Cortical Bone Perfusion Assessment using Inversion Recovery Ultrashort TE Imaging

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Target Audience: Musculoskeletal Radiologists, Bone Metabolism Researchers

Purpose: Perfusion MRI studies of vertebral trabecular bone have shown a direct relation between bone perfusion and remodeling activity.[1] Trabecular bone studies have also shown that decreases in vascularity and perfusion may contribute to increased fracture risk in older individuals.[2] To date, perfusion MRI of the *cortical bone* has been limited by the lack of signal due to its ultrashort T2 of 300 to 500 µs. This makes the tissue undetectable with conventional gradient echo sequences which have much longer echo times. Ultrashort TE (UTE) sequences can detect signal from cortical bone but suffered from significant streak artifacts due to blood flow and pulsatility in dynamic studies.[3] To address this problem, we used an inversion recovery prepared UTE sequence (IR-UTE) for perfusion MRI of cortical bone in dynamic studies.

Methods: MR imaging was performed on a Sigma HDx 3T scanner (GE Healthcare, Milwaukee, WI) using a 3-inch receive only coil (a body coil was used for transmission). A Silver-Hoult adiabatic inversion recovery pulse (duration = 8.64 ms) was used to invert the magnetization of long T2 tissue components, including muscle, fat, and free water in cortical bone. The data acquisition began after a delay time (TI) when the inverted longitudinal magnetization of long T2 tissue components of muscle and fat had reached the null point. Water bound to the organic matrix has a very short T2 (T2* ≈ 0.3ms) and was not inverted due to significant transverse relaxation during the long adiabatic inversion process, and was subsequently detected by the 2D UTE data acquisition. The IR-UTE sequence is capable of detecting contrast enhancement in bone matrix; it may also detect signal from plasma within the bone when its T1 is shortened by the contrast agent. The IR-UTE sequence used the parameters: TE = 10 µs, TR = 300 ms, TI = 110 ms, FA = 45°, BW = 125 kHz, FOV = 12 cm, 128 readout points, 101 radial projections, number of excitation (NEX) = 2, 8 mm slice thickness, scan time = 1 minute. Dynamic data were acquired on healthy volunteers, focusing on the tibia with 5 scans pre-injection and with temporal resolution of 60 seconds over 60 min post-injection of Gd-DTPA, (0.26 mmol/kg) (Magnevist, Bayer Healthcare, Wayne, NJ). Images were processed in ImageJ (NIH). A ROI was drawn in the posterior tibial artery and over the tibial cortex and maximum enhancement from baseline and slope was calculated as follows: $Emax = \frac{[(Imax - Ibase)]}{Ibase} * 100$ $Eslope = (0.8 * Emax)/(t90 - t10)$

Results: High contrast images of cortical bone were achieved with suppression of signal from muscle and marrow fat (**Figure 1**). There was smooth signal enhancement seen in the cortical bone and the posterior tibial artery (**Figure 2**) with minimal artifacts even with highly undersampled IR-UTE data. The cortical bone of the older volunteer showed lower peak enhancement and a lower rate of enhancement compared to the younger volunteer, who showed evidence of an early enhancing vascular component.

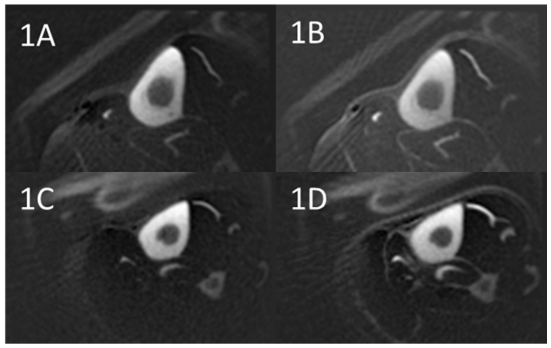

Figure 1: Pre (1A) and post (1B) contrast images of volunteer aged 69. Pre (1C) and post (1D) contrast images of volunteer aged 40.

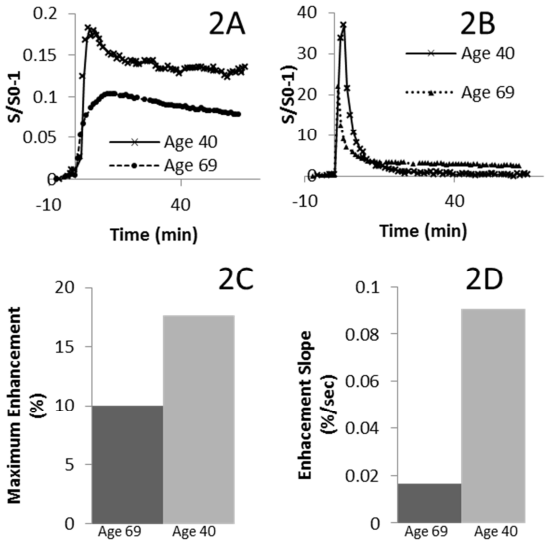

Figure 2: (A) Signal intensity over time in cortical bone of healthy volunteers, age 40 (x) and age 69 (●). (B) Arterial enhancement over time (C) Maximum enhancement as percentage of baseline signal intensity. (D) Slope of enhancement from 10% to 90% of max.

Discussion: Compared to previous UTE perfusion MRI negligible streak artifacts were seen in **Figure 1** because of efficient long T2 signal suppression. The localized signal from cortical bone required only a small FOV which allowed use of an under sampled acquisition to improve temporal resolution. The small fluctuations seen in **Figure 2A** are an improvement over conventional UTE perfusion study where blood flow and pulsatility caused more obvious artifacts**.** The difference in curve shape between volunteers may represent age dependent enhancement of plasma in the lacunocanalicular system.

Conclusion: Perfusion imaging of the cortical bone organic matrix is feasible with an IR-UTE sequence with fewer artifacts that hindered previous UTE imaging. The IR-UTE sequence should allow further study of bone perfusion in this previously MR inaccessible tissue.

References: **[1]** Griffith et al. Radiology. 2010 Mar;254(3):739–46.
[2] Burkhardt et al. Bone. 1987;8(3):157–6.
[3] Girard et al, 19th ISMRM, Poster 3210. 2011 May 7-13.