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Proximal humerus cortical bone thickness correlates with bone mineral density and can clinically rule out osteoporosis

James Mather, MSc[a], Joy C. MacDermid, PT, PhD[b], Kenneth J. Faber, MD, MHPE, FRCSC[b], George S. Athwal, MD, FRCSC[b,*]

[a]University of Western Ontario, London, ON, Canada
[b]Hand and Upper Limb Center, St Joseph's Health Centre, University of Western Ontario, London, ON, Canada

Background: Bone mineral density measurements with dual-energy x-ray absorptiometry (DXA) are commonly used to diagnose osteoporosis and assess fracture risk. This study describes the association between radiographic measures of proximal humeral cortical bone thickness and bone mineral density measured by DXA. The study also assesses the discriminative capability of clinical cortical bone thickness measurements at the proximal humerus to differentiate patients with osteoporosis.

Methods: Patients (N = 108) with shoulder radiographs and DXA studies were evaluated. Cortical bone thickness was assessed with 2 techniques, the gauge method and the average method. Pearson correlations were used to describe the relationship between cortical bone thickness measurement techniques and femoral and lumbar DXA. Sensitivity, specificity, and negative predictive value for predicting osteoporosis were determined for several cortical bone thickness thresholds. Rater reliability of measures was assessed with intraclass correlation coefficients.

Results: The intra-rater and inter-rater reliability of measures was excellent (intraclass correlation coefficient >0.85). Average cortical bone thickness measurements at the proximal humerus strongly correlated with DXA femur measurements ($r = 0.64$, $P < .0001$) and moderately correlated with DXA lumbar measurements ($r = 0.49$, $P < .0001$). Gauge cortical thickness measurements also correlated with DXA femur measurements ($R = 0.53$, $P < .0001$) and DXA lumbar measurements ($R = 0.35$, $P < .001$). An average proximal humerus cortical thickness measurement of 6 mm was identified as a potential threshold value for predicting osteoporosis, with a sensitivity of 93%, specificity of 52%, and negative predictive value of 95%.

Conclusions: Average cortical bone thickness measurements obtained from standard anteroposterior shoulder radiographs are correlated with DXA. Furthermore, they provide a clinically relevant, rapid, sensitive, and inexpensive method for ruling out osteoporosis.

Level of evidence: Level III, Study of Nonconsecutive Patients, Diagnostic Study.

Keywords: Osteoporosis; cortical bone thickness; bone mineral density; proximal humerus; shoulder; fracture

Barnett and Nordin[2] originally investigated the relationship between cortical bone thickness and bone mineralization, developing the metacarpal index in 1960.

This study was approved by our institutional review board (17470E).

*Reprint requests: George S. Athwal, MD, FRCSC, St Joseph's Health Centre, Ste D0-205, 268 Grosvenor St, London, ON, Canada, N6A 4L6.
E-mail address: gathwal@uwo.ca (G.S. Athwal).

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Since then, advancements in digital radiographic technologies have significantly increased the speed and precision of techniques for measuring cortical bone thickness, allowing increased accuracy for estimation of bone mineral density (BMD).[12] Despite these advancements, dual-energy x-ray absorptiometry (DXA) of the proximal femur and lumbar spine remains the gold standard for determination of BMD and for use in the assessment of general fracture risk.[7] Clinically, however, DXA is not always easily accessible. An adjunctive test that could be used clinically to rule out osteoporosis would therefore be helpful to clinicians who do not have immediate access to DXA and have questions about the bone quality of patients in the office.

The usefulness of cortical bone thickness measurements has been investigated at multiple anatomic sites.[17] Studies on the humerus, in particular, have yielded promising results for the use of cortical bone thickness. The relationship between bone density and cortical thickness is supported by a study of humeri from human skeletons, which reported a strong association between the radiographic cortical bone thickness and the local mineral content.[16] A more recent cadaveric study, by Tingart et al,[15] compared the cortical thickness method with DXA at the same anatomic location. They reported that digital radiographic measures of proximal humerus cortical bone thickness could be made with excellent reproducibility based on intraobserver and interobserver reliability testing. They also reported that radiographic measures of cortical bone thickness were strongly correlated with proximal humerus DXA. Unfortunately, this study did not compare the proximal humerus findings with those obtained in standard proximal femur and lumbar DXA used clinically for diagnosing osteoporosis.[15]

The relationship among bone quality of the upper extremities, bone quality of the lower extremities, and bone quality of the spine may not be consistent when considering that loading patterns can vary between individuals. Studies in humans have confirmed that lumbar and femur measures of osteoporosis may not fully represent osteoporosis present in the upper limb.[7] The determination of the optimal measurement methods, as well as their reliability and validity, is fundamental to implementing new measures in practice. The purpose of this study was to investigate the reliability of radiographic methods for assessing proximal humerus cortical thickness. Furthermore, we wanted to investigate the correlation of radiographic methods with BMD in patients. Average cortical bone thickness (CBT_{AVG}) and gauge cortical bone thickness (CBT_G) were assessed for their correlations with standard DXA of the femur and lumbar spine. In addition, this study determined the sensitivity and specificity of CBT_{AVG}, obtained from standard shoulder radiographs, in predicting clinical osteoporosis. Most importantly, we identified the negative predictive value of CBT_{AVG} in ruling out osteoporosis.

Materials and methods

Patients

Between 2007 and 2011, the institutional picture archiving and communication system was queried for patients who had undergone anteroposterior shoulder radiography and a screening DXA study of the femur and lumbar spine. We identified 167 patients who had both investigations performed within 8 months of each other (mean, 3 months; range, 0-8 months). Patients were excluded for reasons that included total shoulder arthroplasty interfering with the cortical bone measurement (16 patients), radiologic report of sclerosis of the lumbar spine interfering with the DXA interpretation (32 patients), internal fixation obstructing the cortical bone measurement (5 patients), fracture line at the cortical bone measurement location (4 patients), or obesity artifacts interfering with DXA (1 patient). The study cohort consisted of 108 patients (19 men and 89 women) with a mean age of 65 years (range, 33-90 years) undergoing 60 right and 48 left anteroposterior shoulder radiographs.

The data collected for each patient included age, sex, the interval between tests, the indication for the radiograph, the radiologic interpretation, and the indication for the DXA scan. DXA femur and DXA lumbar spine (Hologic, Waltham, MA, USA) values were obtained from BMD reports, whereas CBT_{AVG} and CBT_G were measured from digital anteroposterior shoulder radiographs by use of commercially available software (Centricity; GE Healthcare, Princeton, NJ, USA).

CBT_{AVG} measurement

The method for calculating the CBT_{AVG} of the medial and lateral proximal humeral diaphysis was adapted from methods described by Tingart[15] and Bloom.[3] Excellent reliability of these methods has been previously established.[15] By use of an anteroposterior radiographic projection of the proximal humerus, cortical thickness was measured at 2 levels (Fig. 1) using the digital measurement tool on the picture archiving and communication system workstation, which has a precision of ± 0.01 mm. Observers were blinded to DXA measurements before making cortical thickness measurements for all patients.

The first level was the most proximal point on the humerus where the outer medial and lateral cortical borders become parallel, as previously described.[15] A perpendicular line was drawn from the medial outer cortex of the humerus to the lateral outer cortex of the humerus and measured with a digital caliper to provide the thickness of the entire bone (M1). At the same level, a measurement of the width of the intramedullary canal was obtained (M2). The M2 distance was then subtracted from M1 to obtain the combined cortical thickness at level 1 (C1). The second level measurements were obtained 20 mm distal to level 1. The same methods were used to calculate the combined cortical thickness at this second level (C2). The C1 and C2 values were then averaged to determine the CBT_{AVG} for each patient. We denoted the parallelism of the outer proximal humerus cortex at levels 1 and 2 if the bone thickness measurements were not more than 1.0 mm different between levels. A subset of 20 measurements was repeated on 2 separate days by observer 1 (J.M.) to assess intraobserver reliability. The same subset of 20 patient measurements was repeated by a separate blinded observer (G.S.A.) to test for interobserver reliability.