Diffusion Weighted Imaging of Uterine Fibroids: Predicting Volumetric Response Following Uterine Artery Embolization

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Introduction: Uterine leiomyomas (fibroids) are benign tumors that can cause pain and affect fertility, but can be effectively treated with uterine artery embolization (UAE), sparing select patients more invasive surgical procedures. The degree of volumetric reduction of uterine fibroids following UAE has been shown to relate to clinical success[1]. If there was a measure that could help predict patient response, and therefore suitability for the UAE procedure, then patients may be counseled appropriately. Pretreatment apparent diffusion coefficient (ADC) has been shown to predict response of malignant neoplasms to treatment with radiation and chemotherapy and therefore, may be useful for predicting response of benign tumors to treatments such as UAE[2]. While ADC has shown utility for monitoring response of fibroids following UAE[3], to our knowledge no study has investigated whether pre treatment ADC can predict treatment response. The purpose of this study is to evaluate whether fibroid ADC, prior to embolization, could predict volumetric reduction following UAE.

Methods: Patients were included in this IRB approved retrospective study if they had MR imaging prior to and following UAE (> 100 days). All fibroids greater than 3 cm were included (up to 4 fibroids per patient). Fibroid volumes, using an ellipsoid formula, were measured on multiplanar 2D T2 weighted turbo spin echo (TSE) images (Fig 1F) and percent volume reduction was calculated. 3D fat suppressed T1 weighted gradient echo images (Volumetric interpolated breath-hold examination, VIBE) prior to and following administration of intravenous Gd-DTPA contrast (Fig 1D,E), were obtained to calculate relative enhancement (RE), defined as RE = $(SI^{post} - SI^{pre}) / SI^{pre}$, with SI = signal intensity either prior to (pre) or 90 sec following contrast administration (post). 3 ROIs were placed on each fibroid by a single reader to calculate RE.

Diffusion weighted images (DWI) were obtained using a single shot EPI sequence with b values of 0, 500 and 1000 sec/mm^{2}. Fibroid pre-UAE ADC were calculated by two readers based on the b 500 and b 1000 images (Fig 1A,B), using ROIs placed on three consecutive DWI slices. ADC was calculated using the formula $ADC = -\ln(SI^{b1000}/SI^{b500}) / \Delta b$, with SI^b = signal intensity at the respective b value of 1000 and 500 sec/mm^{2}, and Δb = 500 sec/mm^{2}. ADC based on high b values were calculated to avoid confounding perfusion effects at low b values. Signal to noise ratio (SNR) on DWI was also calculated by dividing the average SI^{b1000} of fibroids by the average noise using 4 ROIs. Pearson correlation coefficients were calculated between post UAE fibroid volume reduction and 1) fibroid RE, 2) fibroid size, and 3) fibroid ADC prior to UAE. Inter-reader variability in ADC measurements was calculated by Pearson correlation and intra-class correlation (ICC).
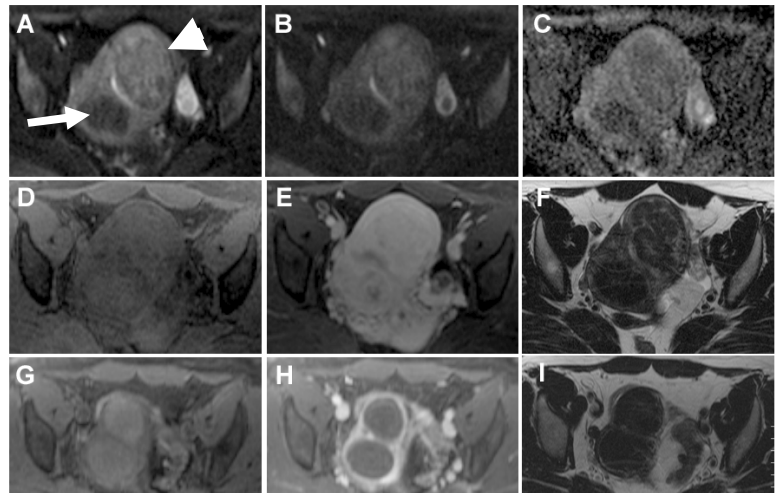

Figure 1. Pelvic MRI with DWI, b=500 (A), b=1000 (B) and ADC map (C). Pre (D) and post-contrast (E) and T2W images (F) before and after UAE (G,H,I). The larger anterior fibroid (arrowhead) demonstrates similar T1, T2 and post contrast enhancement characteristics but higher ADC pre UAE compared to the posterior fibroid (arrow). Following UAE, the anterior fibroid lacks enhancement and has diminished in size by 68% percent while the other posterior fibroid decreased only 26% despite lack of enhancement

Results: 8 female patients (average age 42 y) with 21 fibroids were included, with an average time between UAE and follow up MRI of 218 days. Fibroid volumes ranged from 16 to 430 cc. The average volume reduction was 55% (range 13-100%). There was no significant correlation between fibroid volume reduction and fibroid RE (r = 0.05), or fibroid size (r = 0.12). The correlation coefficient between fibroid volume reduction and fibroid ADC (average of both readers) was r = 0.57. The average fibroid SNR was 2.4 on DWI at b = 1000, with a range from 1.6 to 4.2. The Pearson correlation coefficient between fibroid ADC and volume reduction increased to r = 0.71 (Fig 2), when excluding data from fibroids with SNR < 2 (final cohort: 5 patients with 13 fibroids) When including all patients, 100% of fibroids (n=7) with ADC > 0.75 decreased in volume by greater than 50%. Only 29% of fibroids (4/14) with ADC < 0.75 decreased in volume by greater than 50%. The Pearson correlation and ICC for inter-reader variability in fibroid ADC measurement were 0.960 and 0.957.

Figure 2. Relationship between pre UAE fibroid ADC and fibroid volume reduction following UAE

Conclusion: Pre-treatment ADC value of uterine fibroids predicts responsiveness to UAE therapy. High fibroid ADC values, based on "perfusion-filtered" high b value DWI predicts greater tumor volume reduction.

References: 1. Toor SS, et al. J Vasc Interv Radiol 2008; 19(5): 662-7; 2. Koh, DM et al. Am. J. Roentgenol. 2007;188:1622-1635; 3. Liapi E, et al. J Comput AssistTomogr. 2005; 29(1): 83-6.