

# Estimation of trabecular bone volume with dual-echo ultrashort echo time (UTE) magnetic resonance imaging (MRI) significantly correlates with high-resolution computed tomography (CT)

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**INTRODUCTION:** Fragility fractures are highly prevalent and result in a significant financial cost and reduction in an individual's quality of life. These fractures will likely increase in incidence with the growing population of older adults, with a predicted worldwide incidence of 6.3 million fragility fractures each year by 2050.<sup>1</sup> Osteoporosis represents the most important treatable factor for these fractures. The current clinical standard to measure osteoporosis is dual-energy x-ray absorptiometry (DEXA), but DEXA may fail to predict fracture risk accurately, as many fractures occur in individuals who do not meet the diagnostic criteria for osteoporosis by DEXA.<sup>2</sup> As a result, there has been interest in quantitative assessment of trabecular bone microarchitecture to better predict bone strength, including computation of morphometric indices such as the bone volume density (BV/TV) utilizing micro-computed tomography ( $\mu$ CT).<sup>3</sup> However, like DEXA,  $\mu$ CT also requires exposure to ionizing radiation and has limited clinical feasibility. MRI offers a potential solution to these risks and allows for the assessment of the adjacent soft tissues, but conventional clinical MRI sequences do not allow for quantitative assessment of bone because signal in bone, which has a short transverse relaxation time, has already decayed by the time of image acquisition. UTE MRI employs short echo times (TEs) on the order of several to tens of microseconds, which allows for detection of signal from bone. This study investigates the feasibility of utilizing dual echo UTE MRI to estimate the ratio of bone volume to total volume (BV/TV) of trabecular bone.

**METHODS:** Six donor fresh-frozen cadaveric lower leg specimens were included in this study. This research was designated as exempt from review by the Institutional Review Board. A 20 mm<sup>3</sup> bone cube was excised from the distal tibial metaphysis of each specimen and imaged with a dual-echo UTE-Cones sequence (repetition time (TR) 12.1 ms, TE 0.032 and 2.2 ms, FOV 100 mm, acquisition matrix 200 × 200, slice thickness 0.5 mm, voxel size 0.5 × 0.5 × 0.5 mm<sup>3</sup>). ROIs were placed on 10 slices in the center of each specimen to avoid artifacts produced by air infiltration into trabecular space at the edges of the specimen. For each ROI, the BV/TV was calculated with the following equation:  $BV/TV_{MR} = \frac{Signal_{UTE} - Signal_{TE=2.2ms}}{Signal_{UTE}}$ . The same specimens were imaged by  $\mu$ CT (50  $\mu$ m<sup>3</sup> isotropic voxel size, FOV 100 mm, 60 kV, 32 mA, 0.5° rotation step). Ten consecutive  $\mu$ CT slices were selected manually per MRI slice. The BV/TV for each slice was calculated with the following equation:  $BV/TV_{CT} = \frac{Bone\ voxel\ count}{Total\ voxel\ count}$ . Distribution of the measured BV/TVs was examined with the Kolmogorov-Smirnov test. A two-sided Wilcoxon rank sum test was used to evaluate the difference between the mean MRI and  $\mu$ CT BV/TV values. Spearman's rank correlation coefficient was calculated between the MRI and  $\mu$ CT-based BV/TV values. P-values of less than 0.05 were considered statistically significant.

**RESULTS:** BV/TV was calculated from both UTE-MRI and  $\mu$ CT images (Figures 1 and 2). The mean BV/TV<sub>MRI</sub> was significantly lower than the mean BV/TV<sub>CT</sub> value. Linear regression of BV/TV<sub>MRI</sub> on BV/TV<sub>CT</sub> for all ROIs showed strongly significant correlation (Figure 3, R=0.84).

**DISCUSSION:** The estimation of BV/TV by dual-echo UTE MRI was strongly correlated with  $\mu$ CT values, supporting our hypothesis that UTE-MRI is a feasible technique for the assessment of BV/TV. Although the MRI measurements were highly correlated with the  $\mu$ CT-based values, the MRI values were consistently higher. We speculate that this may be due to differences in proton density between fat and water, such that the fat volume may be overestimated by MRI. Further investigation will be needed to determine whether this may affect BV/TV estimation in *in vivo*, particularly in individuals with differences in body composition. This technique was performed in a rapid fashion (scan time of approximately 5 min) as compared to  $\mu$ CT (80 min). The major limitations of this study are that it was a feasibility study with a small sample size performed on *ex vivo* specimens. Future studies will be needed to evaluate this technique in bone specimens with surrounding soft tissues, as well as *in vivo*.

**SIGNIFICANCE/CLINICAL RELEVANCE:** This study demonstrates the feasibility of utilizing dual-echo UTE MRI to estimate BV/TV in trabecular bone, suggesting that UTE-MRI may be a promising MRI-based technique for assessment of trabecular bone microarchitecture. This would allow for the non-invasive assessment of information regarding bone strength and potentially fracture risk prediction that is not captured by routine clinical DEXA measurements alone, without the use of ionizing radiation.

## REFERENCES:

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## IMAGES AND TABLES:

