MR imaging at 3T of Trabecular Bone Structure inType 2 Diabetes Patients: Comparison with in-vivo Micro-CT

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Background: Affecting 6.3% of the US population, type 2 diabetes is a common disease that is found predominantly in patients that are 55 or older, who are overweight and who do not exercise. While overweight patients are usually less prone to osteoporosis and have a lower fracture risk, recent cohort studies have shown that diabetes itself is associated with an increased risk of fracture of the hip, proximal humerus, and the ankle and foot. However, type 2 diabetes is often characterized by elevated bone mineral density (BMD). This paradox of higher BMD but increased fracture risk in type 2 diabetes patients is not clearly understood and may be explained in part by poorer bone quality. Bone structure has been shown to be an important component of bone quality and may give additional information on how to diagnose fracture risk in this patient population. It can be assessed non-invasively using high resolution MR imaging and peripheral quantitative CT (HR-pQCT).
Purpose: (I) To perform high resolution MRI at 3T of the calcaneus, the distal tibia and the distal radius in (i) type 2 diabetic postmenopausal females with and without low energy fractures and in (ii) age- and BMI-matched normal controls and to calculate trabecular bone parameters. (II) To compare the MRI results with bone parameters assessed by in-vivo high-resolution peripheral quantitative MicroCT (HR-pQCT).

Methods: MR imaging was performed in fifteen women (9 diabetic, 5 controls, mean age 60yrs), using a 3T Signa GE scanner (GE Medical Systems, Milwaukee, WI, USA), equipped with 44mT/m gradient and high-resolution Fiesta-C (TE=5.0 ms, TR= 12.9, t=11min) and FGRE (TE=4.0 ms, TR= 16.1, t=13min) sequences. A FOV of 10cm (in-plane spatial resolution of 0.195 mm) was used for the calcaneus and 8cm for the tibia (in-plane spatial resolution of 0.156 mm) with a slice thickness of 0.5 mm for all MR acquisitions. We employed parallel imaging (1) with a reduction factor of two (R=2) for the imaging protocol of the tibia (t=10min) and for the calcaneus (t=9min). In addition, the radius and tibia of each subject was imaged using HR-pQCT (Scanco Medical, Switzerland) with an isotropic voxel size of 82 μm. For MR acquisition, a coronal scout view was used to position the reference line in order to image a volume similar to the corresponding HR-pQCT volume (14mm from endplate for wrist and 27mm for tibia). In addition, QCT BMD for hip and spine was assessed for each subject.
For structure analysis binarization of the MR images was based on a dual reference model assuming a biphasic histogram as previously described by Majumdar et al. (2). For HR-pQCT images the volume of interest was segmented using a threshold-based algorithm. For radius and tibia, the trabecular bone region was segmented automatically with in-house developed software for MR images and on-board software for the HR-pQCT images. For both modalities, an operator corrected manually for false segmentation results. In the central sagittal slices of the calcaneus MR images, a circular region of interest (ROI) was manually placed posteriorly because of its sensitivity to osteoporotic changes (3). Apparent (app.) MRI bone parameters equivalent to 2D bone histomorphometry (4) and HR-pQCT parameters using the model-assumption-free 3D distance transformation method (dt3d) (5) were calculated for the chosen ROIs, including bone volume/total volume (BV/TV), trabecular (Tb) number (Tb.N), Tb thickness (Tb.Th), and Tb separation (Tb.Sp). We used a Student's t-test to compare the bone parameters of diabetic and normal subjects.

Results: Between the diabetic patients and controls, there was no significant difference in age, weight, BMI, hip QCT BMD and spine QCT BMD ($p>0.1$). However, we found differences in the MR images (Fig. 1) of the radius where app.Tb.N in diabetics ($1.51\pm0.13 mm^{-1}$) was higher compared to normals ($1.33\pm0.15 mm^{-1}$)($p=0.06$, Table 1) and app.Tb.Sp of diabetics (0.49 ± 0.10mm) was lower compared to normals (0.61 ± 0.04mm)($p=0.07$). The HR-pQCT bone parameters were significantly different for both groups for BV/TV, Tb.N and Tb.Sp (Table 1). The MR parameter app. Tb.N. in the tibia was lower in diabetics ($1.32\pm0.17 mm^{-1}$) than in normals ($1.71\pm0.13 mm^{-1}$) ($p=0.07$), whereas the app.Tb.Sp was higher in diabetics (0.62 ± 0.13mm) compared to the control group (0.39 ± 0.07mm) ($p=0.09$). None of the HR-pQCT parameters was significantly different between the two groups in the tibia. In the calcaneus, the app.Tb.Th in diabetes patients (0.27 ± 0.02mm) was significantly higher compared to the control group (0.24 ± 0.01mm) ($p=0.03$).

Table 1: p-values for group comparisons between diabetics and controls for bone parameters. p+ indicates that the parameter for diabetics was higher, p- that the parameter for diabetics was lower; ns indicates that $p>0.1$.

Site	Modality	Trabecular Bone Parameters			
		BV/TV	Tb.N	Tb.Sp	Tb.Th
Radius	MRI	ns	0.06+	0.07-	ns
	HR-pQCT	0.01+	0.05+	0.04-	ns
Tibia	MRI	ns	0.07-	0.09+	ns
	HR-pQCT	ns	ns	ns	ns
Calcaneus	MRI	ns	ns	ns	0.03+

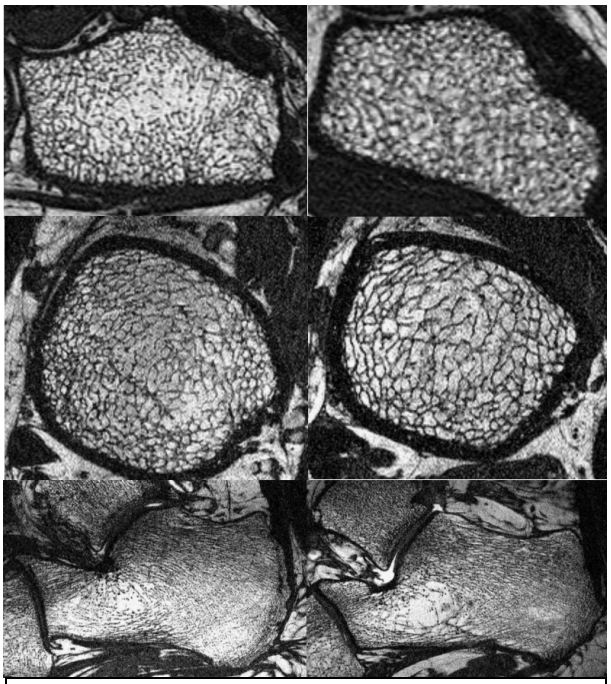

Figure 1: MR images of a control (left column) and a diabetes patient (right column). Upper row: distal radius; middle row: distal tibia; lower row: calcaneus.

Discussion: In this work, we compared the MR and HR-pQCT trabecular bone structure parameter of type 2 diabetes patients with an age-, BMI- and QCT BMD-matched control group. Our results indicate, that type 2 diabetes patients may have a denser bone architecture in the radius (higher Tb.N, lower Tb.Sp) compared to controls, whereas in the tibia, the bone architecture appears more scarce. In calcaneus, we found elevated app.Tb.Th for diabetics. The significance levels of all reported differences is close to or slightly higher than $p=0.05$. This is a pilot study and larger numbers of subjects clearly need to be investigated. Future work will also include the quantification of the cortical bone. We observed that the type 2 diabetes patients revealed a porous cortical bone pattern in the MR images very different from the control group. Currently, we are developing the tools to analyze this interesting characteristic.
We conclude that there are differences in the trabecular bone structure between type 2 diabetes patients and normal subjects and that those differences may be site dependant, we hypothesize that the distal tibia may be more strongly affected by type 2 diabetes than the distal radius. Future work will focus on cortical porosity as a potential measure in diabetic bone disease.

References:

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