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Diffusion-weighted imaging properties of uterine fibroids pre- and post-uterine fibroid embolisation

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ABSTRACT

Objective: To determine the change in apparent diffusion coefficient (ADC) of uterine fibroids following uterine fibroid embolisation (UFE), and if the ADC change correlates with either volume loss or degree of contrast enhancement post-UFE.

Materials and methods: This study was approved by our institutional review board with waiver of consent. The pelvic MRI examinations, including diffusion-weighted MRI (DWI) using 4 *b*-values, of 50 consecutive patients prior to and 6 months post-UFE were analyzed. The volume, ADC and amount of enhancement were calculated for each fibroid both pre- and post-UFE. The percent residual enhancement for each fibroid was categorized as either: no (0–1%) residual enhancement or residual (>1%) enhancement. Statistical analysis compared ADC, enhancement and volume for each fibroid pre- and post-UFE using paired *t*-tests and Pearson correlation coefficients.

Results: The mean ADC of all ($n = 88$) fibroids pre-UFE was $1.30 \pm 0.20 \times 10^{-3}$ mm^2/s, and increased to $1.68 \pm 0.24 \times 10^{-3}$ mm^2/s post-UFE ($p < 0.0001$). Lower pre-UFE ADC correlated with greater ADC change post-UFE ($r = -0.50$; $p < 0.0001$). There was no correlation between ADC change and volume change post-UFE ($r = 0.07$; $p = 0.59$). However, fibroids with no residual enhancement post-UFE had larger ADC change than those with residual enhancement ($p = 0.003$).

Conclusion: The ADC of fibroids rises post-UFE. ADC change post-UFE is associated with the degree of loss of enhancement and may therefore be valuable in predicting response to treatment in pre-procedural counseling.

1. Introduction

Uterine fibroid embolisation (UFE) is a minimally invasive, safe and effective treatment for symptomatic uterine leiomyomas (fibroids) through selective fibroid devascularization and resulting cell death and necrosis [1–3]. The current standard of practice is to use gadolinium-based contrast agent (GBCA)-enhanced pelvic magnetic resonance imaging (MRI) to help monitor the treatment response by assessing for decrease in both volume and vascularity of fibroids post-UFE. Diffusion-weighted MRI (DWI) is a non-contrast MRI technique that can yield quantitative data, such as the apparent diffusion coefficient (ADC), regarding solid masses. Specifically, ADC has been shown to rise when other tumors become devascularized or necrotic, and is used as a tumor biomarker for monitoring treatment response [4]. We hypothesize that DWI and ADC could be used in a similar manner for uterine fibroids to monitor the imaging response to UFE. This may allow for MRI monitoring of uterine fibroids post-UFE without use of GBCAs or provide an alternative to the use of GBCAs for this purpose. However, previous studies assessing ADC post-UFE have reported conflicting results, particularly in terms of whether ADC increases or decreases in fibroids post-UFE [5–9]. Accordingly, the objective of this study is to determine the change in apparent diffusion coefficient (ADC) of uterine fibroids following UFE, and to determine if the ADC change correlates with either volume loss or degree of GBCA enhancement post-UFE.

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2. Materials and methods

2.1. Patient selection

This study was approved by our institutional review board with waiver of informed consent. At our institution, patients who are scheduled to undergo UFE for treatment of symptomatic fibroids routinely have a baseline GBCA-enhanced pelvic MRI prior to UFE, and a follow-up GBCA-enhanced pelvic MRI approximately 6 months post-UFE. For the past several years, this protocol has included DWI. Using this routine UFE protocol which includes DWI, the pre-UFE and corresponding 6-month post-UFE pelvic MRIs of 50 consecutive patients, performed between September 2009 and March 2011, were analyzed retrospectively. No patients were excluded.

2.2. MRI protocol

MRI was performed on one of two identical 1.5T systems of the same model and vendor (Achieva, Phillips Medical Systems, Bothell, WA) using a multichannel anterior phased-array coil. The sequences obtained were: axial T1 2D gradient echo (matrix 208 × 166; slice thickness 7 mm; interslice gap 1 mm; TR/TE 175/4.6; flip angle 80°; receiver bandwidth 647.5 Hz), axial T2 turbo spin echo (matrix 256 × 204; slice thickness 4 mm; interslice gap 1 mm; TR/TE ~3100/90; receiver bandwidth 156.3 Hz), sagittal T2 turbo spin echo (matrix size 288 × 224; slice thickness 4 mm; interslice gap 1 mm; TR/TE ~2600/90 ms; receiver bandwidth 136.6 Hz), breath-hold axial T1 3-dimensional (3D) fat saturated gradient echo (matrix size 256 × 180; slice thickness 1.5 mm; TR/TE 3.6/1.8; receiver bandwidth 620 Hz; flip angle 10°) pre and 2 min following injection of 0.1 mmol/kg IV gadobenate dimeglumine (MultiHance, Bracco Diagnostics Inc., Princeton NJ). In addition, an axial free-breathing respiratory-triggered single shot echo planar DWI sequence was performed with sequence parameters as follows: matrix 128–200 × 110–150; slice thickness 7 mm; interslice gap 1.4 mm; TR/TE 1200/minimum; 3 signal averages; *b*-values 0, 250, 500, and 750 mm^2/s. Respiratory triggering was achieved using a bellows placed on the anterior chest wall. The typical acquisition time for the DWI sequence was 5 min. This longer free-breathing DWI sequence was chosen to allow for multiple *b*-values in the acquisition. Field of view (FOV) was 25 cm or less for all sequences, except DWI, which had FOV of 30–36 cm. ADC maps were generated from the DWI images using all four *b*-values. No anti-peristaltic pharmacological agent was administered as per routine departmental workflow for pre- and post-UFE MRI cases. Neither magnetic resonance angiography (MRA) nor conventional angiography is performed routinely on pre- or post-UFE patients at our institution.

2.3. UFE procedure

A 4 French DAV (Cook Medical Inc., Bloomington, IN) was used for selective uterine artery catheterization. The catheter was placed into the horizontal portion of the uterine artery beyond the cervico-uterine branch bilaterally, via transfemoral approach. A Progreat microcatheter (Terumo Medical Corporation, Somerset, NJ) through the 4 French catheter was utilized if there was significant spasm. Polyvinyl alcohol particles (Contour-SE; Boston Scientific, Natick, MA) of size 355–500 μm were injected into both uterine arteries until stasis was achieved. A single Gelfoam pledget was deployed at the end of particulate embolisation.

2.4. Fibroid analysis

Fibroid analysis was performed by one fellowship-trained radiologist with 2 years of experience in pelvic MRI. The largest fibroid(s) were chosen for analysis on the pre- and post-UFE MRI. If there was more than 1 fibroid identified on the pre- or post-UFE MRI, then only the largest 2 fibroids in 1 patient were chosen for analysis. The fibroid location (submucosal, transmural, or subserosal) and the volume of the fibroid (calculated with the formula for volume of an ellipsoid, given by length × width × height × 0.5236), measured on GBCA-enhanced 3D T1W imaging, were recorded for both the pre- and post-UFE MRI examinations.

ADC values of each fibroid on both the pre- and post-UFE MRI were calculated by placing 1 circular region of interest (ROI) over each fibroid on the axial slice of the ADC maps that contained the largest fibroid cross-sectional area, so as to include the maximum possible fibroid cross-sectional area in the ROI without involving

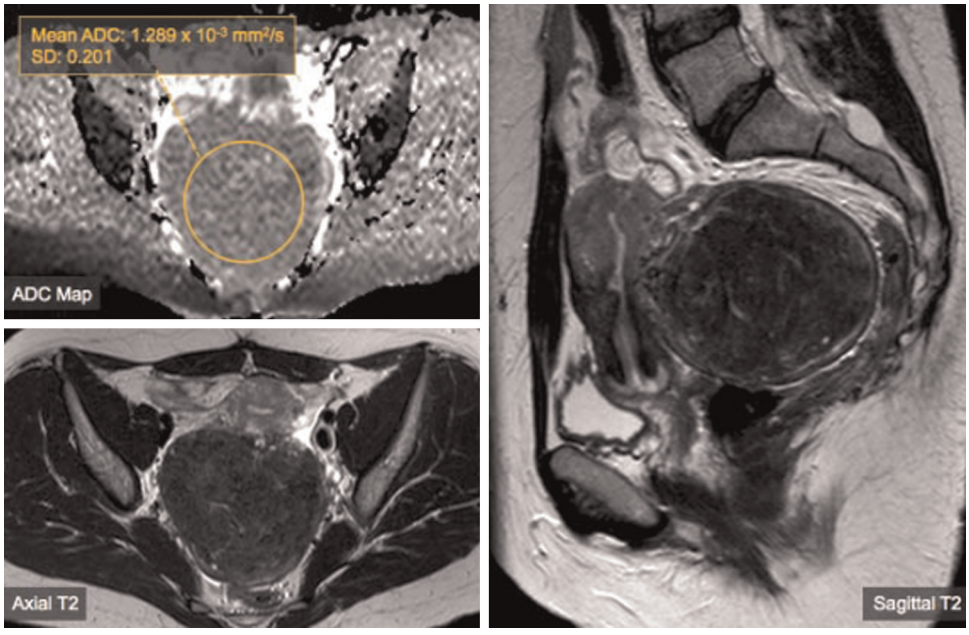

Fig. 1. ADC map, axial T2 turbo spin echo and sagittal T2 turbo spin echo images of a large T2-hypointense posterior subserosal fibroid, demonstrating ROI placement and ADC calculation.