

# 3D trabecular bone volume fraction measurements of the calcaneus for 80 healthy female volunteers using a compact MRI system

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## INTRODUCTION

The calcaneus is a heterogeneous bone, but only its cylindrical part (diameter = 20~25 mm) in the tuber calcanei is used for quantitative ultrasound (QUS) examination for screening of osteoporosis. Although many researches have already reported the heterogeneity of the trabecular bone volume fraction (TBVF) and the microstructure in the calcaneus [1-3], 3D quantitation of the TBVF and its relation to QUS measurements are not reported. In this study, we measured 2D and 3D distribution of the TBVF in the calcaneus using 2DSE and 3DFSE sequences for 80 healthy female subjects to clarify the above relation.

## MATERIALS AND METHODS

MRI measurements were performed on the right calcaneus of 80 healthy female volunteers (age: 15-86 yo., mean: 42.1 yo.) using a dedicated compact MRI system with a 0.21 T permanent magnet (gap = 16 mm, homogeneity = 35 ppm over 20 cm × 20 cm × 12 cm dev, weight = 520 kg). For 74 subjects, speed of sound (SOS) through the calcaneus was measured using a commercially available QUS instrument. TBVF measurements in the 2D sagittal plane and 3D volume were performed using a 2DSE sequence (TR = 1200 ms, TE = 16 ms, slice thickness = 15 mm, FOV = 150 mm × 150 mm, image matrix = 128 × 64, scan time = 1.28 min) and a 3DFSE sequence (TR = 1200 ms, TE<sub>eff</sub> = 48ms, FOV = 150 mm × 150 mm × 64 mm, image matrix = 128 × 128 × 32, ETL = 16, interecho spacing = 16 ms, scan time = 5.12 min). The location of the sagittal plane was carefully determined to be the central plane of the calcaneus using MR images perpendicular to the sagittal plane. 2D and 3D images of the calcaneus were segmented using a dedicated segmentation program developed in our laboratory. TBVF for the segmented image data was calculated using an external reference phantom made of plant oil and a reasonable assumption that T<sub>2</sub> of the bone marrow protons is constant for all subjects [5].

## RESULTS AND DISCUSSION

Figures 1 and 2 show TBVF distribution obtained from the 2D and 3D measurements for an identical subject superimposed over the corresponding original MR images. Because the thickness for the 3D distribution in Fig.2 is 2 mm, heterogeneity of the TBVF in the calcaneus is more clearly visualized comparing with that for the 2D distribution (slice thickness = 15 mm). Figure 3 shows 3D distribution of the TBVF, which clearly shows a change perpendicular to the sagittal plane as already reported [6].

Figure 4 shows a histogram of the ratio of 2D segmented volume to 3D segmented volume of the calcaneus calculated for the 80 subjects. This figure clearly shows that considerable part of the calcaneus (about 67% on average) is included in the 2D sagittal cross section with 15 mm slice thickness. Figure 5 shows correlation between TBVF averaged over the 2D and 3D segmented volume calculated for the 80 subjects. The correlation coefficient 0.78 represents difference in the regions for 2D and 3D measurements as shown in Fig.4 and some experimental or segmentation errors. Figure 6 shows TBVF averaged over the circular ROI (diameter = 20 mm), of which center is the weighted center of the 2D segmented area, nearly corresponding to the area for the QUS measurements, plotted against TBVF averaged over the 2D segmented area for the 80 subjects. Because the correlation coefficient is very high (0.967), the TBVF in the circular ROI, located near the tuber calcanei, represents the TBVF averaged over the sagittal plane. This result strongly supports that QUS measurements in the circular ROI in the tuber calcanei can represent total bone status of the calcaneus.

Table 1 summarizes correlation coefficients between age, SOS by QUS, TBVF averaged over the 2D segmented volume, and TBVF averaged over the 3D segmented volume, calculated for the 74 subjects. The TBVF in the 2D sagittal section has relatively high correlation with QUS and age, which demonstrates that 2D TBVF is an excellent parameter for bone evaluation of the calcaneus by MRI. In conclusion, 2D and 3D TBVF measurements of the calcaneus have clarified that the circular ROI in the tuber calcanei can represent total bone status, which supports the validity of the QUS measurements.

**REFERENCES:** [1] Lin JC et al, Osteoporosis Int. 1998;8:16-24. [2] Wehrli FW et al. J Bone Miner Res 2002;17:2265-2273. [3] Phan CM et al. Radiology 2006;239:488-495. [4] Kose K et al. Magn Reson Med 2004;52:440-444. [5] Tomiha S et al. Magn Reson Med 2008;60:485-488. [6] Tomiha S et al. ISMRM Proc. 2005, p1983.

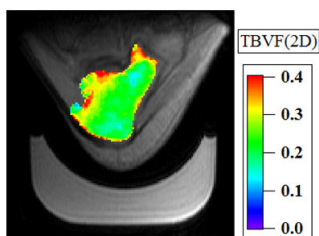


Fig.1 TBVF in 2D section

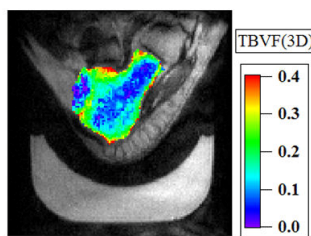


Fig.2 TBVF in 3D section

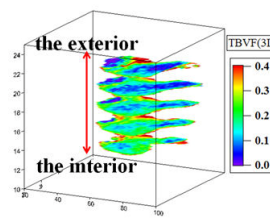


Fig.3 TBVF 3D mapping

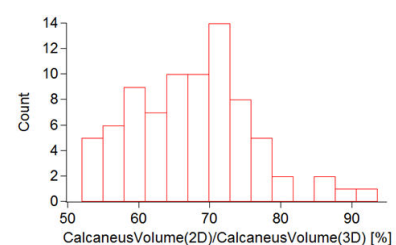


Fig.4 2D to 3D volume ratio for the calcaneus

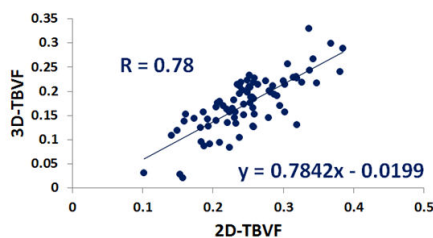


Fig.5 Correlation between 2D and 3D TBVF

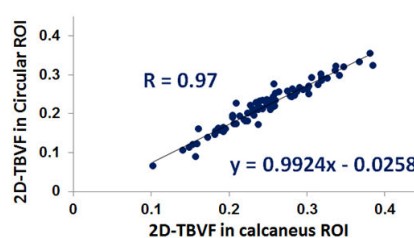


Fig.6 TBVF in circular ROI vs 2D total

	Age	SOS	2D-TBVF	3D-TBVF
Age		-0.50 (p < .00001)	-0.43 (p < .0001)	-0.28 (p < .02)
SOS			0.55 (p < .00001)	0.45 (p < .00001)
2D-TBVF				0.78 (p < .00001)
3D-TBVF				

Table 1 Correlations between parameters