Combined Water and Fat Suppressed Proton Projection MRI (WASPI) and Micro CT Measurement of Bone Mineralization

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Introduction

Non-invasive measurement of the degree of bone mineralization is critically needed to diagnose metabolic bone diseases. We have demonstrated that water and fat suppressed proton projection magnetic resonance imaging (WASPI) can quantitatively measure the 3D organic matrix density of bone tissue, which cannot be measured by any other non-invasive method (1). Micro CT has been widely used to measure the 3D mineral density of bone tissue. Therefore, we hypothesize that combined WASPI and Micro CT measurement can provide us information of the degree of bone mineralization, which is equivalent to the ratio of bone mineral density to organic bone matrix density. The purpose of this study is to evaluate this new method on bone specimens from pigs fed diets with either marginal (MR) or excess (EX) Ca and P.

Materials and Methods

Crossbred pigs were managed by standard procedures at the University of Wisconsin Swine Center until ~13 kg. Pigs were housed in individual pens and randomly assigned diets with either MR (75%Ca, 70%P) or EX (150%Ca, 120%P) minerals (expressed as a percentage of requirements). After a 4-wk trial pigs were euthanatized, femur specimens were harvested and cleaned of adherent muscles and soft tissues. WASPI measurements were carried out with a Siemens 3T clinical scanner and a homemade RF probe with a 9 cm ID Teflon coil (no proton signal) at room temperature. The ^{1}H Larmor frequency was 123.2 MHz. Three 20%PEO/PMMA blend calibration phantoms with densities of 1.095, 0.800, and 0.616 g/cm^3 were imaged together with the bone specimens. A cylindrical marker made of polymer/hydroxyapatite blend was bound to the bone specimen with Teflon tape. The blend marker was visible in both WASPI and micro CT and served as a landmark for the registration of the images obtained by the two modalities. The registration of WASPI and micro CT images was performed using Amide (SourceForge, Inc.). WASPI protocol for imaging the polymer pellet and the specimens was the following: excitation pulse: 10 µs (14°); receiver dead time: 10 µs; water and fat suppression pulse 2 ms (90°); FOV: 120 mm; projection gradient: 20 mT/m; number of projections: 8148 (51 independent pixels in each dimensions); TR: 65 ms; signal average: 4; total imaging time: 34 min. Micro CT imaging was obtained with a Siemens MicroCT II (Knoxville, TN, USA) and a hydroxyapatite phantom supplied by the manufacturer to convert X-ray attenuation coefficient (µ) of the femur to an equivalent bone mineral density.

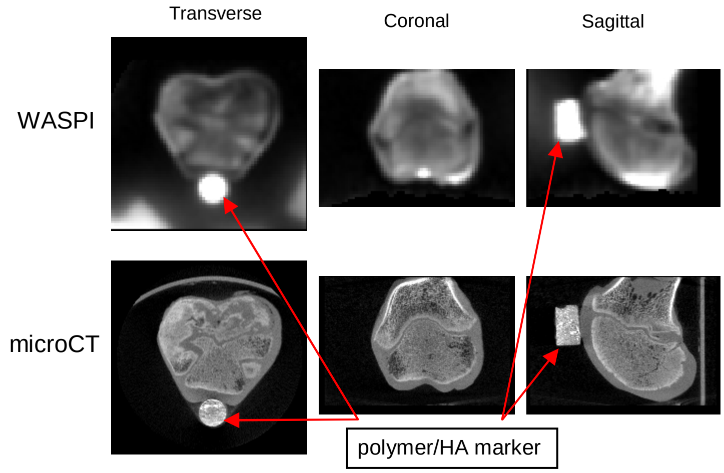

Figure 1. WASPI/microCT image registration using a polymer/hydroxyapatite marker and anatomic landmarks of a porcine bone specimen. The polymer/HA marker can be seen both in microCT and WASPI images.

Results

Figure 1 shows the representative WASPI/ micro CT image registration of the porcine femur specimen in axial, coronal, and sagittal directions respectively. The FOV of WASPI imaging was larger than that of micro CT in this study due to the limitation of MRI and micro CT systems. The isotropic 3D field of view in WASPI is 120 mm^3 which gives an image resolution of 2.4 mm^3. The maximum allowed FOV for micro CT is 70 mm X 70 mm X 50 mm, giving a resolution of 0.091 mm X 0.091 mm X 0.091 mm. The WASPI images were cropped and registered to the micro CT images using Amide manually. The cylindrical polymer/hydraxyapatite marker was matched in both micro CT and WASPI images. Figure 1 illustrates the ability to acquire good image registration between these two image modalities. Figure 2 shows the trabecular bone mineral density, bone matrix density and the ratio of these two measurements between diet groups. Decreased trabecular bone mineral density was observed in MR vs EX groups (0.23±0.02 vs. 0.26±0.01 g/cm3, p=0.001). While bone matrix density was slightly lower in MR vs EX groups (0.20±0.03 vs. 0.23±0.02 g/cm3, p=0.14), difference were not significant. No significant change of the degree of bone mineralization was observed between the two groups (1.16±0.20 vs. 1.18±0.11 g/cm3, P=0.89).

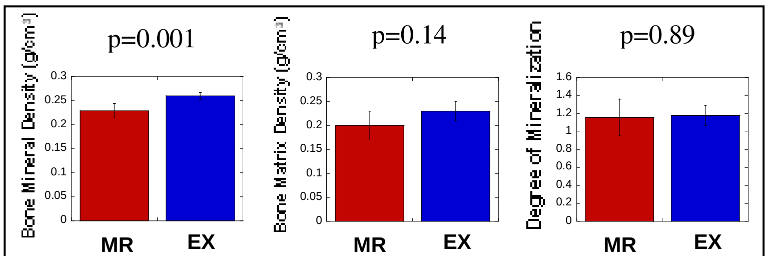

Figure 2. Trabecular bone mineral density, bone matrix density and the degree of bone mineralization in the femoral head of porcine bone specimens from pigs fed diets with MR or EX minerals. The number of samples N is 6 for each group.

Discussion

By transferring CT and MRI images into one coordinate system, one can extract bone mineral density measured by micro CT and bone matrix density measured by WASPI from the same region of interest in bone specimens. The results indicate that trabecular bone mineral densities were lower in pigs fed MR diets, but no change in the degree of bone mineralization was detected. The preliminary data in this study shows that combined WASPI and micro CT measurement has the potential for *in vivo* noninvasive quantitative characterization of the degree of bone mineralization.

References

(1) Cao H, Ackerman JL, Hrovat MI, Graham L, Glimcher MJ, Wu Y. Quantitative bone matrix density measurement by water and fat suppressed proton projection MRI (WASPI) with polymer calibration phantoms. Magn Reson Med. In press.