Ultrasonic Assessment of the Forearm

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BACKGROUND & PURPOSE

Bone mineral density (BMD) is a key component of bone strength and for evaluating an individual's risk for fracture. Dual energy X-ray absorptiometry (DXA) at the forearm has been well-studied and can be a useful site for osteoporosis screening. Ultrasound has been proposed as a proxy for BMD that is radiation free and simple to implement and use [1,2]. The purpose of this study was two-fold. The first was to determine the variation of BMD along the radius, and the second was to evaluate the ability of a new ultrasound device to track these axial variations in radial BMD. The long range objective of this study is to bring ultrasonic bone assessment of the forearm into primary care, so that osteoporosis will become less under-diagnosed and less undetected, and ultimately to reduce the incidence of fragility fractures and associated morbidity.

MATERIALS AND METHODS

Nine subjects with no history of fragility fracture were measured at the forearm (all except two had both forearms measured) using DXA (QDR-4500, Hologic, Inc., Bedford, MA) to obtain their BMDs (g/cm²). The BMD was computed using Hologic's general region of interest software. The BMD of the radius was measured from the 1/3rd (33%) location to the 10 percent location (the percent being percentage of ulnar length) in 5 mm steps, using a rectangle of 5 mm constant height and a length that varied with the width of the radius; this produced approximately 14 discrete values of BMD for each radius. The BMD (BMD_S) of a small (5 mm square) central ROI of each radius at each location was also measured. Three of the nine subjects were also measured using a thru-transmission desktop ultrasound device, Fig. 1 (*UltraScan 650*, CyberLogic, Inc., New York, NY). The left and right forearms of each of the three subjects were measured starting at the 1/3rd location (Fig. 2) in steps distally of 3.33 mm, ending at the 10% location; this produced about 16 discrete ultrasound measurements for each radius. Each ultrasound measurement at any given location along the forearm took about five (5) seconds. The received ultrasound signals were processed to obtain two net time delay (NTD) parameters, NTD_{DW} and NTD_{CW} (Fig. 3) [3,4]. The square root of the product of the two NTD parameters was used in a linear regression to compute an ultrasound-based estimate, BMD_{US}, of radial BMD, *i.e.*, $BMD_{US} = a \cdot \mathrm{sqrt}[NTD_{DW} \cdot NTD_{CW}] + b$, while NTD_{DW} alone was used to estimate BMD_S.

Fig. 1. UltraScan 650 Ultrasound Forearm Scanner

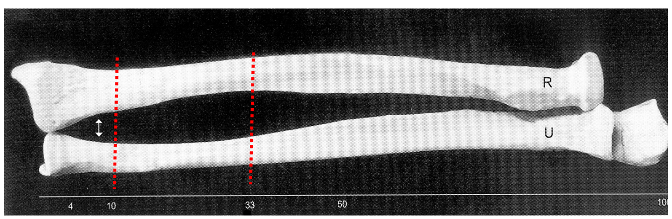

Fig. 2. ***Radius (R) and ulna (U) with a scale showing the percent locations (the two dotted lines indicate the 1/3rd and 10 percent locations).***

Fig. 3. Schematic set-up showing single element source in a through-transmission configuration with a linear array receiver. The arrows denote direction of propagation of ultrasound. CW is the portion of the signal that propagates through radial cortex only, DW is the portion of the signal that propagates through both radial cortex and medullary cavity, and SW propagates through soft tissue only.

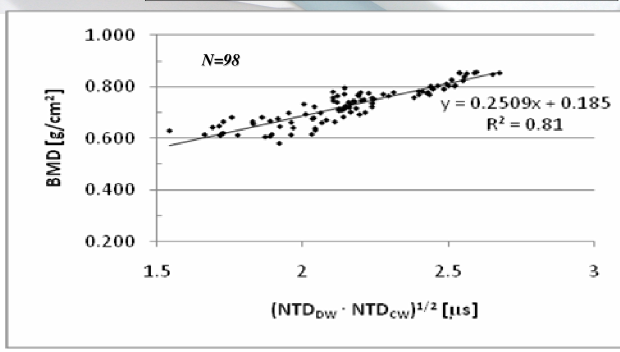

Fig. 5. DXA-BMD vs Ultrasound-BMD Estimate.

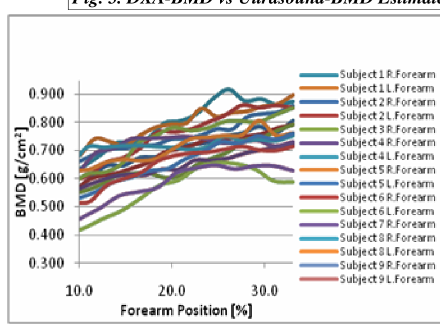

Fig. 4. DXA-BMD vs Forearm position for the 16 forearms.

RESULTS

Figure 4 displays the radial BMD vs. percent location along the forearm for sixteen radii of the nine subjects. As may be seen, there appears to be a relatively constant rate of decrease (i.e., slope) for most of the subjects, while there is about a fifty-percent range in BMD (0.6 – 0.9 g/cm2) at the 1/3rd location. In particular, the BMD decreases at an average rate of 0.01 g/(cm²•%) from the 1/3rd (mean BMD = 0.75 g/cm²) to the 10% (mean BMD = 0.58 g/cm²) locations. The ultrasound data are shown in Figs. 5-6. As may be seen, there is excellent correlation between both the actual BMDs and the ultrasound estimates, with linear correlation coefficients of r = 0.9 (BMD) and r = 0.93 (BMD_S), P<0.001 for both.

DISCUSSION

This study showed that there is a relatively constant rate of decrease in BMD along the radius, from the 1/3rd to about the 10% locations. Prior studies have generally reported BMD at either the 1/3rd or the ultra-distal (UD) sites. It would be interesting to examine whether the axial profile of BMD at the radius might be relevant in terms of estimating the risk of radius fracture, as compared with using the BMD at the 1/3rd or UD sites alone. This study also shows that ultrasound is an excellent proxy for BMD, with a correlation coefficient of 0.9. The data also suggests that ultrasonic assessment of BMD at the radius is robust with respect to variations in geometry as well as to changes in percentages of trabecular bone content. For example, the mean radial width in the 16 forearms (data not shown) was observed to increase almost thirty (30) percent from the 1/3rd to the 10% locations. In addition, it has been noted that the percentage of trabecular bone increases from 1% to 20% from the 1/3rd to the 10% locations [5]. Ultrasound measurements remained highly correlated with BMD, in spite of these geometric and compositional variations.

CONCLUSION

In conclusion, ultrasound measurements at the forearm appear to be an excellent proxy for BMD. This study demonstrates the potential for a simple, radiation-free desktop ultrasound device that can be used to identify those individuals with reduced bone mass, so that therapeutic interventions can be instituted in a timely and effective manner.

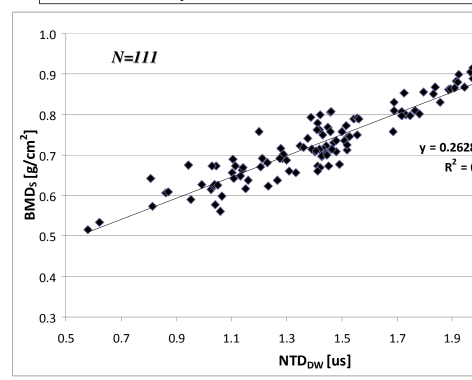

Fig. 6. DXA-BMD_S vs Ultrasound-BMD_S Estimate.

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