Reproducibility of In Vivo Bound and Pore Water Imaging of Cortical Bone

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Target Audience: Researchers and clinicians interested in human cortical bone MRI and ultrashort-echo time imaging.

Purpose

NMR measures of ultrashort-T_2 collagen bound water and pore water in cortical bone have been shown to correlate to mechanical properties[1], suggesting that evaluating cortical bone using ultra-short echo time (UTE) MRI[2] may give new diagnostic information for measuring fracture risk compared to current bone assessment tools such as DXA or qCT. Bound and pore water signals can be distinguished through relaxation-selective magnetization preparations—Double Adiabatic Full Passage (DAFP) and Adiabatic Inversion Recovery (AIR) sequences[3,4], or bi-exponential T_2^* analysis[5]. In this study, these DAFP and AIR sequences were used to quantitatively map bound and pore water in the wrist and lower leg on healthy volunteers in order to establish feasibility and reproducibility measures *in vivo*.

Methods

Scans were obtained from three volunteers (age 24-49) on three separate visits each, approximately one week between scans. 3D UTE images of the wrist and lower leg were acquired with DAFP and AIR sequences on a 3T Philips Ingenia using the knee coil for receiving. Resolution was 1.5 mm isotropic, with 150×150×150 mm^3 FOV for the wrist and 200×200×200 mm^3 for the lower leg. The AIR sequence used TR/TI/TE = 400/85/0.07 ms and a 10 ms 3.5 kHz HS8 preparation pulse. The DAFP sequence used used TR/TD/TE = 400/5/0.07 ms and two consecutive 10 ms HS8 pulses. As described previously[5], bound and pore water concentrations were computed using signal equations, B_1 and imaging point-spread function corrections, and a reference marker with a known ^1H concentration. Mean signals were tabulated from ROIs defined by anatomical landmarks (three in the tibia, two in the radius). Inter-scan variation was computed for each bone ROI across the three repeated scans.

Results and Discussion

Figure 1 shows representative slices from conventional 3DUTE images of the lower leg and wrist with bound and pore water maps overlaid on the tibia and radius bones. Across subjects, the mean and range of bound and pore water concentrations were 20.8 (13.6-25.9) and 9.8 (4.9-18.2) mol $^1H/L_{bone}$ (Table 1), consistent with previous measures from cadaver bones[3,4]. Inter-scan uncertainties, reported as standard error of ROI means, shown in Table 1 (mean and range), were largely consistent with image SNR. In some ROIs, particularly in the lateral radius, signal variation was increased due to small, hard to resolve cortical bone. In future studies, scan resolution and/or efficiency may be increased using a dedicated wrist and/or surface coil, or using an anisotropic 3DFOV.

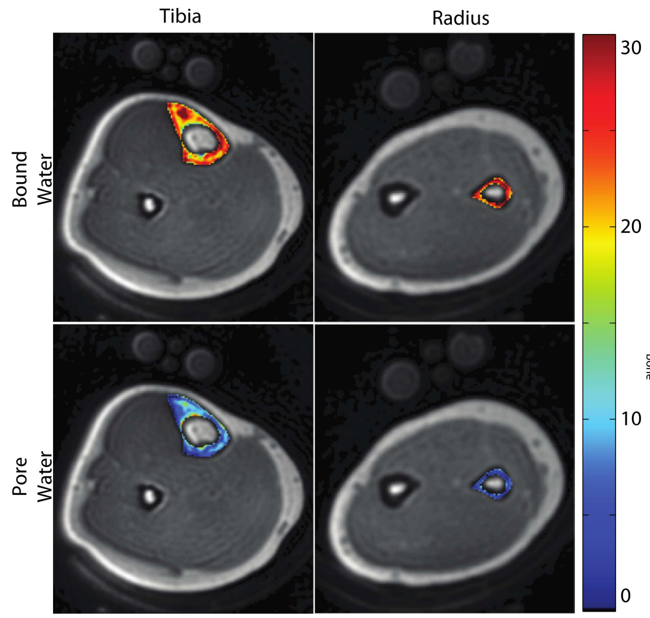

Fig 1: Axial slices of UTE images with bound and pore water maps overlaid.

	Bound Water		Pore Water	
ROI	Mean	Inter-scan Variation (%)	Mean	Inter-scan Variation (%)
Tibia				
Anterior	20.5	9.1 (5.6-11.5)	6.8	9.5 (7.4-12.1)
Medial	20.5	8.8 (5.1-13.3)	8.3	11.4 (10.2-12.1)
Posterior	23.4	3.3 (2.7-7.1)	8.0	9.7 (6.0-18.1)
Radius				
Medial	19.2	5.4 (1.4-6.9)	12.7	11.9 (8.2-15.7)
Lateral	20.5	14.0 (8.4-23.6)	11.3	23.0 (22.2-27.2)

Table 1: Mean concentrations (mol $^1H/L_{bone}$) and inter-scan variation (standard error, %), mean and range across subjects.

Conclusions

Quantitative bound and pore water maps in cortical bone were acquired *in vivo*, with good repeatability (≈10% SE per ROI). These maps provide diagnostic information on bone quality and could assist clinicians in determining care for those at high fracture risk.

References

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