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Prediction of early response to uterine artery embolization in fibroids: Value of MR signal intensity ratio

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ABSTRACT

Objective: To quantitatively assess magnetic resonance (MR) imaging findings that help predict early post-therapeutic response in fibroids following uterine artery embolization (UAE).

Methods: Fifteen patients with a total of 52 fibroids underwent UAE. The signal intensity ratio (SIR) on T1-, T2-, diffusion weighted and gadolinium-enhanced images was calculated by dividing the mean signal intensity of fibroids by that of the abdominal rectus muscle. Fibroids were divided into the two groups: affected (post-UAE volume reduction rate > median of all fibroids) and unaffected (<median rate). The SIRs were compared between the two groups. ROC analysis was used to evaluate the predictive performance for differentiating the affected from unaffected lesions.

Results: The SIRs of the affected group were significantly lower on T1-weighted images (0.85 ± 0.1 vs 0.95 ± 0.2) ($P = 0.0001$), but higher on T2-weighted (1.30 ± 0.6 vs 1.12 ± 0.9) ($P = 0.026$) and gadolinium-enhanced images (1.51 ± 0.2 vs 1.20 ± 0.4) ($P = 0.0002$) than those of the unaffected group. There was no significant difference in ADC values between the two groups ($P = 0.510$). The sensitivity, specificity, and area under the ROC curve (AUC) in the prediction of the affected lesions were 92%, 50%, and 0.712 with SIR on T1-weighted images, and 85%, 62%, and 0.731 with SIR on gadolinium-enhanced images, respectively.

Conclusions: The SIRs on T1-weighted images and gadolinium-enhanced images were useful for the prediction of the changes in size of fibroids responding to UAE.

1. Introduction

Uterine fibroid, the most common benign tumor of the uterus, is a substantial cause of morbidity in women of reproductive age [1]. Symptomatic uterine fibroids can cause menorrhagia, pelvic pain, severe dysmenorrhea, dyspareunia, and reduced fertility [2].

Uterine artery embolization (UAE), which has the advantage of being minimally invasive and potentially preserving fertility, is an established alternative to surgery in the management of patients with symptomatic uterine fibroids [3–5]. In order to improve the effectiveness of UAE treatment and minimize post-therapeutic complications, we need to appropriately select who would respond favorably to UAE treatment. Magnetic resonance (MR) imaging is not only an accurate and noninvasive modality for the diagnosis of uterine fibroids, but also a useful modality for the characterization and differentiation of uterine fibroids from other pelvic disorders. Studies reported that pre-therapeutic MR imaging is useful for predicting the outcome of UAE, which could lead to the selection of alternative treatment plans and managements [6,7]. However, clinical indications and determination of UAE versus surgical treatment have yet to be established in patients with symptomatic uterine fibroids.

Radiologists and gynecologists acknowledge the usefulness of MR imaging in therapeutic planning and post-therapeutic monitoring. However, there have been only a few quantitative studies regarding MR imaging characteristics of uterine fibroids as the predictors for UAE outcome. Thus, the purpose of this study was to evaluate the pre-therapeutic MR imaging findings that help predict early post-therapeutic responses in uterine fibroids following UAE.

2. Materials and methods

2.1. Patients

This retrospective study was approved by our institutional review board and written informed consent was waived. Between

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May 2007 and April 2013, 15 patients (age range, 36–53 years; mean age, 45.7 ± 3.6 years) with 52 uterine fibroids (volume range, 0.7–842.4 cm^3; mean volume, 78.0 cm^3 ± 136.8 cm^3) underwent MR imaging one month prior to UAE. The diagnosis of uterine fibroid was established by clinical history, gynecological examination, and MR imaging findings. A post-therapeutic MR imaging was performed as a follow-up of UAE (31–126 days, mean 89.1 ± 21.5 days).

2.2. MR imaging protocol

MR imaging was performed using a 1.5-T MR system (Intera Achieva 1.5-T Pulsar; Philips Medical Systems, the Netherlands) and a SENSE Torso coil. The basic MR imaging protocol consisted of the following sequences: axial T1-weighted turbo spin-echo imaging (repetition time [TR]/echo time [TE], 759/15 msec; matrix, 416 × 208; field of view, 26 × 26 cm; parallel imaging factor, 2.3; 5-mm section thickness with a 2-mm intersection gap; acquisition time for 20 sections, 2 minutes); axial T2-weighted turbo spin-echo imaging (TR/TE, 5,694/90 msec; matrix, 280 × 240; field of view, 26 × 26 cm; parallel imaging factor, 2; 5-mm section thickness with a 2-mm intersection gap; acquisition time for 20 sections, 2 minutes); sagittal T2-weighted turbo spin-echo imaging (TR/TE, 3,000/100 msec; matrix, 368 × 258; field of view, 28 × 22 cm; parallel imaging factor, 1.4; 5-mm section thickness with a 2-mm intersection gap; acquisition time for 20 sections, 2 minutes); diffusion-weighted single-shot turbo spin-echo echo-planar imaging (TR/TE, 5,008/60 msec; matrix, 112 × 90; field of view, 28 × 28 cm; parallel imaging factor, 2; *b* factors, 0 and 1000 sec/mm^2; 5-mm section thickness with a 2-mm intersection gap; acquisition time for 20 sections, 2 minutes). After obtaining unenhanced images above, gadolinium-enhanced fat-suppressed turbo spin-echo images (TR/TE, 755/17 msec; matrix, 448 × 224; field of view, 28 × 28 cm; 5-mm section thickness with a 2-mm intersection gap; acquisition time for 20 sections, 3 minutes) were obtained immediately after an intravenous injection of 0.2 mmol/kg of gadopentetate dimeglumine.

2.3. Embolization technique

Two interventional radiologists (H.K. and S.G., with 16 and 13 years of post-training experience at interventional radiology) underwent UAE using the unilateral femoral approach with local anesthesia. After a 5-French sheath introducer was percutaneously inserted in a common femoral artery, a 5-French loop catheter was inserted into the internal iliac artery. Gelatin sponge particles in 1-mm cubes mixed with contrast medium (350 mg/mL) were infused with a 1-mL syringe under fluoroscopic monitoring through a 2.7-French microcatheter advanced into the transverse segment of the uterine artery.

The UAE was continued until the bilateral, proximal ascending uterine arteries were adequately occluded. Uterine arteriography was performed at the completion of the embolization procedure to ensure that the bilateral, ascending uterine arteries were occluded, whereas the main descending uterine arteries were patent.

2.4. Quantitative image analysis

Two radiologists (H.W. and H.K., with 9 and 5 years of post-training experience at interpreting genitourinary images), in consensus, recorded the uterine fibroid locations (fundal, body, or cervix) or depth (subserosal, intramural, or submucosal) and measured the volume of each uterine fibroid simultaneously on T2-weighted images obtained pre- and post-UAE using the ellipsoid formula (length × depth × width × 0.5233) [8]. We determined length as a maximum diameter of uterine fibroid in sagittal plane, and depth and width as maximum and transverse diameter orthogonal to each other in axial plane. The volume reduction rate of a uterine fibroid was determined using the following formula: Volume reduction rate $= (V_{\text{pre}} - V_{\text{post}})/V_{\text{pre}}$, where V_{pre} and V_{post} are the volumes of a uterine fibroid pre- and post-UAE, respectively. We determined the median volume reduction rate of all uterine fibroids in this study and then labeled each fibroid as either affected (volume reduction rate above the median) or unaffected (below the median).

The radiologists further measured the pre-UAE signal intensities of uterine fibroids and abdominal rectus muscle on T1-weighted, T2-weighted, diffusion-weighted, and gadolinium-enhanced images obtained prior to UAE using a commercially available DICOM viewer. ADC values were measured for placing ROIs on the ADC map computed on a voxel-by-voxel basis using a standard mono-exponential approach between $b = 0$ and 1000 s/mm^2 images, based on the equation $S = S_0 \times \exp(-b \times \text{ADC})$, where S is the signal intensity after application of diffusion gradient (b) and S_0 is the signal intensity when $b = 0$ s/mm^2.

For each uterine fibroid, a circular region-of-interest cursor (ROI) was placed to encompass the entire lesion over the largest cross-section area of the lesion visualized on the MR images. Artifacts and cystic or necrotic areas of uterine fibroids were carefully avoided. For abdominal rectus muscle, a ROI (approximately 100 mm^2) was placed in the central portion of the abdominal rectus muscle in axial plane. The mean signal intensity of uterine fibroids and the abdominal rectus muscle was measured from the ROIs. For all measurements, the size, shape, and position of the ROI were constantly kept among all MR images by applying a copy-and-paste function on the viewer. The signal intensity ratio (SIR) was calculated as the ratio of signal intensity of uterine fibroid to that of the abdominal rectus muscle at each imaging sequence.

2.5. Statistical analysis

Statistical analyses were performed using MedCalc Software for Windows (version 12.7.2). The difference in the frequency of the uterine fibroid locations (fundal, body, or cervix; subserosal, intramural, or submucosal) between the affected and unaffected groups was assessed using Fisher's test. Moreover, the difference in the uterine fibroid volume reduction rate between the locations was compared using one-way analysis of variance.

The Mann–Whitney test was conducted to evaluate the differences in age, SIRs on T1-weighted, T2-weighted, and gadolinium-enhanced images, and ADC value between the affected and unaffected groups. Stepwise multiple regression analysis was used to assess the association of uterine fibroid volume reduction rate and the SIRs on T1-weighted, T2-weighted, gadolinium-enhanced images, ADC value, patient age, and pre-UAE fibroid volume.

Receiver-operating-characteristic (ROC) curves were fitted to assess the diagnostic performance for the differentiation the affected and unaffected uterine fibroids. From the ROC curve with the largest AUC, we computed the optimal threshold that yields the maximal sensitivity and specificity for the differentiation of the affected and unaffected uterine fibroids. The sensitivity, specificity, and area under the ROC curve (AUC) were compared between the affected and unaffected uterine fibroids using the Fisher's test and Hanley and McNeil method [9]. A P value of less than 0.05 was considered to be significant.

3. Results

3.1. Patient background factors

No significant difference was found in terms of patient age ($P = 0.88$) between the affected and unaffected groups.