Comparison of High-resolution MRI and Optical Microscopy in Quantitation of Trabecular Architecture in the Rat Femur

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Synopsis

Recently, magnetic resonance micro-imaging (μMRI) has been applied to the study of trabecular bone structure in the diagnosis of osteoporosis [1-5]. In vitro studies using clinical MR scanners have shown the potential of μMRI to predict the biomechanical strength of bone [2], and in vivo studies have demonstrated the ability to discriminate between patients with and without osteoporotic fractures [3-5]. MRI also has the potential to quantify both trabecular bone density and architecture. The aim of this project was to compare quantitative measures of rat femur bone morphology obtained from MRI with those obtained by conventional optical microscopy.

Methods

Magnetic resonance imaging has been used to analyse trabecular bone architecture in samples of the neck of the femur from six adult Wistar rats. The MR images were obtained on a Bruker Avance 4.7 T micro-imaging system using a 3D spin echo sequence with spatial resolution of 23 μm in-plane and a slice thickness of 43 μm. The 3D SE images were obtained with the following parameters: TR of 1000 ms, TE of 4.08 ms, and a bandwidth of 100 kHz. A data matrix size of $256 \times 256 \times 128$ was used with a field of view (FOV) of 6 mm × 6 mm ×5.5 mm. The optical images were obtained by decalcifying the bone in EDTA and then sectioning 5 μm thick slices. Correlation coefficients between the MRI and optical derived measures of morphology, including ratio of bone to total volume (BV/TV), trabecular spacing (Tb.Sp), trabecular number density (Tb.N) and trabecular thickness (Tb.Th) were calculated as well as the difference between the MRI and optical measures (as a percentage of the optical data).

Results

These calculations were completed for both unfiltered and filtered images. The filtering method removed small objects with a perimeter less than 0.1 mm that did not appear to be trabecular bone. The filtering was mostly only necessary for the optical images due to their very high resolution. In the filtered images the average difference between the MR and optical images for ratio of bone to total volume (BV/TV) was 1.2 %. Correlation between the two methods was lowest for parameters sensitive to trabecular architecture, ranging from r = 0.77 (BV/TV) to r = 0.55 for trabecular number (Tb.N). These relatively low correlations are thought to be caused primarily by distortion of the bone structure in the decalcification process used to section the bone and hence obtain the optical images. MRI of decalcified bone samples prior to sectioning confirmed this.

Discussion

There is growing evidence to suggest that variations in trabecular structure are important in determining bone strength, independent of bone mineral density (BMD). This work demonstrates the potential of MRI in determining quantitative information on bone morphological parameters. The high resolution achieved in this study was essential to reducing the large partial volume effects normally associated with small animal bone studies. Due to the much larger trabecular architecture in humans a much lower resolution can be used. The ultimate aim of this work is to be able to assess the efficacy of various therapeutic regimes on patients with osteoporosis.

References

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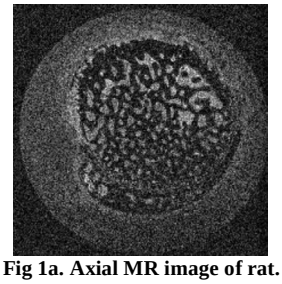

Fig 1a. Axial MR image of rat. bone.

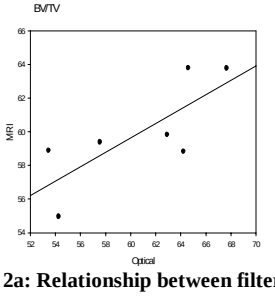

Fig 2a: Relationship between filtered MRI and Optical data for BV/TV. r=0.77, p=0.04.

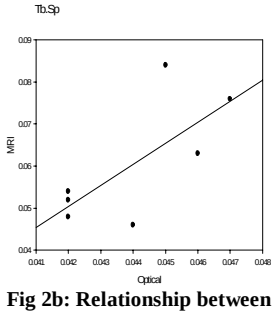

Fig 2b: Relationship between filtered MRI and Optical data for Tb.Sp. r = 0.71, p = 0.07

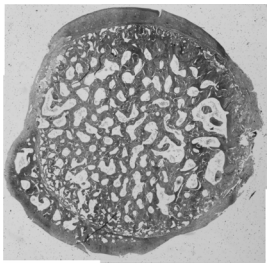

Fig 1b. Optical image of rat bone from a similar location to Fig.1a (image slightly rotated).

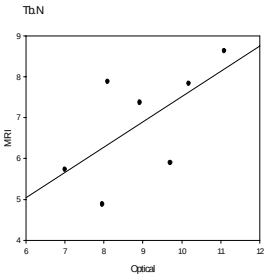

Fig 2c: Relationship between filtered MRI and Optical data for Tb.N. r=0.64, p=0.13

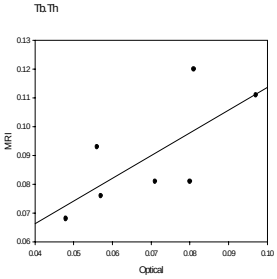

Fig 2d: Relationship between filtered MRI and Optical data for Tb.Th. r = 0.72, p = 0.07.