

Methodology Dependent Variation in Volumetric Bone Mineral Density

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Background

Assessment of human bone quality is often performed using dual x-ray absorptiometry (DXA) despite evidence suggesting fracture risk increases independently of outputs from this technology. Quantitative computed tomography (QCT) allows for more discriminant quantification of three-dimensional *in vivo* volumetric bone mineral density (vBMD). QCT methods often utilize phantom calibration rods of known densities to convert Hounsfield units (HU) to vBMD. Little research has been conducted on the effects of HU variation in these phantom rods that may significantly alter resulting vBMD values used in fracture risk assessment. Additionally, common methods for HU calibration may only use one vBMD calibration for the entire scan or HU calibration may be performed weekly and the asynchronous calibration is used for all scans completed during that time. These methods do not account for x-ray attenuation from the individual that may alter HU values of the phantom rods. The purpose of this study was to investigate variation in vBMD when using location-specific phantom-based calibrations compared to a single generalized scan-specific phantom calibration.

Methodology

Clinical quality CT scans of 50 male post-mortem human subjects (PMHS) ranging in age from 24 to 89 years (61.7 ± 15.4) were retrospectively analyzed. Trabecular and total skeletal HU values were collected at the 50% location of the 2nd and 4th lumbar vertebrae (L2 and L4) and the left calcaneus. HU values from the left femoral neck were quantified for the trabecular, total, and both superior and inferior cortices. Using a validated custom MATLAB code, phantom vBMD calibrations were generated from each skeletal location as well as a general calibration generated from the slices associated with the 3rd lumbar vertebra (L3). Volumes of interest (VOI) for the calcaneus and lumbar vertebrae had an axial in-plane volume of 3mm^3 and the femoral neck VOI was obtained at a coronal in-plane volume of 3.6mm^3 . Each skeletal site's HU value was converted into vBMD using both calibration methods, resulting in two separate vBMD values for comparison. All data were normally distributed and paired t-tests were conducted to test for significant differences between the means of vBMD values from location-specific phantom calibrations and the general phantom calibrations.

Results and Discussion

Results showed no significant differences between method dependent vBMD values at L2 or L4 for both the total and trabecular compartments ($p > 0.05$). In contrast, all other sites had significantly different vBMD values from the location-specific method compared to the general phantom calibration method ($p < 0.01$). Trabecular compartment vBMD values demonstrated a larger mean difference between calculation methods than total or cortical VOIs which may be due to trabecular bone's lower density. Significant differences in vBMD between calculation methods highlight intra-scan variation in phantom rod HU values, potentially due to differential linear x-ray attenuation of the PMHS. Methods like asynchronous calibration may show greater differences in vBMD values as these methods measure HU values of phantom rods without an individual in the scan, ignoring x-ray attenuation. Since vBMD calculations are dependent on calibration methods, research utilizing vBMD for fracture prediction should use location-specific phantom calibrations for more accurate injury risk assessments.