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Research Directions

In vivo HR-pQCT and MRI structure measurements and visualization of macro-porosity

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High-field magnetic resonance imaging (MRI) and high-resolution peripheral quantitative computed tomography (HR-pQCT) are currently being used in longitudinal bone structure studies. In ex vivo experiments, trabecular and cortical structure measures calculated from both MRI and HR-pQCT have been shown to be highly correlated with those obtained by μCT imaging, the current standard for 3-D structural analysis. No equivalent gold standard exists for the in vivo imaging environment. Therefore, we compared measures obtained from these two modalities to further our understanding of how they perform in the in vivo scenario.

Postmenopausal osteopenic women (n = 48) were recruited for this study. HR-pQCT imaging of the radius and tibia was performed with an isotropic voxel size of 82 μm. MR imaging was performed with a pixel size of 156 μm in-plane and slice thickness of 500 μm. Structure parameters were calculated using standard HR-pQCT and MRI analysis techniques. Relationships between HR-pQCT and MRI measures were investigated.

Significant correlations between HR-pQCT and MRI parameters were found ($p < 0.0001$), and were strongest for Ct.Th ($R2 = 0.59$), Tb.N ($R2 = 0.52$) and site-specific Tb.Sp ($R2 = 0.54$-0.60). However, MRI and HR-pQCT provided statistically different values of structure parameters ($p < 0.0001$), with BV/TV and Tb.Th exhibiting the largest discrepancies (MR/HR-pQCT = 3-4). These findings are consistent with ex vivo MRI and HR-pQCT studies comparing trabecular parameters to those quantified using μCT imaging.

Systematic differences between MRI and HR-pQCT analysis procedures leading to discrepancies in Ct.Th values were observed. HR-pQCT analysis resulted in lower values of Ct.Th (mean pQCT/MR ratio = 0.8). This observation is consistent with earlier findings that in ex vivo specimens cortical thickness values obtained by HR-pQCT are highly correlated to the μCT standard but significantly underestimated.

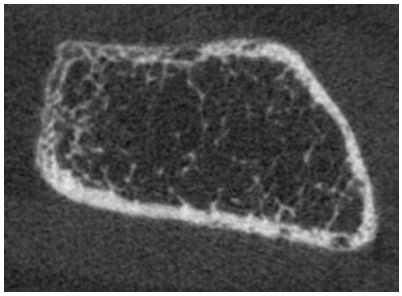
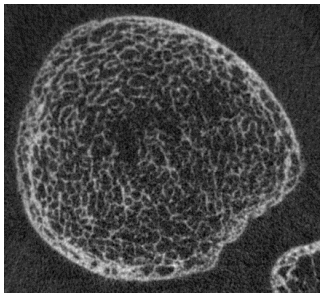


Figure 1. HR-pQCT image of the radius of an osteopenic female with porous cortex. **Left:** Single slice grayscale image. **Right:** Automated segmentation of cortex excludes all zones of macro-porosity or cortical thinning.



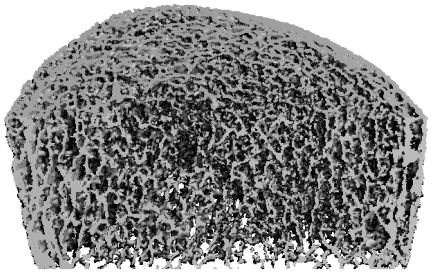


Figure 2. HR-pQCT image of the tibia of an osteopenic female with porous cortex. **Left:** Single slice grayscale image. **Right:** Rendering of 3D reconstruction of 9 mm scan zone shows continuous canals in cortex.

08/22/2008

An important source of underestimation of cortical thickness was the large-scale intracortical porosity — or macro-porosity — found in at least 10% of the osteopenic women enrolled in this study (Figures 1 and 2). This porosity is on a larger scale than the Haversian canals and resorption cavities generally seen in histological studies and exceeds dimensions of porosity previously documented. Full-width trabecularization of radius and tibia cortices was also observed. A strong Gaussian blurring filter is employed in the HR-pQCT Ct.Th analysis, which tends to remove portions of the cortex that are particularly thin or contain large porosities (Figure 1). Because the HR-pQCT image analysis algorithm calculates Ct.Th as the ratio of cortical cross-sectional area to periosteal perimeter, removal of portions of the cortex results in lowering the observed Ct.Th.

For more information on this work, please see "In vivo Determination of Bone Structure in Post-menopausal Women: A Comparison of HR-pQCT and High-field MR Imaging," Kazakia et al., Journal of Bone and Mineral Research*, 2007. As a consequence of the common finding of cortical porosity in this study, we will be investigating the occurrence, structure, and consequence of cortical porosity in greater detail in future studies.*