Measurements of bone marrow proton relaxation times and trabecular bone volume fraction (TBVF) of the calcaneus for 100 subjects using a compact MRI

S. Tomiha[1], N. Iita[1], F. Okada[1], S. Handa[1], K. Kose[1]

[1]Institute of Applied Physics, University of Tsukuba, Tsukuba, Ibaraki, Japan

Introduction

The low resolution MRI method for trabecular bone volume fraction (TBVF) measurements requires T_1 and T_2 corrections [1,2]. Relaxation times of the bone marrow protons in the calcaneus, however, seemed to be nearly constant for adult healthy human subjects [3]. If the relaxation times can be treated constant within experimental errors, the correction scan becomes unnecessary and the examination time for TBVF measurements could be drastically reduced. In the present study we measured relaxation times of the bone marrow protons, TBVF, and QUS-SOS for the calcaneus of 100 female subjects to clarify the properties of the relaxation times.

Materials and Method

100 healthy female subjects (age: 16-81, mean: 42.5) voluntarily participated in this study. After the informed consent was obtained, MRI and QUS measurements were performed for the right calcaneus. A compact dedicated MRI with a 0.21 T and 16 cm gap permanent magnet was used for the MRI measurements [2]. Three 2D single spin-echo sequences (slice thickness 15mm, TR/TE = 1200ms/12ms, 1200ms/96ms, and 200ms/12ms) were used to measure T_1, T_2, and density of the bone marrow protons with external oil phantoms. The total measurement time for the three 128 x 128 pixel images was about 3 minutes, because the doubly zero-filled interpolation technique was applied for the 64-step phase encoding direction. Relaxation times and the TBVF was calculated in the 20 mm diameter circular ROI shown in Fig.1. SOS measurements were performed using a commercially available QUS instrument (DM-US100: Panasonic).

Results and Discussion

Table 1 shows R^2 between T_1, T_2, TBVF, AGE, and SOS. The largest R^2 was that between T_1 and T_2. As shown in Fig.2, two isolated data points (T_1 = 135, 200 ms) were observed but found to be located along the regression line. The second largest R^2 (=0.452) was that between TBVF and SOS as shown in Fig.3. This high correlation was obtained primarily because the ROI was common in MRI and QUS.

The most remarkable result was the definite correlation between T_1 and SOS, and T_1 and age as shown in Figs.4 and 5. Because T_1 has no correlation with TBVF, i.e. amount of bone, as shown in Table 1, the correlation between T_1 and SOS suggests that T_1 is affected by mechanical or elastic property of the bone marrow (yellow marrow). The age dependence of T_1 also suggests that mechanical or elastic property of the bone marrow changes with age.

Mean and standard deviation of T_1 and T_2 were 171.0±9.0 ms and 80.1±3.1 ms for the 100 subjects. These results show that if we use T_1 weighted sequence (TR/TE=200ms/12ms) and mean values of T_1 for proton density correction, several % error will be produced, and if we use density weighted sequence (TR/TE=1200ms/12ms) and mean value of T_2 for proton density correction, about 1% error will be produced. Therefore, substitution of mean T_2 value in T_2 correction can be used for healthy subjects as shown in Fig.6 (R^2=0.977). In this figure, the horizontal axis is TMVF (trabecular marrow volume fraction) calculated with individual T_2 and the vertical axis is TMVF calculated with the mean T_2.

Conclusion

It was found and suggested that T_1 of bone marrow protons in the calcaneus have no correlation with TBVF but has a definite correlation with elastic or mechanical property of the bone marrow. Distribution of T_2 of bone marrow protons was relatively small compared with that of T_1. As a result, T_2 correction scan can be skipped for adult healthy subjects, which can reduce the examination time to 50%.

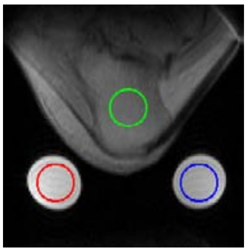

Fig.1 Heel cross section

-	T_1	T_2	TBVF	AGE	SOS
T_1	-	0.812	0.004	0.159	0.146
T_2	0.812	-	0.0006	0.098	0.144
TBVF	0.004	0.0006	-	0.234	0.452
AGE	0.159	0.098	0.234	-	0.311
SOS	0.146	0.144	0.452	0.311	-

Table 1 Correlation coefficient (R^2)

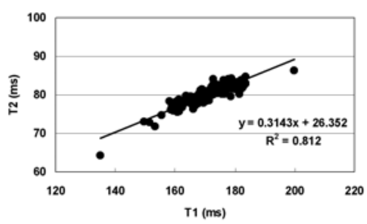

Fig.2 T_1 vs T_2

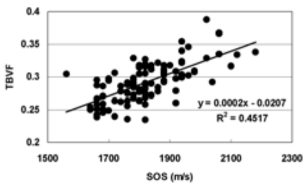

Fig.3 SOS vs TBVF

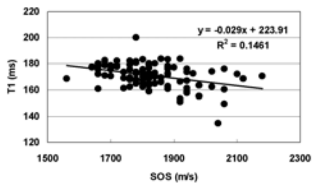

Fig.4 SOS vs T_1

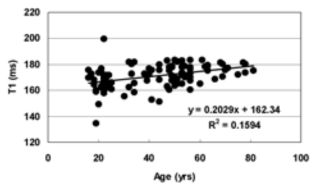

Fig.5 Age vs T_1

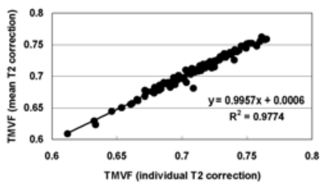

Fig.6 TMVF-TMVF′

References

[1] Fernandez-Seara MA, Song HK, Wehrli FW, Magn Reson Med 2001;46:103-113. [2] Kose K, Matsuda Y, Kurimoto K, Hashimoto S, Yamazaki Y, Haishi T, Utsuzawa S, Yoshioka H, Okada S, Aoki M, and Tsuzaki T, Magn Reson Med 2004;52:440-444. [3] S.Tomiha, T.Furuya, N.Iita, F.Okada, K.Kose, T.Haishi, Proc 13th ISMRM, Miami, p1984.