found to degrade image quality and diminish the reliability of ADC values in the abdominal field. Recent developments in MR units and imaging techniques have improved the quality of DW images (DWIs). However, problems still exist, especially in the left lobe of the liver and the pancreas in spite of the use of parallel imaging technique [12].

Two previous reports suggested that the use of a single motion probing gradient (MPG) direction has the potential to improve DWI quality [2,13]. However, they evaluated the differences in ADCs between isotropic and anisotropic DWIs restricted to the liver and focal hepatic lesions of patients, or to the liver, spleen, and kidney of young, healthy volunteers. Furthermore, to our knowledge, no study evaluating the correlation between abdominal ADCs and quality of DWIs has been described.

* Corresponding author. Tel.: +81 78 382 6104; fax: +81 78 382 6129.
E-mail address: yoshikawa0816@aol.com (T. Yoshikawa).

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The purpose of this study was to evaluate the effect of DWI quality on ADC measurements and the feasibility of using anisotropic imaging for the assessment of DWI and ADC measurements in the abdomen.

2. Materials and methods

2.1. Patients

During a 10-month period from March 2005 to December 2005, 282 consecutive patients (185 men and 97 women; mean age, 60.7 years) suspected of having abdominal diseases underwent MR imaging with a standard protocol of our hospital that included DW imaging. The patients with obvious abdominal disorders were excluded from the study population. Twenty-six patients without evidence of diffuse or focal disease on abdominal MR images and 6- to 12-month follow-up examinations were eligible for this study (10 men and 16 women; age range, 32–71 years; mean age, 58.1 years). Our institutional review board exempted this retrospective study from requiring its participants to submit an informed consent.

2.2. Imaging technique

All MR studies were performed with a 1.5-T superconducting imaging system (Gyroscan Intera; Philips Medical Systems, Best, The Netherlands). A body coil was used for signal transmission and a four-element phased-array body multicoil was used for reception.

All patients underwent breath-hold single-shot echo-planar DW imaging [repetition time (TR)/echo time (TE) =1500/66, matrix size=96×96 (reconstructed to 256×256), field of view=400–450 mm, number of excitations=2 (for each MPG direction), *b* values=0 and 600, EPI factor=33 (i.e., the number of gradient-recalled echoes per spin echo), slice thickness/gap=6/2 mm, 30 transverse slices, parallel imaging factor=3, bandwidth=32.2 kHz, selective presaturation using inversion recovery (SPIR) for fat saturation] in addition to a routine abdominal imaging protocol including T_1-weighted dual fast gradient-recalled echo (TR/TE=126/2.3, 4.6 ms, FA=70°, matrix size=256×196, field of view=280–350 mm, number of excitations=1, slice thickness/gap=8/0 mm, 30 transverse slices, parallel imaging factor=2) and T_2-weighted respiratory-triggered fast spin echo (TR/effective TE=2500/80 ms, echo train length=9, matrix size=256×196, field of view=280–350 mm, number of excitations=2, slice thickness/gap=8/0 mm, 30 transverse slices, SPIR for fat saturation, parallel imaging factor=2). The MPG pulses were applied in three orthogonal directions called P′, M′ and S′, which are defined as $P'=(-0.5x, y, z)$, $M'=(x, -0.5y, z)$ and $S'=(x, y, -0.5z)$, with x pointing from floor to ceiling, y from left to right when standing in front of the magnet and z from feet to head. Anisotropic DWIs were created for each MPG direction and were referred to P′, M′ and S′ images, respectively. Isotropic DWIs were also created and were referred to as I images. Phase encode direction was set anteroposteriorly in all sequences. For DWI, 15 sections were obtained during a breath-hold of 15 s; hence, two sequential acquisitions were required to encompass the upper abdomen. Saturation bands were not used for DWI.

2.3. Image analysis

All ADC maps were created from I and each anisotropic image, and ADCs were calculated on a workstation with standard software (Functool and Advantage Workstation version 3.2; GE Medical Systems, Milwaukee, WI). ADCs were measured for liver (four segments), spleen, pancreas (head, body, tail) and bilateral renal parenchyma for each image by using operator-defined region-of-interest (ROI) measurements performed by the same radiologist. The ROI was an oval of 100 mm^2. Liver ROIs were located peripherally in each segment, and the spleen ROI was placed centrally. Vessels in the liver and spleen, as well as vessels, pancreatic duct and common bile duct in the pancreas, were avoided as much as possible. The ROI of the renal parenchyma was placed peripherally in the posterior labrum. ADCs of the cortex and medulla could not be measured separately because the matrix sizes used for the DWI were so small that it was difficult to distinguish these structures on the images. Mean ADCs were calculated for each image and compared to evaluate changes in ADC depending on the MPG direction.

Overall image quality including distortion and signal inhomogeneity on isotropic and anisotropic images was visually scored for each organ part on a three-point scale (1, organ partially or completely disappeared; 2, organ appeared heterogeneous; 3, organ appeared homogenous) on the same workstation by two experienced radiologists, who were blinded to the results of ADC measurements and recorded a consensus opinion. The average image quality scores were calculated and compared for each organ part. The number of patients in whom anisotropic images showed better quality than isotropic images was counted.

The relation between ADCs and image quality scores was evaluated for isotropic, anisotropic and overall images for each organ part.

2.4. Statistical analysis

Statistical analysis of the mean ADCs was done by one-way analysis of variance and Scheffé criterion. Statistical analysis of mean image qualities was done by the Kruskal–Wallis test and Scheffé criterion. The correlation between ADCs and image quality scores was estimated by means of the Pearson’s correlation coefficient (r).

All values were expressed as mean±standard deviation. For all tests used, a P value of less than .05 was considered statistically significant.

3. Results

The left lobe of the liver was out of scan coverage in two cases, and the same is true for the spleen in one case.