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ORIGINAL ARTICLE

Glenoid neck Hounsfield units on computed tomography can accurately identify patients with low bone mineral density

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Background: Osteoporosis is a costly and morbid disease with the first presentation often with a fragility fracture. The purpose of this study was to assess whether Hounsfield unit (HU) measurements on shoulder computed tomography could identify patients at risk of osteoporosis and aid in its diagnosis.

Methods: We identified patients who had both a computed tomography scan of the glenoid and a dual-energy x-ray absorptiometry scan. Dual-energy x-ray absorptiometry results and HU measurements of the patients' glenoid were recorded. Differences in HU measurements between patients with normal and abnormal central bone mineral density (BMD) were assessed. Correlations were calculated, and receiver operating characteristics were examined.

Results: A total of 51 glenoids met the criteria. The mean glenoid HU measurement was 140.6 (95% confidence interval [CI], 120.1-161.1) in the osteoporotic group, 168.1 (95% CI, 152.7-183.5) in the osteopenic group, and 233.2 (95% CI, 210.1-256.4) in the normal BMD group ($P < .001$). There was a significant correlation between mean glenoid HU measurement and patients' t scores in the femoral neck ($r = 0.581$), total hip ($r = 0.524$), and lumbar spine ($r = 0.345$). The area under the receiver operating characteristic curve was 0.918. With 197 HUs used as the cutoff for diagnosis of abnormal BMD, the positive predictive value was 96.6%. With 257.1 HUs used as the cutoff, the negative predictive value was 100%.

Conclusion: A patient with an HU measurement below 197 has a 97% chance of having low BMD, and a patient with a measurement over 257 likely has normal BMD. In patients with measurements between these values, a definitive diagnosis should be aggressively pursued. Opportunistic screening for a modifiable disease that has significant morbidity and mortality rates at no additional cost, radiation, or time is of great value.

Level of evidence: Level III; Diagnostic Study

Keywords: Osteoporosis; dual-energy x-ray absorptiometry; DEXA; DXA; opportunistic screening; computed tomography

Orthopedic surgeons have a unique opportunity as the initial point of care for patients who have yet to be diagnosed with abnormal bone mineral density (BMD). The diagnosis of osteoporosis or osteopenia is usually unknown until patients sustain a fragility fracture. Low BMD affects over half of the

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population older than 50 years in the United States.[24] This number is projected to increase to over 70 million, as the population ages, by 2030,[24] which will only magnify the current burden on the health care system.[5,20] The gold standard for diagnosis of abnormal BMD is dual-energy x-ray absorptiometry (DXA),[19] yet only 2.8%-23% of patients actually undergo a DXA scan after a fragility fracture.[2,3,11,12,15,20] Appropriate follow-up and treatment rates are equally low.[2,3,10,15] To increase the proportion of patients appropriately diagnosed and treated for abnormal BMD, opportunistic screening on imaging that has been obtained for other indications is growing in popularity.[1,13,16,21,22] Wagner et al[21] showed that measuring Hounsfield units (HUs) of the distal ulna on computed tomography (CT) correlates with DXA forearm *t* scores, and Johnson et al[13] showed that there was a correlation between capitate HU measurement and central BMD. Both groups of authors also established HU cutoff values measured on wrist CT scans that can risk stratify patients based on the likelihood that patients have low BMD. Schreiber et al[16] showed a similar correlation in the lumbar spine and determined normative values of HUs based on age and sex. More so, using this information to potentially predict future fragility fractures could help increase diagnosis and treatment rates of abnormal BMD.

CT of the shoulder and chest represents yet another opportunity for opportunistic screening given the high frequency of these scans. HU measurement techniques of the proximal humerus have shown good intraobserver and interobserver reliability and correlate to central decreases in BMD[14]; however, these techniques are not applicable in the setting of proximal humeral fractures, nor can they be used when the humerus is incompletely imaged. Furthermore, no value has been reported to help stratify patients and predict BMD disease. The optimal measurement site should be a location that is reliably imaged on any CT scan that includes the shoulder and an area that is rarely injured, such as the glenoid neck. Standard DXA scans do not measure any area of the shoulder, so no direct comparison between glenoid neck and DXA results is possible.

The purpose of this study was to compare glenoid neck HU measurements between patients with normal and abnormal BMD to develop an HU cutoff value that could predict a high likelihood of having abnormal BMD. We hypothesized that there would be a significant difference in glenoid neck HU measurements between patients with abnormal BMD and those with normal BMD and that, on the basis of these values, an accurate prediction of abnormal BMD from CT of the shoulder could be made.

Materials and methods

This is a retrospective chart review comparing DXA results with blinded HU measurements from shoulder CT scans. We queried the Military Health System Management Analysis and Reporting Tool (M2) for all records of all active military members and their dependents with Current Procedural Terminology codes for an upper extremity or chest CT scan performed at our institution and a DXA scan over the past 5 years. Patients were included if they were aged 50 years or older with a shoulder or chest CT scan that had at least 4 axial slices through the glenoid. The exclusion criteria included glenoid fracture, incomplete DXA data, metabolic bone disease, or degenerative cystic and sclerotic changes within the glenoid neck that would preclude measurement of cancellous bone. Each glenoid that was entirely imaged was included as a unique data point. Glenoid necks were measured on axial imaging using IMPAX software (AGFA HealthCare, Mortsel, Belgium) to produce HU measurements. The circle region-of-interest tool was used to abut but not include subchondral bone, sclerosis or cysts, and the anterior cortex and posterior cortex of the neck at each level (Fig. 1). Four slices of the glenoid neck were measured at regular intervals as a representative column of cancellous bone traversing the glenoid neck. To account for variable cranial-to-caudal distances and different slice thicknesses between CT scans, the number of slices that traversed the glenoid were counted and divided by 4 to obtain the number of slices between measurement points. Measurements started at the caudal aspect of the glenoid neck. To account for the complex 3-dimensional anatomy of the scapular neck and to ensure that no cortical bone was included, measurements began 1 slice cranial to the most caudal slice that contained the glenoid surface. Attempts were made to include the most cancellous bone without including cortex or arthritic abnormalities. Ultimately, a total of 4 slices of the glenoid neck were measured and averaged together for the final glenoid HU measurement.

DXA results were obtained from the electronic medical record, including BMD and *t* score of the lumbar spine, femoral neck, and

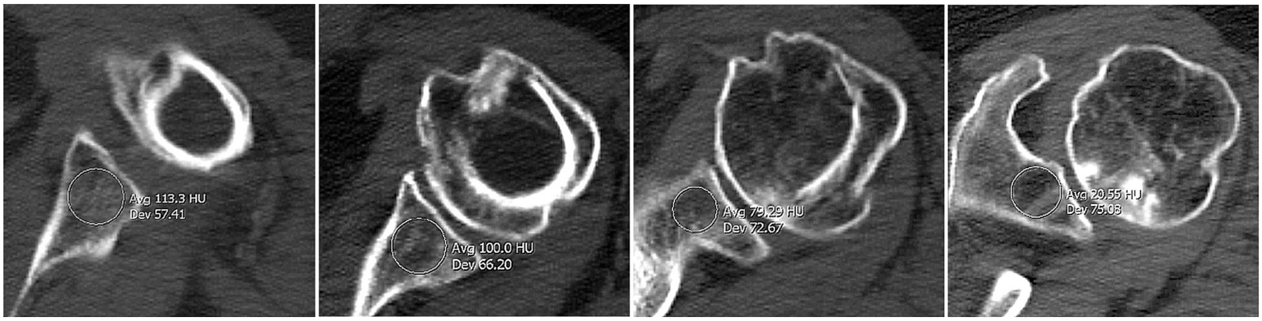

Figure 1 Measurement technique moving from caudal to cranial (*left* to *right*) on computed tomography demonstrating a healed, impacted proximal humeral fracture. *Avg*, average Hounsfield units; *HU*, Hounsfield units; *Dev*, deviation of Hounsfield units.