A histogram deconvolution method for trabecular bone microstructure measurements using high resolution MRI in the presence of the partial volume effect

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Introduction

Trabecular bone (TB) microstructure measurements of the distal radius and tibia using high resolution MRI (HR-MRI) are essential for estimation of bone strength and evaluation of drug therapy against osteoporosis (1,2). In the TB measurements of such peripheral sites, however, because of relatively low SNR, limited spatial resolution, and RF field inhomogeneity, separation of bone and bone marrow voxels using a global threshold is difficult, and several approaches to this problem have been proposed (3,4).

On the other hand, in a compact MRI for TB measurements of the finger, because of relatively high SNR and homogeneous RF field produced by a solenoid coil, two peaks for bone and bone marrow voxels were clearly observed in the image intensity histogram (5). However, because the spatial resolution is not sufficient for TB, a quantitative or reliable method to separate the bone and bone marrow is indispensable. In this study, we have developed a histogram deconvolution method in which the partial volume effect is considered in the histogram of the real part image and applied it to image datasets acquired with the compact MRI for a finger TB.

Deconvolution Method

If there is no thermal noise in the NMR signal, the image intensity histogram of a TB system can be expressed by two δ functions and a uniform distribution between them (Fig.1) (4). The two δ functions correspond to trabecular bone and bone marrow voxels and the uniform distribution corresponds to mixed voxels. The uniform (square) distribution is based on a simple assumption on the partial volume effect.

In the presence of thermal noise, the δ functions are broadened to be Gaussian distributions in the histogram of the real part image. The square distribution is convolved with the Gaussian distribution to be a "smooth trapezoidal" distribution. This distribution cannot be expressed in a simple formula but can be easily calculated using a convolution.

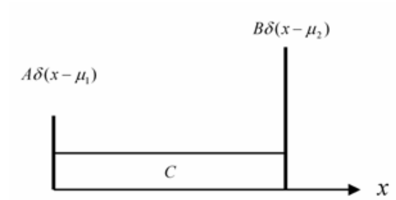


Fig.1 Noiseless histogram for a TB system

Experimental Evaluation

Two subjects (A: 53 aged man, B: 45 aged woman) were used for experimental evaluation of the proposed method. A compact MRI developed for TB microstructure measurements of a finger was used (Fig.2) (5). The middle finger of the subjects was measured using a 3D driven equilibrium spin echo sequence (TR = 50 ms, TE = 6 ms, image matrix = 128×128×128, FOV = (20.48 mm)^3). Subject B was repeatedly measured for reproducibility evaluation.

0th order phase correction was performed for the raw image datasets and they were reconstructed using a 256 × 256 × 256 voxel Fourier transform. Therefore, the spatial resolution and the voxel size were (160μm)^3 and (80μm)^3, respectively. Figure 3 shows sagittal and transverse cross-sections of the real part image of subject A.

Figure 4 shows fitted curves for image intensity histograms in a parallelpiped region (about 80,000 voxels included) located in the TB area of the finger. Fig.4(a) shows a conventional method, fitting of the magnitude image histogram with Rayleigh distribution (bone) and Gaussian distribution (bone marrow). Fig.4(b) shows the proposed method, fitting of the real part image with three distributions. As shown in Fig.4, the proposed method gives much better fitting than the conventional method. For 19 repeatedly acquired datasets of subject B, averaged square error for fitting with the proposed method was about 40% of that with the conventional method.

Fig.2 Compact finger MRI

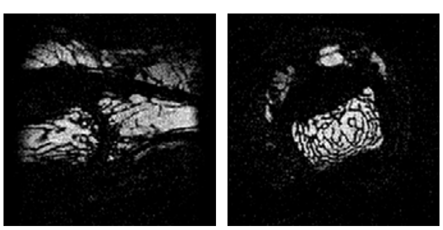
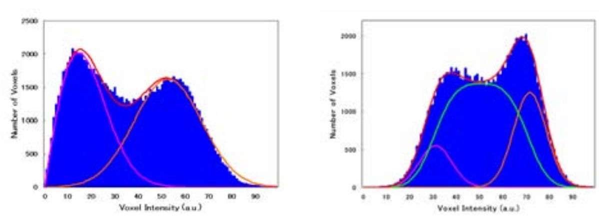


Fig.3 Cross sections of a middle finger



(a) magnitude image (error=600435) (b) real part image (error=145417)

Fig.4 Fitted curves for the histogram

Discussion and conclusion

The partial volume effect was successfully formulated for deconvolution of the histogram of TB using the real part image. The proposed method is useful for calculation of reliable BVF and threshold value between bone and bone marrow voxel acquired with the compact MRI for a finger TB.

References

[1] Majumdar S. Top Magn Reson Imaging 2002;13:323-334. [2] Wehrli FW, Saha PK, Gomberg BR, Song HK, Snyder PJ, Benito M, Wright A, Weening R. Top Magn Reson Imaging 2002;13:335-355. [3] Majumdar S, Genant HK, Grampp S, et al. J Bone Miner Res 1997;12:111-118. [4] Hwang SN, Wehrli FW. Int J Imaging Syst Technol 1999; 10:186-198. [5] Iita N, Handa S, Tomiha S, and K Kose. Magn Res Med, accepted for publication.