

# Feasibility of the residual red marrow assessment in tibia epiphysis after age 25 using DTI: the initial investigation on healthy volunteers

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**Introduction:** The conversion between red (hematopoietic) and yellow (adipose) marrow may be a sign for an alteration of the local microvascular environment caused by diseases such as bone or hematopoietic tumours [1]. It is commonly considered that the red bone marrow distribution is limited to the axial skeleton, and proximal ends of the humeri and femurs after early adult age [2]. However several clinical cases have been reported that red-marrow signals appeared in locations such as tibia epiphysis on healthy subjects [3]. The distribution pattern of red bone marrow, residual or reconverted, may assist the differentiation between normal and pathologic bone marrow. Such residual red marrow is sometimes difficult to be detected by conventional T<sub>1</sub> or T<sub>2</sub> weighted sequence [3]. Here we presented an *in-vivo* diffusion based MR protocol to assess the red marrow quantitatively in the tibia epiphysis. The preliminary results in 3 healthy volunteers were also shown.

**Methods: Subjects and imaging protocol:** The right knee joints of three healthy male adults (avg. age: 40 ± 10) were scanned on a 3T GE SIGNA HDx system (General Electric Healthcare, WI) using an eight channel knee coil. A dedicated DTI protocol was employed, with the following parameters: dual-echo PGSE with EPI read-out, acq. matrix 128×128, slice thickness 3.2 mm, pixel spacing 1.4×1.4(mm<sup>2</sup>), NEX=4, TE=76.8ms, TR=7000ms, b-value=400s/mm<sup>2</sup>, 20 diffusion gradient directions with 4 b<sub>0</sub> acquisitions. The RF excitation was spectrally selective on the water frequency. Parallel imaging (acceleration factor = 2) and partial Fourier were used to reduce the EPI distortion. The overall acquisition time was 10 mins per volunteer. Diffusion parameters (i.e. trace and fraction anisotropy) were analyzed using CAMINO [4] after all the DWI data were aligned with the b<sub>0</sub> data using in-house registration software in MATLAB (R2007b, The Mathworks, Natick, MA).

**Noise assessment:** In order to confirm the existence of the diffusion phenomenon, volunteer 1 was also scanned using 5 different b-values (200, 400, 600, 800, 1000 s/mm<sup>2</sup>) with other parameter setting similar as above. The resulted overall normalized signals (S<sub>DWI</sub>/S<sub>T2</sub>) from three types (muscle, bone marrow and noise) of ROIs (10×10) were plotted against different b-values.

**Reproducibility:** An intra-subject intra-protocol reproducibility study was performed on the first two volunteers. The same protocol was repeated

twice on each volunteer without repositioning the coil. The trace of diffusion tensor was compared based on chosen ROIs (10×10) in seven slices covering the tibia epiphysis. The Bland-Altman (BA) analysis was exploited to assess the reproducibility statistically.

**MRS identification:** To further confirm the composition of the bone marrow in tibia epiphysis, a MRS (<sup>1</sup>H) exam was performed on the last volunteer's tibia epiphysis using a PRESS-single voxel sequence (without water suppression, voxel size 20×20×20 mm<sup>3</sup>). The spectroscopic data were analyzed on the GE workstation.

**Results:** An example of DW images is shown in Fig. 1(b) with signal drops (yellow arrows) as compared to the non-diffusion weighted one (Fig. 1(a)). The normalized signal against b-values at the chosen of ROIs is plotted in Fig. 2 (with mean and standard deviation of the normalized signal from all diffusion directions). The bone curve shows a descent tendency compared to that of the noise, indicating the existence of water diffusion. The calculated mean ADC of red marrow ROI is 0.55×10<sup>-9</sup> m<sup>2</sup>/s (muscle mean ADC 1.58 ×10<sup>-9</sup> m<sup>2</sup>/s). Since the diffusion of fatty yellow marrow is much slower ((1.8 ± 0.1)×10<sup>-11</sup> m<sup>2</sup>/s) [5], the detected water diffusion signals can only be attributed to red marrow. Volunteer 1's BA on red marrow trace is given in Fig. 3, showing good agreement. The spectrum of the chosen ROI in tibia epiphysis (Fig. 4(a)) is shown in Fig. 4(b), where a peak (relative amplitude 0.1 against the (CH<sub>2</sub>)<sub>n</sub>-CH<sub>3</sub> peak) is spotted at water chemical shift around 4.7 ppm.

**Conclusion:** We presented a tuned DTI protocol to assess residual red marrow in the tibia epiphysis where yellow marrow is considered to dominate and conventional sequences provide less specific information. Our results on three healthy male adults showed that water signal in red marrow is detected. The proposed DTI based protocol may potentially be used to assess the distribution pattern of the residual red marrow in the adult lower limbs. This technique would help to further characterize red marrow distribution and may help detect abnormal patterns which can be related to local and systemic pathology such as inflammatory or hematopoietic diseases.

**Reference:** 1. Y. Nonomura et al. JMRI (2001) 13(5): 757-767 2. ME Kricun Skeletal Radiol(1985) 14:10-19 3. F.W. Roemer et al. Osteoarthritis Cartilage(2009) 17(9) 1115-1131 4. <http://www.cs.ucl.ac.uk/research/medic/camino/> 5. G. Steidle et al. MRM (2011) 65:1119-1125

