3D Rigid Registration of MRI and HR-pQCT trabecular bone images

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Introduction

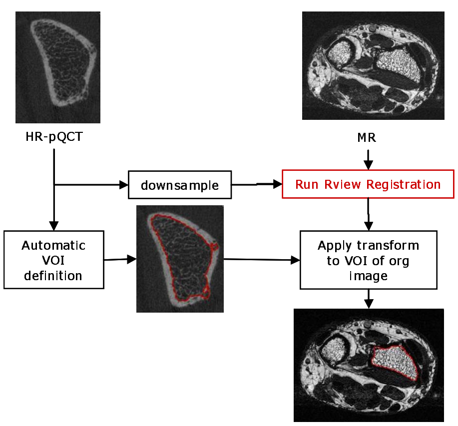
Osteoporosis is a metabolic disease characterized by bone loss, decreased bone strength, and increased fracture risk. Studies have investigated the relationship between trabecular bone structure and bone strength[1]. It has been shown that both MRI and High Resolution peripheral Quantitative Computed Tomography (HR-pQCT) are able to visualize and analyze bone structure in-vivo and non-invasively[2,3]. Recently there have been studies comparing trabecular bone structure parameters obtained by 3T MRI and HR-pQCT[4,5]. These studies have shown that there are considerable variations in trabecular structure parameters along the length of the imaged regions and consistent alignment of analysis volume between modalities is crucial for comparing trabecular bone structure parameters. Alignment between MRI and HR-pQCT images using a normalized mutual information registration algorithm (Rview)[6,7] would have a profound impact on the quantitative comparison of trabecular bone structure parameters between these two modalities.

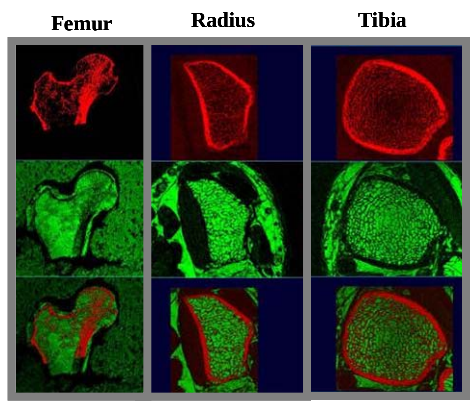
Methods

The distal radius and the distal tibia of 6 post-menopausal women and 6 proximal femur human cadaveric specimens were scanned by 3T MRI and HR-pQCT. MR images were acquired on a 3T (GE Signa) MRI scanner using a bSSFP sequence with a 512x384 matrix and 60º flip angle. The radius and tibia images were acquired with a 0.5mm slice thickness and 8cm FOV. The femur images were acquired with a 1mm slice thickness and a 10cm FOV. HR-pQCT images were acquired on a XtremeCT (Scanco Medical, Bassersdorf Switzerland) with an isotropic voxel size of 82 µm. The HR-pQCT tibiae and radii images were evaluated using standard evaluation routines provided by the manufacturer which automatically defines a 9mm volume of interest (VOI) located 9.5mm and 22.5mm proximal to the endplate in the radius and in the tibia, respectively. The HR-pQCT standard evaluation routine then calculates the average trabecular bone structural parameters (BV/TV, Tb.Sp., Tb.Th., and Tb.N) for that VOI. Automatic image alignment with registration was performed using the following steps (Fig 1): 1) HR-pQCT images were down-sampled to the MR resolution to conserve memory 2) Rview was used to determine the transform required to align the HR-pQCT image to the MR image 3) The transform is applied to the original HR-pQCT volume of interest (VOI). For comparison, VOIs in tibiae and radii MR images were also established without registration by visually selecting the slice containing the endplate and using this slice as a reference for finding the VOI corresponding to the HR-pQCT VOI. MR-derived trabecular bone structure analysis was performed using previously described methods[7].

Results

All femora, radii, and tibiae were successfully aligned. Average transformations are shown in Table 1 and the successful alignment can be visually assessed in Figure 2. Trabecular bone structure parameters were calculated for both the HR-pQCT and MR images with the same VOI (Fig 3).





	Femur	Tibia	Radius
Avg. Trans. X (mm)	-1.00	-0.08	-1.82
Avg. Trans. Y(mm)	-14.82	3.87	6.97
Avg. Trans. Z(mm)	-4.04	-2.20	-0.81
Avg. Rot. X(o)	93.20	-5.06	113.80
Avg. Rot. Y(o)	-5.91	1.32	62.39
Avg. Rot. Z(o)	175.98	-0.05	-60.05

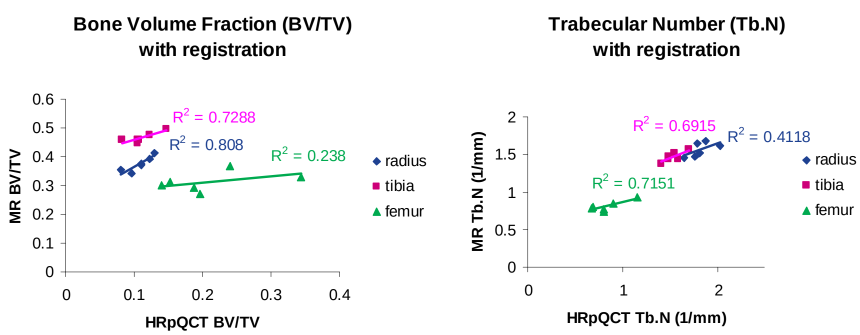
Table 1. (above) Average transformations required to align the HR-pQCT image to the MR Image.

Figure 1 (far left). Chart illustrating the steps required to apply the registered VOI to the MR image.

Figure 2. (left) . Successful image alignment can be visually assessed. (HR-pQCT = red, MR = green)

Figure 3. (below-left) Comparison of trabecular bone structure parameters, bone volume fraction and trabecular number, calculated by MR and HR-pQCT in the radius, tibia, and femur.

Table 2.(below) Improvement in trabecular bone structural comparisons due to the improved alignment in analysis regions can by seen in the resulting correlations (R^2)



Radius	R^2 Without Registration	R^2 With Registration
BV/TV	0.40	0.80
Tb.Th	0.17	0.46
Tb.Sp	0.18	0.21
Tb.N	0.13	0.41
Tibia	R^2 Without Registration	R^2 With Registration
BV/TV	0.02	0.72
Tb.Th	0.15	0.10
Tb.Sp	0.01	0.44
Tb.N	0.49	0.69

Discussion

There are significant differences in acquisition and analysis of trabecular bone images from MR and HR-pQCT which may have an impact on interpretation of results from research studies analyzing risk of fracture or new pharmacotherapies. Registration of MRI and HR-pQCT images ensures that the same VOI is analyzed in both modalities and improves the accuracy of trabecular bone structure parameter comparisons.

References

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