Quantitative Measurement of Bone Marrow Composition and Bone Structure Using Simultaneous Acquisition of Fat Fraction and T2* with Multiple-echo Gradient-echo Method in the Normal Volunteers and Hematological Disease Patients

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Introduction

MR imaging is an ideal technique for non-invasively studying bone marrow cellularity and bone marrow invasion in the spine. While marrow composition has been inferred qualitatively from MR appearance, there are a few quantitative studies directly measuring the two constituents of fat and water [1,2]. In addition, the method we present here is able to provide the rate constants, T2*. T2* values are sensitive to local magnetic susceptibility arising from the interface between trabecular bone and bone marrow [3,4].

Here, we illustrate its use for measuring lumbar spine of fat fraction and T2* in normal volunteers and malignant hematological disease.

Materials and Methods

The study included eleven normal volunteers ranging in age from 23 to 48 years old (mean: 33.9 year old) without any medical histories of fracture, hematological disease, malignant disease or irradiation and eleven malignant hematological disease of acute lymphocytic leukemia, acute myeloid leukemia, myelodysplastic syndrome, and non-Hodgkin's lymphoma in ranging age from 25 to 82 years old (mean: 55.6 years old). MR imaging was performed on 1.5T whole-body imager (Nova Dual, Philips Medical Systems). The pulse sequence generates gradient echoes at TE = 2.3, 4.6, 9.2, 13.8, 18.4, 23.0, 27.6, 32.2, 38.8, 43.4 and 48 msec. Then the real image of the first echo was used to differentiate between the areas above and below the 50 % fat fraction. The last ten in-phase echoes were used for measuring bone marrow T2*. The imaging parameters were TR= 500m sec, a field of view of 38x38cm^2, matrix= 256x256, slice thickness=10 mm, flip angle=12 degree. Lumbar region were scanned in sagittal plane using phased array coil. Data were reconstructed on-line workstation yielding fat fraction, water fraction and T2* images due to the real image differentiating fat fraction and the effects eliminating the T1 effect. The region of interest (ROI) was measured at lumbar vertebrae excluding the cortex at the L3 vertebrae. In order to assess the accuracy of the fat and water fraction, localized MR spectroscopy (MRS) using the standard PRESS sequence was performed in the same location. Mean and SD of fat fraction and T2* were calculated from ROIs (80-150) pixels) by using same ROI's in the lumbar spine of normal volunteers and malignant hematological disease. Fat fraction (fat /fat +water) of multiple echo gradient echo images (MEGE) vs. MRS were analyzed by linear regression using commercially available software, and the mean values of T2* were compared using Mann-Whitney rank test and commercially available software (JMP; SAS Institute Inc.). Significance was defined as $P < 0.05$.

Results

Typical fat fraction, water fraction, and T2* images were shown in Fig. 1. The mean fat fraction and T2* values of normal volunteer group (Normal) and malignant hematological disease group (Malignant) for L3 vertebra were (mean+/-SD) as table 1. Fat fraction values of MEGE vs. MRS showed very good agreement (R^2 =0.81) in Fig. 2. The mean o T2* of normal volunteers for the L3 showed was significantly higher than that of malignant hematological disease ($P < 0.05$) (Fig. 3).

Discussion and conclusion

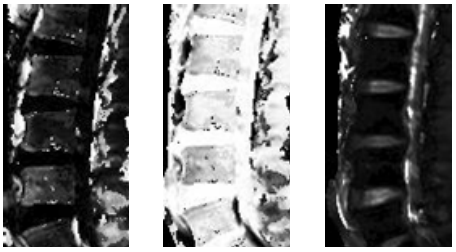
Fat fraction values of MEGE vs. MRS were shown very good agreement. This result suggests that MEGE could accurately measure the fat component and the water component of spinal bone marrow.As Wehrli FW et al. report that bone marrow T2* is determined by bone marrow suseptability difference, our results could show significant difference of each group by bone marrow susceptibility difference due to malignant cell invasion [4]. In summary, MR determination of those parameters could be used to assess and diagnose a deficiency in marrow composition and bone structure using fat fraction and T2*.

References

1. Dixon WT. Radiol 153: 189, 1984.
2. Ishijima H, et al. AJR 167: 355, 1996.
3. Ma J, et al. J Magn Reson Ser B 111: 61, 1996.
4. Wehrli FW et al. Radiol 196:631, 1995.

	Normal	Malignant
Fat fraction	0.51±0.10	0.46±0.31
T2* (msec)	12.1±1.68	9.80±3.10

Table 1: Fat fraction and T2* of Normal and Malignant



(a) (b) (c)

Fig. 1: A 41-year old female of normal volunteer (a) Fat fraction image (b) Water fraction image (c) T2* image

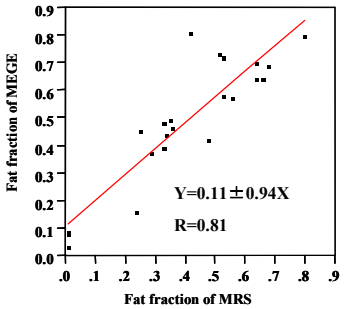


Fig. 2: A comparison of fat /(fat+water) ratio

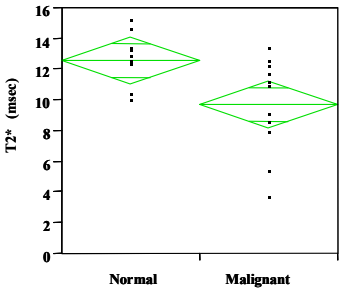


Fig. 3: T2* value of each group