Can Computed Tomography Hounsfield Units be Reliably Measured in the Setting of Proximal Humerus Fractures?

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INTRODUCTION:

Hounsfield units (HU) are a measurement of the standardized linear attenuation coefficient of tissue and can be measured within a region of interest (ROI) on modern computed tomography (CT) scans to quantitatively measure bone mineral density (BMD). Extensively used and validated in the spine literature, the purpose of this study was 1) to determine if there is good inter- and intra-rater reliability of HU measurements in the setting of proximal humerus fractures (PHF) and 2) validate HU against deltoid-tuberosity index (DTI) and dual x-ray absorptiometry (DEXA) scans.
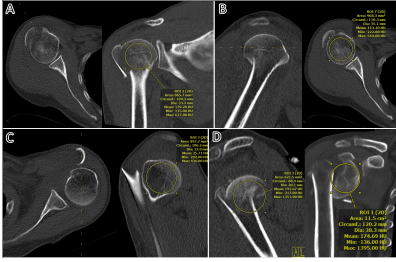
METHODS:

Sixty-six consecutive patients who underwent fixation of a PHF and had both plain films and a CT available were retrospectively reviewed. Demographic information was recorded. In addition, 22 patients underwent DEXA scanning (at standard femoral neck and lumbar spine) within 1 year of injury. Radiographic measurements included the DTI on preoperative AP shoulder radiographs, and the HU from the operative proximal humerus was determined by measuring the humeral head at the mid-axial, mid-coronal, and mid-sagittal CT image of widest diameter using a circle-type ROI (≥35 mm2) (**Figure 1**). Measurements were performed by two independent authors, twice in each proximal humerus separated by three weeks. Intra-class correlation was performed for each measurement (DTI, axial, coronal, sagittal and mean HU) for each reviewer's two measurements, and between an average of each reviewer's measurements. For intra-class correlations, values between 0.75 and 0.9 were considered to have good reliability and values greater than 0.9 excellent reliability. Patients with and without DEXA scans and patients who developed complications were compared. Pearson's correlation was performed for femur and lumbar spine DEXA scan T-scores and BMD, respectively, versus DTI and HU in all planes as well as overall.

RESULTS:

The 66 included patients had an average age of 63.8+/-12.7 years, with 47 (71.2%) females. Mean DTI of the entire cohort was 1.44+/-0.1, range 1.30-1.75. DTI showed excellent and good intra-rater reliability for reviewers 1 and 2, respectively, and good intra-rater reliability. For axial HU (mean 84.67+/-58.9, range 5.95 to 229.97), there was excellent and good intra-rater reliability for reviewers 1 and 2, respectively, and excellent inter-rater reliability, while both coronal (mean 83.91 +/- 53.0, range 0.24 to 202.09) and sagittal (75.74 +/- 53.1, range 9.53 to 167.67) HU had excellent intra-rater reliability for both reviewers and excellent inter-rater reliability. Similarly, the overall average HU (mean 81.44 +/- 52.36, range 17.24 to 184.86) had excellent intra-rater reliability for both reviewers and excellent inter-rater reliability (**Table 1**). 22 patients had a DEXA scan performed within 1 year of injury. Patients who underwent DEXA scan were significantly older (67 vs. 62 years, p = 0.021), however there were no other demographic differences. DEXA scan patients also had significantly lower HU measurements in all CT planes and overall, but no significant difference in DTI. DEXA scan T-scores and BMD values in the femur and lumbar spine had a moderate and significant correlation with the mean DTI, mean HU across all 3 CT planes, as well as the mean overall HU of the proximal humerus (**Table 2**).

DISCUSSION AND CONCLUSION:

HU measurements of proximal humerus CT scans have good-excellent intra- and inter-rater reliability. Proximal humerus CT HU measurements correlate strongly with both DTI and DEXA scans of the hip and lumbar spine, allowing surgeons to reliably use preoperative shoulder CT scans to quantitatively and quickly estimate a patient's BMD at the anatomic location of possible fixation. Furthermore, this may obviate the need for further BMD testing.

	Average Value	Reviewer 1 Intra-Rater Reliability	Reviewer 2 Intra-Rater Reliability	Inter-Rater Reliability
Deltoid Tuberosity Index	1.45±0.1	ICC*: 0.919 95% CI**: 0.877-0.946 p: < 0.001	ICC: 0.889 95% CI: 0.832-0.926 p: < 0.007	ICC: 0.752 95% CI: 0.625-0.835 p: <0.001
Hounsfield Units Axial	105.16±48.1	ICC: 0.902 95% CI: 0.853-0.935 p: <0.001	ICC: 0.771 95% CI: 0.655-0.849 p: <0.001	ICC: 0.910 95% CI: 0.864-0.940 p: <0.001
Hounsfield Units Coronal	109.48±51.9	ICC: 0.958 95% CI: 0.937-0.972 p: <0.001	ICC: 0.932 95% CI: 0.896-0.955 p: <0.001	ICC: 0.948 95% CI: 0.921-0.966 p: <0.001
Hounsfield Units Sagittal	103.44±51.8	ICC: 0.950 95% CI: 0.937-0.972 p: <0.001	ICC: 0.932 95% CI: 0.896-0.955 p: <0.001	ICC: 0.948 95% CI: 0.921-0.966 p: <0.001
Hounsfield Units Total	106.03±48.6	ICC: 0.950 95% CI: 0.930-0.953 p: <0.001	ICC: 0.932 95% CI: 0.902-0.953 p: <0.001	ICC: 0.937 95% CI: 0.904-0.958 p: <0.001

*ICC: intra-class correlation
**CI: confidence interval