Ultradistal Ulnar Bone Density From Digital Wrist Tomosynthesis Imaging Is Effective for Screening of Osteoporosis

Yener N. Yeni[1,2], Ilayda C. Yeni[1], Daniel Oravec[1], Ram N Yadav[1], Sudhaker D. Rao[1,3],
[1]Bone & Joint Center, Henry Ford Health, Detroit, MI, [2]Henry Ford Health + Michigan State University Health Sciences, Detroit, MI,
[3]Division of Endocrinology, Diabetes and Bone & Mineral Disorders, Henry Ford Health, Detroit, MI
yeni@bjc.hfh.edu

Disclosures: Yener N. Yeni (N), Ilayda C. Yeni (N), Daniel Oravec (N), Ram N. Yadav (N), Sudhaker D. Rao (N)

INTRODUCTION: Diagnosis of osteoporosis is based on T-scores derived from dual energy x-ray absorptiometry (DXA) of the hip and spine. Forearm is not a preferred site, and the standard mid- and distal third forearm results are recommended only in the absence of a hip or spine image. However, more recent studies strongly support the use of the cancellous-rich ultradistal radius for assessing bone quality and fracture risk [1]. CT-derived bone mineral density (BMD) of the distal *ulna* has also been shown to successfully discriminate osteopenic (OPN), osteoporotic (OPR) and normal subjects [2], those with and without prevalent osteoporotic fractures [3] and predict incident fractures [4]. Digital wrist tomosynthesis (DWT) using 3D breast scanners was proposed for osteoporosis screening due to high accessibility of breast scanners in the mammography environment and high adherence to breast cancer screening guidelines with anticipation that it can help increase adherence to osteoporosis screening guidelines [5]. It has been shown that DWT derived ultradistal radius BMD is highly effective in identifying individuals with OPN and OPR [6]. Minute details of ulna are also visible in a DWT image (**Fig 1**); however, the extent to which DWT of ulna is useful for assessing OPN and OPR has not been examined. Therefore, the objective of this clinical study was to determine the efficacy of DWT derived ulnar BMD for assessing OPN/OPR status of patients, and compare between modalities (DXA vs DWT) and anatomic sites (radius vs ulna).

METHODS: Under IRB approval and informed consent, 150 women were recruited (Age 53.6 ± 20.3, 20-88 years). The study was limited to female patients due to the disproportionate burden of fracture in women due to postmenopausal osteoporosis. Those with history of fractures, cancer, treatment for osteoporosis in the prior year, bone disorders other than osteoporosis and prior treatment with corticosteroids in the prior year were not included. Standard hip, lumbar spine, and forearm DXA images were obtained (Hologic Horizon A), from which total hip, femoral neck, spine, ultradistal radius and ultradistal ulna BMDs were calculated. T-scores based on total hip, femoral neck and spine as well as the minimum of the three (Min-T) were recorded.

The nondominant arm of each participant was then DWT scanned in a 3D breast scanner (GE Senographe Essential) using a standard manual technique (25^o angulation, 35 kV/50 mAs) and reconstructed at 0.1 mm^2 pixel size in the frontal plane with 1 mm slice thickness. From the DWT image, an ultra-distal (UD) volume of 8 central slices (8 mm in depth, 15 mm in length) was extracted, offset 10 mm proximal to the ulnar styloid process (**Fig 1**). Radius and ulna were thresholded from soft tissue, and DWT based BMD was calculated as the average grey value within each segmented volume. Relationships between ulna and radius BMDs were examined using linear regression. The extent to which DWT-derived radius and ulna BMD measures agree with DXA-derived diagnosis of osteopenia (OPN) and osteoporosis (OPR) was examined using logistic regression, and area under the receiver operating characteristic curve (AUC) was determined. DeLong's test was used to examine the differences between AUC values [7]. The analyses were performed in R with significance set at $p<0.05$.

Six additional participants were scanned thrice in the same DWT scanner, and 30 participants in two different scanners, to determine repeatability and reproducibility of DWT measurements, which were quantified as the percent root mean square coefficient of variation (%CV_{RMS}) of repeated measurements.

RESULTS: Radial and ulnar BMDs from DWT were strongly correlated to those from DXA (R=0.902 and R=0.843, respectively, $p<0.0001$). Both radius and ulna BMDs derived from DXA or DWT were discriminative of OPN and OPR at all sites as well as those determined by Min-T (AUC=0.78 to 0.96; $p<0.0001$; **Table 1**). DXA derived ulnar BMDs were better in discriminating OPN and OPR at the femoral neck and OPN at the hip than DWT derived ulnar BMDs (**Table 1**). DWT derived radial BMD was better than DWT derived ulnar BMD in discriminating OPN at the hip. All other relationships were statistically similar. In multiple regression models with DXA-derived radial and ulnar BMDs, ulna was selected ($p<0.0001$ to $p<0.02$) over radius ($p>0.1$) for OPN/OPR determined by Min-T, femoral neck or total hip T-scores, whereas radius was selected over ulna for OPN/OPR of the spine ($p<0.05$ vs $p>0.1$, respectively). An exception was OPR of total hip, where both radius and ulna were significant ($p<0.04$ and $p<0.0005$, respectively), albeit with a negligible increase in AUC (AUC=0.961, vs 0.955 for ulna alone). When both radial and ulnar BMDs from DWT were considered, radius was selected ($p<0.002$) over ulna ($p>0.08$) in all models. Exceptions were OPN determined by Min-T and femoral neck: radius ($p<0.0001$) and ulna ($p<0.02$) independently contributed to these models, again with a negligible increase in AUC (from 0.885 and 0.909 for radius alone to 0.899 and 0.919, respectively).

Repeatability of DWT BMD (expressed as %$CV_{RMS)}$ for radius and ulna, respectively, was 1.17% and 1.50%, and reproducibility was 2.30% and 1.26%.

DISCUSSION: The current results indicate that DXA derived ultradistal ulna BMD discriminates OPN/OPR status by various T-score criteria with high accuracy. Results were similar for DWT derived radial and ulnar BMDs, although radius had higher AUC than ulna for discriminating OPN at the hip. The AUC values are consistent with those reported between forearm density and OPR of the hip and spine [8, 9]. Measurement precision of DWT was comparable between radius and ulna, with the ulna having slightly better reproducibility. Overall, ulna is as good a site as ultradistal radius, if not better in some cases, for assessing OPN/OPR, but there is little gain from using both. As such, the ulna may serve as a surrogate for the radius in situations imaging of one is not feasible due to reasons such as prior fracture, implants and degenerative abnormalities.

The participants included young women who would normally not be screened for osteoporosis. Limiting the analysis to women ≥ 50 years of age did not change the conclusions (data not presented); however, doing so substantially reduced the number of normal participants (as low as 20 for min-T). Future work would include a more balanced representation of age and participant numbers in the OPN, OPR and normal groups. The extent to which properties other than ulna density (e.g., microstructure and bone geometry) improve bone quality assessment and osteoporosis screening with DWT remains to be determined.

SIGNIFICANCE/CLINICAL RELEVANCE: BMD of the ultradistal ulna can be used for osteoporosis screening when ultradistal radius is not available, and the results from this study can be utilized to determine the equivalent threshold BMD values relative to hip and spine T-scores. The current results also support the utility of ulna BMD in DWT during routine breast screening of women in the mammography setting.

REFERENCES: [1] Holloway-Kew 2024, Osteoporos Int 1-9. [2] Wagner 2017, JBJS Am, 99: e38. [3] Schreiber 2015, JBJS Am, 97: 1095-1100. [4] Dworak 2018, J Hand Surg Am, 43: 1010-1015. [5] Yeni 2021, Bone, 144: 115804. [6] Oravec 2025, Osteoporos Int, 36: 1165-1173. [7] DeLong 1988, Biometrics, 44: 837-845. [8] Clowes 2006, Osteoporos Int, 17: 1293-1302. [9] Pouiles 2001, Osteoporos Int, 12: 71-76.

ACKNOWLEDGEMENTS: DOD PRMPRP W81XWH-21-1-0530 (YNY), NIH R01AR085637 (YNY)

IMAGES AND TABLES:

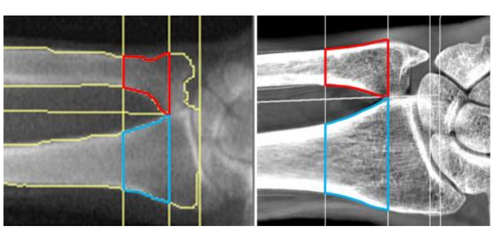

Fig 1. Typical images of the forearm from a) DXA and b) DWT. Radial and ulnar regions of interest for BMD calculations are shown in blue and red, respectively.

Table 1. AUC values for relationships between OPN/OPR status and radial and ulnar BMDs from DXA and DWT.

AUC values; p<0.0001 for all	DXA				DWT			
	Radius		Ulna		Radius		Ulna	
OPN/OPR by	**OPN**	**OPR**	**OPN**	**OPR**	**OPN**	**OPR**	**OPN**	**OPR**
Min-T	0.89	0.88	0.91	0.89	0.89	0.85	0.87	0.84
Spine	0.83	0.87	0.82	0.85	0.82	0.82	0.78	0.81
H Neck	0.91	0.85	0.94*	0.88*	0.91	0.85	0.87	0.80
T Hip	0.92	0.95	0.94*	0.96	0.92†	0.95	0.84†	0.90

* Different between modalities; † Different between sites within modality