Uterine fibroids: quantitative assessment of baseline T_1, ADC and microvascular properties with T_1w DCE-MRI

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Introduction: Uterine fibroids are benign masses affecting ~20% of women of reproductive age, resulting in poor quality of life due to pelvic pain and dysmenorrhea. Available treatments vary in their effectiveness and invasiveness; hysterectomy is highly effective but involves major surgery whereas the less-invasive uterine arterial embolisation (UAE) or noninvasive high intensity focused ultrasound (HIFU) can have variable results depending on the vascular characteristics of the fibroid (1,2). Selection of the most appropriate treatment on a case-by-case basis is therefore important, and although it has been noted that there is a wide variation in MR appearance of fibroids (3), there is little quantitative data characterising baseline appearance. It is hoped that multiparametric MRI can provide an assessment of fibroid characteristics that will help to identify the most appropriate treatment. Dynamic contrast-enhanced (DCE) MRI allows estimation of tissue perfusion through tracer kinetics modelling. Several models have been proposed, but *a priori* selection of the most appropriate model for a given application can be problematic. In this study, two models are used; the adiabatic approximation to the tissue homogeneity (AATH) model (4) and the separable compartment (SC) model (5). Both include an estimate of flow by introducing a non-negligible transit time between the arterial and venous ends of the capillary bed. This study presents quantitative T_1, apparent diffusion coefficient (ADC) and dynamic contrast-enhanced (DCE) MRI results from the two different models of the microvasculature, from 6 patients imaged at 3 T (Philips Achieva).

Methods: Patients were imaged prone using a torso phased array coil. The imaging protocol included T_2w TSE images, 3D SE-EPI diffusion weighted imaging (DWI) (240x240x(84-156) cm, 144x144x12, b-values 0, 10, 20, 50, 75, 100, 1000 s mm^{-2}). For T_1 measurement (6), 3D axial IRTFE (400x400 cm, 128x128, 26-38 x 4mm slices, TR = 2.8 ms, flip angle = 15º, 4 s shot interval, turbo factor = 50, TI = 80, 500, 1400, 2250, 3850 ms) were acquired, followed by 3D FFE images (TR = 5.1 ms, flip angle = 17º, 150 timepoints, 2.4-3.6 s time resolution) during injection of a reduced dose of Gadovist (5 ml injected at 2 ml s^{-1}) to minimise signal saturation and temporal undersampling at the bolus peak. AIFs were obtained from the external iliac arteries. Fibroids were outlined on T_2w images, and ROIs transferred to ADC (calculated at the console), T_1, and dynamic images. Measured T_1, values were used to convert to ΔR_1-time curves which were analysed by fitting (method as in (7)) both the AATH and SC models to give estimates of extraction fraction (E), plasma flow (F_p), mean transit time (T_c), extravascular extracellular volume (v_e) and the time offset between the AIF and the uptake curve (t_{off}). Fitted parameters were compared for the two models using a Wilcoxon signed ranks test.

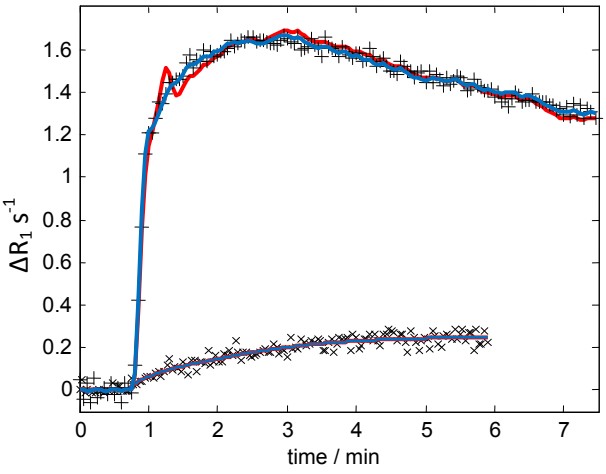

Figure 1 – Example uptake curves (data + and x) and fits (AATH red, SC blue)

Results: Figure 1 shows example uptake curves and model fits for two patients, including one (black x) that had previous UAE and therefore very low contrast agent uptake. In this case, the fitted curves for the two models overlapped closely, and had similar parameter estimates apart from T_c (E=(0.37, 0.38) ml (ml tissue)$^{-1}$, F_p=(0.22, 0.22) ml (ml tissue)$^{-1}$ min^{-1}, T_c=(0.03, 0.01) min, v_e=(0.28, 0.28) ml (ml tissue)$^{-1}$ for AATH and SC respectively). In the other case (blue +), the SC model had a lower χ^2 and parameters were different between models (E=(0.66, 0.33) ml (ml tissue)$^{-1}$, F_p=(0.20, 0.23) ml (ml tissue)$^{-1}$ min^{-1}, T_c=(0.47, 0.71) min, v_e=(0.25, 0.18) ml (ml tissue)$^{-1}$ for AATH and SC respectively). Figure 2 shows summary statistics for all fibroids in the box plots, including DCE-MRI parameters from both models, and the χ^2 value for the fit. The estimates of E, F_p, t_{off} and χ^2 were significantly different for the two models, with significantly lower χ^2 for the SC model.

Discussion: The results of this small preliminary study show a wide variation in measurements of all parameters, and there was often a similarly large variation between fibroids in the same patient. The significantly lower χ^2 for the SC model indicates that this model is a better fit to the data. In the patient who had undergone previous UAE, F_p was significantly lower than that found in all other patients ($p<0.005$, Wilcoxon rank sum test) for both models. For all fibroids in one patient, both models estimated very large v_e and flow values that are unlikely to be physiologically valid (F_p > 1 ml (ml tissue)$^{-1}$ min^{-1}). ADC values are similar to those found in previous work (8). These data represent the first patients of a larger dataset that will include followup data for all patients. This will allow any correlation of treatment outcome with baseline imaging parameters to be assessed, and examination of the most appropriate model for predicting treatment response.

Acknowledgements: MR technologists at Sunnybrook, support from Philips. **References:**(1) Lenard *et al* Radiol 2008 (2) Jha *et al* Radiology 2000 (3) Namimoto *et* al Eur Radiol 2009, (4) St Lawrence *et* al JCBFM 1998 (5) Sourbron *et al* Invest Radiol 2008 (6) Brix *et al* MRI 1990 (7) Kershaw MRM 2010 (8) Whittaker *et al* Radiographics 2009

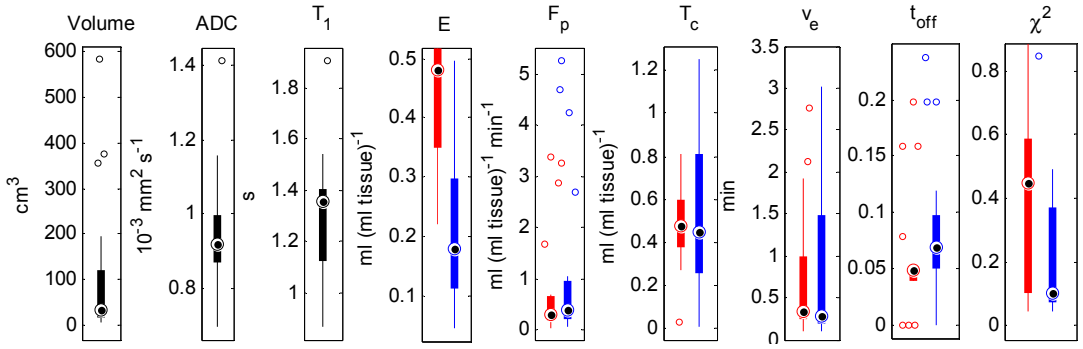

Figure 2 – Box plot for each parameter and model (red – AATH, blue – SC). On each box, the central mark - median, box edges – interquartile range, whiskers - most extreme points not considered to be outliers, which are plotted individually