Ultrafast T2* mapping of bone marrow at 1.5 Tesla and 3.0 Tesla

R. Toffanin[1,2], M. Cadioli[3,4], G. Scotti[4], M. A. Cova[5]

[1]PROTOS Research Institute, Trieste, Italy, [2]ARCHES, Castellana Grotte, Italy, [3]Philips Medical Systems, Monza, Italy, [4]Neuroradiology Dept., San Raffaele Scientific Institute, Milano, Italy, [5]Dept. of Radiology, University of Trieste, Trieste, Italy

Introduction. The presence of the trabecular bone matrix affects the signal intensity of bone marrow, an effect that is particularly enhanced in specific MRI sequences. With respect to gradient-echo acquisitions, B_0 inhomogeneities produced by the difference between trabecular bone and neighboring bone marrow cause a more rapid decay of the MR signal, which can be quantified by measuring T2*. Several pioneer studies have demonstrated that T2* depends on trabecular bone density (1,2) such that the effective transverse relaxation (T2*) should be shorter in normal trabecular bone than in the less dense trabecular network of osteoporotic tissue. T2* also has been found to reflect the trabeculae's orientation and correlate with biomechanical strength (3-5). Therefore, together with trabecular bone volume fraction (BVF) T2* is another important parameter that can be measured by MRI to obtain new information about bone quality. In a recent study, Wehrli *et al.* (6) have shown that R2* (1/T2*) measured in the calcaneus of women with varying degrees of osteopenia and vertebral deformity status is sensitive to alterations in bone quality not captured by bone mineral density (BMD). In light of the above, it is clear that MRI has the potential to follow the progression of osteoporosis and help predict who is most at risk of debalitating fractures. However, quantitative MRI protocols commonly used for the study of trabecular bone are rather slow and, therefore, unsuitable to clinical applications. The development of rapid quantitative methods could promote the use of MRI in the clinical investigation of osteoporosis. The purpose of this study was to evaluate the feasibility of a multi-shot EPI sequence for the ultrafast T2* mapping of bone marrow.

Methods. Experiments were performed on the calcaneus of six healthy volunteers on a 1.5-T Philips Intera scanner using a dual phased-array receiver coil and on a 3.0-T Philips Intera using a head coil. At 1.5 Tesla, T2* was measured from a series of fifteen sagittal images (TE_{min} = 3.4 ms, TE_{max} = 20.2 ms) of only one foot obtained whereas at 3.0 Tesla, T2* was derived from a series of eleven axial images (TE_{min} = 2.0 ms, TE_{max} = 15.8 ms) of both feet. In both cases, the multislice multishot EPI sequence was applied with removed blip gradients in order to apply the same phase encoding to all gradient echoes and the total examination time was approximately 1 minute and 50 seconds. For all acquisitions, a flip angle of 30°, a repetition time (TR) of 200 ms, a slice thickness of 5 mm and a matrix of 256×256 with a field of view of 150×150 mm were used. On both scanners, a standard gradient-echo sequence with similar acquisition parameters was also used for comparison. Estimation of T2* was performed on manually defined circular regions of the calcaneus. T2* parametric maps without and with B_0 correction were calculated off-line as described in Ref. 7.

Results and Discussion. In all volunteers, the T2* values obtained with the multi-shot EPI sequence were comparable to the corresponding values measured with the standard gradient-echo approach. At 1.5 Tesla, the average T2* values estimated with the EPI sequence on three volunteers were in the range 8.3 – 13.4 ms. Ii is important to note that for both sequences the relaxation data illustrated characteristic regional variations in marrow T2* reflecting the architectural features of the calcaneus (8). This implies that, given the large regional variations in bone density and structure, the choice of a specific ROI plays a major role in the accuracy and precision of the T2* measurements.

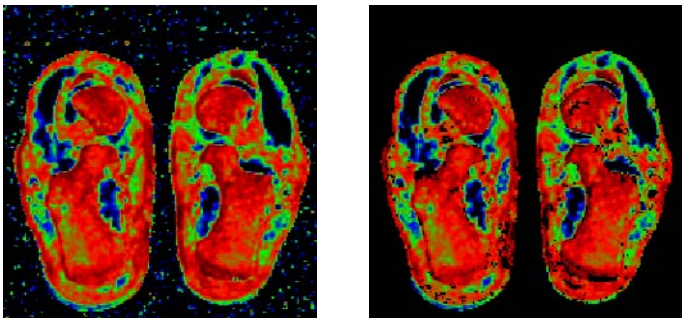

Figure 1. T2* map obtained from a series of axial images of both feet at 3.0 Tesla: (a) without and (b) with B_0 correction.

At 3.0 Tesla, the average T2* values were in the range 4.6 – 6.8 ms. In Figure 1 is reported the T2* map of an axial slice of both feet in a healthy volunteer, which also shows the characteristic regional T2* variations in both calcanei. However, no evident underestimation of T2* due to signal loss induced by macroscopic ΔB_0 inhomogeneitis can be observed.

Conclusion. These preliminary results indicate that ultrafast T2* mapping of bone marrow is feasible at 1.5 Tesla and at3.0 Tesla. Furher studies have to be performed to investigate the full potential of the proposed approach in the clinical investigation of osteoporosis.

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