Development of a compact MRI using a permanent magnet for trabecular bone microstructure measurements

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INTRODUCTION

Measurements of trabecular bone (TB) microstructure are essential for estimation of bone strength and evaluation of drug therapies against osteoporosis. High resolution MRI (HR-MRI) is a safe and powerful tool for the TB microstructure measurements. Up to now, several groups have reported in vivo TB measurements using HR-MRI using whole body MRI systems (1,2). However, they are not cost effective for this purpose. In this study, we have developed a compact MRI for TB microstructure measurements of the distal radius and the calcaneus using a 1.0 T permanent magnet.

MATERIALS AND METHODS

Figure 1 shows the compact MRI system developed in this study. The entire system was installed in a 1 m × 2 m space. The specification of the permanent magnet (NEOMAX, Osaka, Japan) is; magnet field strength: 1.0 T, gap space: 10 cm, homogeneity region: 8.6 ppm over a 5 cm diameter spherical volume, and weight: 1350 Kg. The magnet temperature was regulated at around 30 °C to minimize Larmor frequency drift. The maximum gradient field strengths are 132, 140, and 196 mT/m for Gx, Gy, and Gz.

Two RF probes were developed for this system. A 6-turn solenoid (oval aperture (5.5 cm width × 8 cm height) and 4 cm length) was used for wrist imaging (Fig.2). A 4-turn solenoid (oval aperture (7 cm width × 13 cm height) and 4 cm length) was used for calcaneus imaging (Fig.3). Both solenoids were stored in RF shield boxes for electrical stability. 3D driven equilibrium spin-echo sequences (3D-DESE) were used for imaging of TB. Typical matrix size, voxel dimension, and data-acquisition time were 512 × 256 × 32 and 150 × 150 × 500 micron cube, and 22 minutes (TR/TE = 80 ms/10 ms, NEX = 2) for the radius, and 256 × 256 × 128 and 250 × 250 × 500 micron cube, and 27 minutes (TR/TE = 50 ms/8 ms, NEX = 1) for the calcaneus.

RESULTS AND DISCUSSION

Figures 4 and 5 show 2D images selected from 3D image datasets of the distal radius and the calcaneus. Although the TB microstructure were clearly visualized in the MR images, no distinct peaks for bone and bone marrow were observed in the global histograms due to the partial volume effect and signal intensity variation over the volume of interest. Therefore, some histogram deconvolution method should be applied to these image datasets to obtain TB microstructure parameters [3,4].

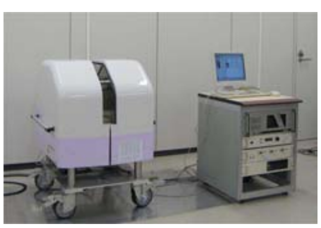

FIG.1

FIG.2

FIG.3

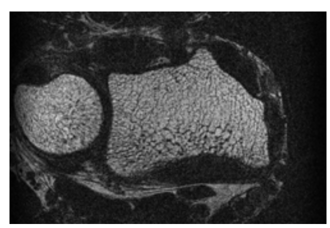

FIG.4

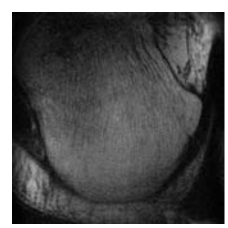

FIG.5

CONCLUSIONS

A compact MRI for in-vivo TB microstructure measurements of the distal radius and the calcaneus was developed. Using 3D-DESE sequences, TB microstructures were clearly visualized less than 30 min. Although further improvements in measurement time and image processing will be needed, our system has a promise for a diagnostic tool for osteoporosis.

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