Opportunistic Osteoporosis Screening— Gleaning Additional Information from Diagnostic Wrist CT Scans

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Background: Although screening for and treating osteoporosis can prevent subsequent fractures, the rates of such interventions are low following a distal radial fracture. One potential method for identifying metabolic bone disease is via Hounsfield unit (HU) measurements from diagnostic computed tomography (CT) scans. We hypothesized that HU values of the distal aspect of the radius could be used to assess local bone quality and would be predictive of distal radial fracture risk, thereby allowing the identification of patients in need of further management.

Methods: Measurements of bone mineral density (BMD) were made for 100 patients on the basis of HU values of cancellous portions of the distal aspect of the radius, the ulnar head, and the capitate. The HU values in twenty-five male and twenty-five female patients with an acute distal radial fracture documented on CT were compared with those of age and sex-matched control patients who had a CT scan obtained for other indications.

Results: Among the control patients, HU values decreased as age increased. When assessed on the basis of sex, both male and female patients with a distal radial fracture had significantly lower regional BMD compared with nonfracture control patients. A distal radial HU value of 218 for females and 246 for males optimized sensitivity and specificity; values below this threshold were associated with an increased risk of distal radial fracture.

Conclusions: HU measurements can be obtained from any diagnostic CT scan using modern software programs and can be obtained by physicians in the office setting with minimal effort and at no additional cost or radiation exposure to the patient. Regardless of imaging indications, we suggest that patients with HU values below the identified thresholds be considered for further metabolic bone disease work-up, such as additional imaging, laboratory assessments, the initiation of osteoporosis treatment, or appropriate referral.

Level of Evidence: Diagnostic Level III. See Instructions for Authors for a complete description of levels of evidence.

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Osteoporosis and resultant fragility fractures are a major public health concern and result in substantial patient morbidity. In the United States, the annual incidence of fragility fractures exceeds two million, with resultant costs of approximately $20 billion—both notable figures that are continually increasing[1]. Distal radial fractures are the most common type of symptomatic fragility fracture and are routinely managed by orthopaedic surgeons[2].

Low-energy distal radial fractures have been associated with decreased bone mineral density (BMD)[3-5]. Such a fracture can be considered a sentinel event that provides a "teachable moment" for the patient in order to prevent subsequent fractures[1], as these patients are at a notably increased risk for future fracture[6]. Distal radial fractures often occur ten to twenty years before hip or vertebral fractures, which are associated with even greater patient morbidity[7,8]. Fortunately, the initiation of

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TABLE I Patient Characteristics*

	Control Cohort	Fracture Cohort
Male age *(yr)*		
Mean	44.0	43.8
Range	18-81	17-79
Female age *(yr)*		
Mean	45.4	45.1
Range	17-79	17-80

*N = 50 in each cohort (twenty-five male and twenty-five female patients).

treatment can reduce the future risk of hip and distal radial fracture[9,10]. Although screening for osteoporosis and treatment have been shown to decrease the risk of future distal radial fracture[10], the rates of these interventions remain disappointingly low[11,12]. In an effort to address the osteoporosis treatment gap and to prevent subsequent fragility fractures, the American Orthopaedic Association developed a quality-improvement program, launched as "Own the Bone" in 2009. The Own the Bone initiative provides tools to institutions to facilitate a fracture liaison service to ensure appropriate evaluation, diagnosis, and treatment of osteoporosis in postfracture patients, and it has been shown to improve these outcome measures[1,13].

One means of increasing the appropriate diagnosis and intervention rates could be through opportunistic diagnosis of metabolic bone disease via Hounsfield unit (HU) measurements from diagnostic CT (computed tomography) scans of the wrist. An HU value represents a standardized linear attenuation coefficient of tissue, based on a defined scale of 0 for water and −1000 for air. Values are calculated from the following formula: $HU = ([\mu - \mu_w]/\mu_w) \times 1000$, with μ defined as the linear x-ray attenuation coefficient of the selected voxel, and μ_w, as the attenuation coefficient of distilled water at room temperature and pressure. HU values can be easily obtained from diagnostic CT scans to calculate regional BMD using modern radiological imaging programs, with no additional financial cost or radiation exposure to the patient. In assessments of the spine, correlations between HU values and T scores, BMD, compressive strength, and fracture risk have been firmly established[14,15], as have thresholds for the diagnosis of osteoporosis and osteopenia[14,16].

The purpose of our study was to assess local bone-density measurements and their reliability for patients with a distal radial fracture, and to compare those HU values with those of a matched cohort of nonfracture patients. We hypothesized that HU values of the distal aspect of the radius could be used to assess local bone quality and would be predictive of distal radial fracture risk, thereby allowing the identification of patients in need of further management.

Materials and Methods

Study Cohort

Institutional review board approval was obtained for this case-control study. Fifty patients who had a diagnostic CT scan documenting a distal radial fracture were included for evaluation. A sample of convenience was utilized to generate identical numbers of male and female patients between 2011 and 2013, in order to evaluate the study question equally between the sexes. The sample was obtained by identifying patients with an ICD-9 (International Classification of Diseases, Ninth Revision) diagnosis code for a distal radial fracture and cross-referencing these medical record numbers with a PACS (picture archiving and communication system) database search for a wrist CT scan. All CT scans in the fracture cohort were confirmed to have been obtained within one week of injury, thereby minimizing the effect of disuse osteoporosis. A PACS database search was used to identify fifty age and sex-matched control patients who had a wrist CT scan on which a senior musculoskeletal radiologist did not identify any fracture (Fig. 1). For both cohorts, the study was limited to imaging data; no medical record analysis of comorbidities or metabolic bone health was performed.

Hounsfield Unit Methodology

Unenhanced CT of the wrist was performed with a 16-MDCT (multidetector CT) scanner (MX8000; Philips Healthcare). IDS7 PACS software (Sectra) was utilized to calculate HU values within the distal radial metaphysis, the ulnar head, and the capitate (Fig. 2). All measurements were isolated to cancellous regions of bone, with avoidance of cortical regions, which is consistent with our previously reported methodology optimized for assessments of the lumbar spine[14].

For the distal radial measurements, axial images proximal to the physeal scar and within the metaphysis were utilized. Measurements were made from three axial cuts, and an average of those measurements was used in the final analysis. In the case of fracture patients, regions of interest were localized to uninvolved portions of the metaphysis (Fig. 3). In pilot testing, we found no difference between sampling one representative region of interest without traversing fracture lines and employing an average of multiple small measurements taken from individual regions or fragments. This methodology is

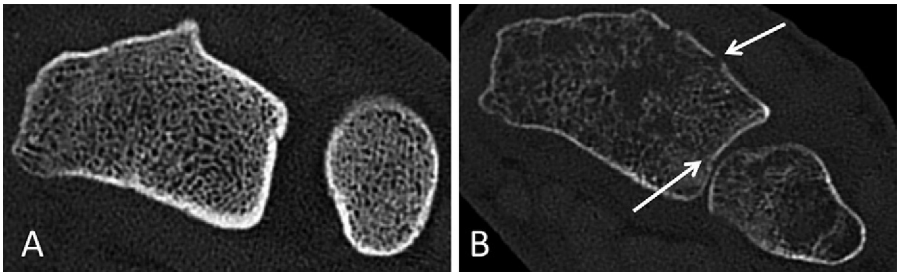

Fig. 1

A comparison of BMD imaging features of a representative patient in the control cohort (**Fig. 1-A**) and a patient in the fracture cohort (**Fig. 1-B**) (arrows mark the fracture lines). Note the imaging characteristics of osteoporosis in Figure 1-B, including lower attenuation, decreased trabecular density, and apparent cortical thinning.

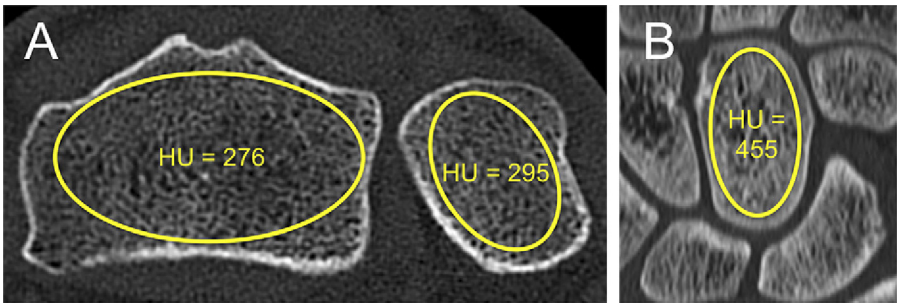

Fig. 2

Images demonstrating the technique for obtaining regional Hounsfield unit (HU) values from cancellous portions of the distal aspect of the radius and the ulnar head (**Fig. 2-A**) and from cancellous portions of the capitate (**Fig. 2-B**). Cancellous bone density was assessed with the use of standard radiology software.

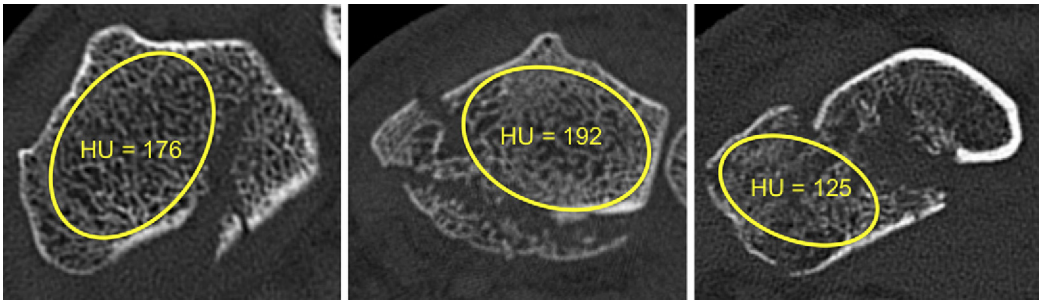

Fig. 3

The technique for obtaining Hounsfield unit (HU) values for the distal radial fracture cohort is demonstrated on images from three different patients. In each patient, measurements were made from the largest metaphyseal fragment at three different levels, and an average was used in the analysis.

also consistent with previous reports on the reliability of HU measurements in assessments of the lumbar spine[16].

Measurements in the ulnar head were made at axial levels similar to those used for the radius. Coronal images were used to obtain measurements within the capitate, and a mean of three slices was used in the analysis. All measurements were made by two independent orthopaedic surgeons.

Statistical Analysis

Continuous variables were reported as means and compared using a two-tailed Student t test. Interobserver reliability of HU measurements was assessed using the Pearson product-moment correlation coefficient. A value of >0.8 is considered an excellent inter-rater correlation. A two-tailed Pearson r analysis was used to assess the correlation between age and HU values for both male and female patients in the control cohort. A threshold cutoff value of HU that optimized sensitivity and specificity was identified using a receiver operating characteristic (ROC) curve. The threshold cutoff value was assessed using a chi-square test, and unadjusted odds ratios (ORs) were calculated.

Source of Funding

No external funding source was utilized for this investigation.

Results

Over the study period, 31% of the patients who were evaluated for a distal radial fracture at our institution underwent a CT scan as part of their diagnostic work-up. The fracture and control cohorts were similar in age and sex (Table I). Inter-rater reliability of the measurement of HU values was excellent, with $r = 0.908$ for the distal radial measurements ($p < 0.0001$), $r = 0.947$ for the distal ulnar measurements ($p < 0.0001$), and $r = 0.885$ for the capitate measurements ($p < 0.0001$).

In the distal radial metaphysis and in the ulnar head, no differences were observed among the axial measurements made at distal, middle, or proximal locations. Within the capitate, no differences were observed among the volar, middle, and dorsal measurements (Fig. 4).

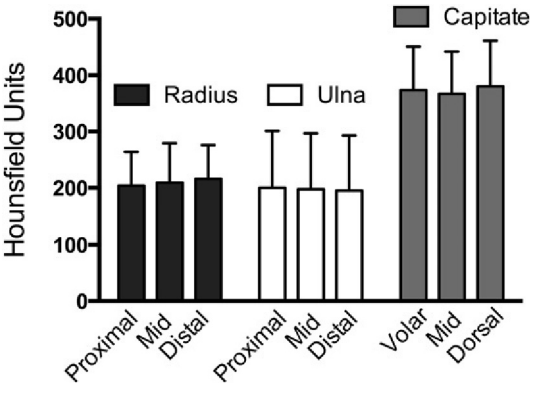

Fig. 4

A comparison of the average Hounsfield unit values, along with standard deviations, for the three areas where measurements were made. For each patient, an average of the three measurements was used in the analysis. No trends were observed toward increased or decreased values at any location within the radius, the ulna, or the capitate. Given that finding, a single measurement at any region is likely a sufficient estimate of regional BMD.

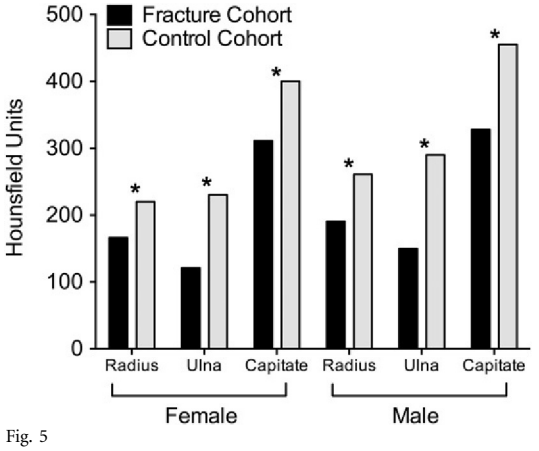

Fig. 5

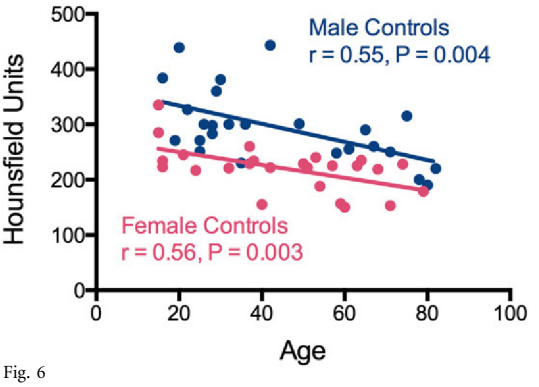

Fig. 6

Fig. 5 A comparison of the mean Hounsfield unit values in the distal radial fracture cohort (n = 50) and the control cohort (n = 50) from measurements made within the distal aspect of the radius, the ulnar head, and the capitate. Differences between the two cohorts were significant at each anatomic site for both sexes (*p < 0.0001). **Fig. 6** An analysis of the correlation between patient age and BMD of the distal aspect of the radius, as assessed by Hounsfield unit measurements, in twenty-five male control patients and twenty-five female control patients. A significant decrease in BMD with increasing age was observed in patients of both sexes.

When assessed on the basis of sex, both male and female patients with a distal radial fracture had significantly lower regional BMD, as measured by HU values, at each site (the distal aspect of the radius, the ulnar head, and the capitate) compared with age-matched nonfracture control patients ($p < 0.0001$) (Fig. 5).

For females, an HU value of 218 for the distal aspect of the radius optimized sensitivity (96%) and specificity (72%) for distinguishing fracture patients from controls. Patients below this threshold were at increased risk of a distal radial fracture (OR = 3.4; $p < 0.001$). For males, an HU value of 246 optimized sensitivity (88%) and specificity (84%) (OR = 5.5; $p < 0.001$).

Both male ($r = 0.55$; $p = 0.004$) and female ($r = 0.56$; $p = 0.003$) control patients showed an age-related decline in distal radial BMD (Fig. 6). However, male ($r = 0.32$; $p = 0.12$) and female ($r = 0.34$; $p = 0.10$) fracture patients had lesser correlations between age and BMD, suggesting that fracture patients had lower HU values, regardless of age.

Discussion

With an aging population and the health burden of osteoporosis-related fractures progressively increasing, additional diagnostic tools may be useful for optimizing appropriate management. Distal radial fractures are commonly encountered injuries, particularly in the setting of osteoporosis[3-5], and can predict future fracture risk on an individual basis[6,7,17]. Despite such fractures being an important harbinger of future fracture and morbidity, multiple studies have shown that <25% of distal radial fracture patients receive an osteoporosis work-up or intervention[2,6,11,12].

Various intervention strategies to improve these rates have been explored. Establishing a fracture liaison service with an osteoporosis specialist nurse[18], implementing a predefined fragility fracture clinical pathway[19], integrating treatment with that by endocrinologists[2], or simply obtaining a dual x-ray absorptiometry (DXA) scan[11] can substantially increase the likelihood of subsequent diagnosis and treatment. The efficacy of these programs can be dramatic, and their implementation can increase adequate care rates to as high as 96.8%[20]. Appropriate screening and pharmacological intervention significantly decrease both future distal radial fracture risk[10] and the risk of more serious hip and vertebral fractures[9,21].

HU values determined from CT scans may provide a means of diagnosing osteoporosis and allow for immediate in-office identification of patients with decreased bone quality, regardless of the indications or the findings of the scan. Using modern software programs, surgeons can obtain HU measurements from any diagnostic CT scan, with minimal effort in an office setting. Importantly, these values can be quickly obtained at no additional cost or radiation exposure to the patient. This technique, if routinely implemented, could facilitate early detection of osteopenia or osteoporosis.

The average of three measurements was used for HU assessment in this study. However, given the overall uniformity of measurements from various slices, as demonstrated in Figure 4, we propose that a single measurement would be sufficient for future analyses and would minimize user burden. We also demonstrated excellent reliability between independent observers. Both of these findings are consistent with reports on the methodology and reliability of HU as a tool for assessing local BMD in the spine[14,16].

In the present study, we showed that patients with a distal radial fracture had lower BMD, as assessed by HU measurements, in the distal aspect of the radius, the ulnar head, and the capitate. Additionally, we identified distal radial HU-value thresholds that optimize sensitivity and specificity and can be used as guidelines for alerting the treating physician to potential decreased bone quality. On the basis of our results, we

suggest that males with a distal radial HU value of <246 and females with a value of <218 be considered for further metabolic bone disease work-up. These numbers represent the best thresholds based on this imaging-only study. If medically appropriate, further interventions may include additional imaging, such as DXA scanning, and obtaining metabolic bone disease laboratory markers. When appropriate, these patients may be indicated for the initiation of osteoporosis treatment or referral to a physician more versed in appropriate management guidelines.

This study was not without limitations. CT scanning subjects patients to radiation exposure and is not routinely indicated for the management of distal radial fractures. We do not suggest that CT scans that are not necessary for fracture management be obtained to assess bone quality. Rather, we emphasize that when this information is already available, it may serve as another diagnostic tool to assist in efforts to "own the bone." At our institution, 31% of patients who were managed for a distal radial fracture underwent CT as part of their evaluation. Although this number is low for a screening test, it is incidentally higher than published utilization rates of other osteoporosis screening tools such as DXA[2,6,11,12]. Given that only a minority of patients underwent CT for the management of a distal radial fracture, it is unknown whether our fracture cohort is truly representative of the larger distal radial fracture cohort.

The control group in this study consisted of patients who underwent CT for a variety of conditions other than a distal radial fracture. Ideally, a healthy cohort with no upper-extremity pathology would have been used as controls. Additionally, given that no clinical or DXA data were included, we cannot definitively state that our control cohort represents patients with normal bone health. As such, the generalizability of the identified thresholds is uncertain, and we recommend that a thorough medical history be used in conjunction with HU values in determining best practice and appropriateness of further evaluations and interventions.

DXA is currently the gold standard for the diagnosis of osteoporosis, with well-established standards and documented correlations with fracture risk and treatment efficacy[22]. Unfortunately, DXA results were not available for patients in our study. Potential advantages of CT bone-density measurements compared with DXA measurements include their volumetric assessment of BMD, as opposed to planar values obtained in routine DXA studies. Rozental et al. showed that CT may be a more accurate BMD assessment tool than DXA, as distal radial fracture patients demonstrated poorer trabecular bone microarchitecture than did controls, despite similar DXA values[23]. Additionally, HU measurements can be localized to any region of interest, allowing for reliable and highly reproducible values, even in the case of fracture. While the present study identified thresholds and ORs, additional studies are needed to establish correlations between wrist DXA values and HU values before this promising measurement system can be truly diagnostic.

In conclusion, this novel technique adds to a surgeon's fragility fracture diagnosis and treatment armamentarium and can potentially quickly and accurately identify patients at risk for a distal radial fracture on the basis of a single HU regional assessment from any diagnostic CT scan. ■

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