

Variability Of CT-Based Regions Of Interest In The Proximal Humerus For Densitometric Evaluation

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INTRODUCTION: Proximal humerus fractures account for 5% of all fracture types (Kelly & Myeroff, 2020). In United States alone 122 per 100,000 emergency department visits due to humerus fractures occur per year (Kim et al., 2012). Poor bone density increases the risk of fragility fractures (Kim et al., 2012). For the humerus, a diagnosis of osteoporosis is defined by using values obtained from CT and DEXA scans, including cortical bone thickness and bone mineral density (BMD) (Taskesen et al., 2020). However, DEXA scans are not obtained directly from the humerus, rather a correlation is made using values obtained from the femoral neck or lumbar spine (Zhang et al., 2021). In many cases, the first indication of osteoporosis is the first fragility fracture, therefore increasing the risk for a subsequent fragility fracture in the future (Sriuanthong et al., 2022). Ross et al. reported 25.8% of patients who sustained a primary fragility fracture obtained osteoporosis screening or management in the 2 years prior to the fracture. Improvements in diagnostic measures and prevention strategies are necessary in addressing the growing number of underdiagnosed and undermanaged osteoporotic patients and treatment of humerus fragility fractures. Prior studies have proposed various imaging approaches in determining bone quality of the proximal humerus. Liu et al. (2023) measured trabecular BMD across the humeral head, reporting strong correlation with DEXA and fracture occurrence (Liu et al., 2023). Earp et al. (2021) measured HU across multiple consecutive slices in the proximal humerus with strong correlation between the BMD in the central slice to DEXA and FRAX (Earp et al., 2021). Zhao et al. (2024) found strong correlation between single slice ~20 mm below the articular surface HU values and DEXA (Zhao et al., 2024). However, existing literature lacks a widely recognized protocol for CT imaging of the proximal humerus to determine bone quality. Given the heterogeneity of the ROIs currently reported in literature for fragility fracture evaluation, the current study aims to identify the agreement of the density values extracted from five previously proposed ROIs. We hypothesize that while the density values between regions are different a degree of correlation exists.

METHODS: Following Institutional Review Board (IRB) approval, ten human cadaver shoulders specimens underwent Computed Tomography (CT) scanning using the GE Lightspeed (GE Healthcare, Waukesha, WI, USA) at 120 mA and 100 kV and 0.625 mm slice thickness. The average age of the sample size was 72±4 years old (yo) ranging from 65yo to 75yo. Following scanning, the bones were reconstructed in 3D Slicer and the HU values were converted to volumetric density (VD) values using the value of reference taken from a Mindways Model 3 CT calibration phantom (Slicer Community, Boston, MA, USA) using a previously published calibration protocol (Giambini et al., 2015). The obtained reconstructions were then exported in Rhinoceros 3d (Robert McNeel & Associates, Seattle, WA, USA) for identifications of the ROIs using a custom-made grasshopper algorithm. For the purpose of the study, we considered a total of 5 ROIs: superior (SHH), central (CHH), and inferior (IHH) humeral head slices in thicknesses of 13.1mm, followed by humeral surgical neck (HSN) defined by a 19.65 mm axial extension beginning at 39.3 mm from the articular surface; and the trabecular humeral head (THH) defined by a 13.1 mm axial extension beginning at 19.5 mm from articular surface. Paired T-tests or the equivalent nonparametric Wilcoxon signed-rank test was used to evaluate agreement between ROIs while Pearson’s correlation coefficient or the equivalent Spearman were used to determine correlations between ROIs. All the analyses were performed with reference to the values found for SHH in R with a level of significance of 0.05 (R Core Team, 2015).

RESULTS SECTION: All the ROIs considered were normally distributed ($p < 0.05$) with exemption of THH ($p = 0.04$). SHH ranged from 179mg/cc to 503 mg/cc (see Figure 1) and was higher than both CHH ($p < 0.01$, Cohen's $d = 1.60$) and IHH ($p < 0.02$, Cohen's $d = 1.51$) and was strongly correlated to both with ($r = 0.90$, $p < 0.01$) and ($r = 0.74$, $p = 0.01$) respectively for CHH and IHH. HSN ranged from 181 mg/cc to 397 mg/cc and its comparison with SHH was underpowered ($p = 0.9337$, Cohen's $d = 0.027$) and not significantly correlated (0.41 , $p = 0.239$). THH was lower than SHH ($p < 0.01$) ranging from 27 mg/cc to 150 mg/cc and was also not significantly correlated to THH ($r = 0.6$, $p = 0.07$).

DISCUSSION: In the current study we have found that within the envelope of the humeral head the Superior Humeral Head ROI was correlated to the values extracted from the humeral head while it wasn't found correlated to the values of the diaphyseal region. This later comparison was limited by the small sample size used in the current study and deserves further investigation. However, the results for the humeral head suggest that these ROIs are interchangeable as long as the shift in values is accounted for. Additional limitation is given by the fact that genders were not differentiated while proximal humerus fractures occur more frequently in women, particularly post-menopausal women, due to a difference in bone mass, microarchitecture, and geometry (Iglesias-Rodríguez et al., 2021).

SIGNIFICANCE/CLINICAL RELEVANCE: The strong correlations we have found among the ROIs of the humeral head indicate its suitability in becoming a widely recognized region for densitometric evaluations of the proximal humerus.

IMAGES AND TABLES:

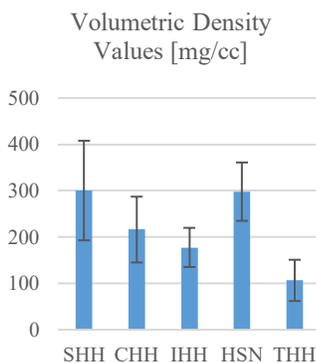


Figure 1: Average VD values found.

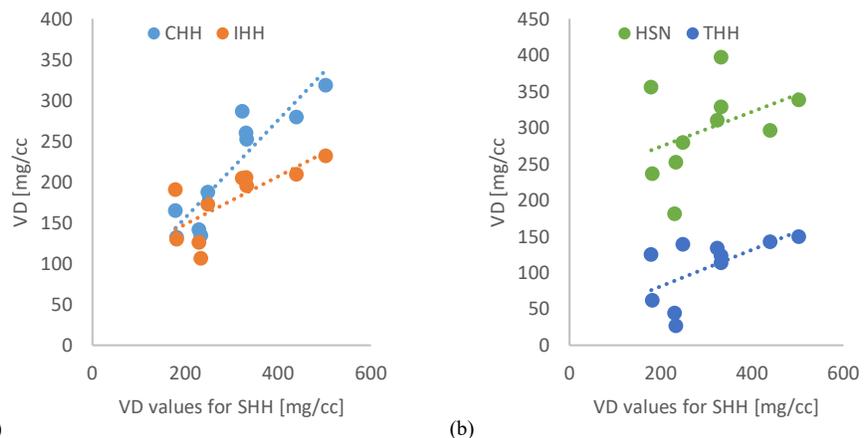


Figure 2: SHH in relation to head (a) and diaphyseal (b) humeral regions.