

Ultrasound of the Tibia-Precision Error, Left versus Right Sides and Correlation with Bone Mineral Density

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Abstract

Ultrasound of the tibia measures the speed of sound through cortical bone and is a measure of bone density and strength. Ten subjects were measured twice each on the same side by a single operator using the Myriad Soundscan 2000. Intra-operator precision error expressed as CV% was 0.3%. Inter-operator precision error was also found to be 0.3% when results on the same ten subjects by two operators were analysed. Seventy-four subjects had their speed of sound (SOS) measured on both the left and right tibiae by a single operator. The Pearson correlation co-efficient was 0.83.

Fifty subjects had their SOS measured as well as their bone mineral density (BMD) determined by dual energy X-ray absorptiometry (DEXA) using the Hologic QDR 2000. BMD measurements were made at the lumbar spine AP view, neck of femur, trochanter, Ward's triangle and total hip. Pearson correlations between these various sites and SOS were as follows: SOS versus BMD AP spine $r = 0.61$, $P < 0.0001$; SOS versus neck of femur $r = 0.68$, $P < 0.0001$; SOS versus trochanter $r = 0.71$, $P < 0.0001$; SOS versus Ward's triangle $r = 0.7$, $P < 0.0001$; SOS versus total hip $r = 0.67$, $P < 0.0001$. In conclusion, ultrasound of the tibia is a precise and promising tool in the assessment of osteoporosis. Further studies are needed to document its clinical usefulness.

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Key words: Bone densitometry, Fracture risk, Osteoporosis, Speed of sound, Ultrasound velocity

Introduction

Osteoporosis is an increasingly important problem and effective interventions are now available.¹ An important advance in the last ten years has been the availability of techniques which are able to detect patients who are at risk for osteoporotic fractures so that treatment can be instituted to reduce fracture risk. Currently; bone densitometry of the spine and hip using dual energy X-ray absorptiometry (DEXA) is the most acceptable method because of its precision, accuracy, ability to predict fracture risk, its role in monitoring the efficacy of treatment and relatively low cost.² Quantitative computed tomography is a good measurement tool but suffers from the disadvantages of high cost and significant radiation. DEXA on the other hand exposes the patient to a level of radiation six times less than the exposure when undergoing a chest X-ray.³

Densitometry needs to be institution-based and hence a more portable instrument will have considerable advantages, especially in situations where densitometry is not widely available. Many of such instruments utilise ultrasound techniques. Measurement of the os calcis has been found to be an independent predictor for hip fractures and may measure bone strength in addition to bone density.⁴ However, its usefulness as a single diag-

nostic test has not been fully documented. The role of monitoring using ultrasound of the heel is not established as yet.

Ultrasound of the tibia measures the speed of sound (SOS) through the cortical bone and is a measure of bone density and strength. When compared to the heel, the tibia is predominantly cortical bone and it is interesting to assess the correlation with various sites at the hip, where cortical bone is affected in osteoporosis.

The aims of this study were to assess the inter- and intra-operator precision of the ultrasound instrument (Myriad Soundscan 2000), determine if there are significant differences between measuring the left and right sides and document the correlation between SOS tibia and bone mineral density (BMD) at various sites.

Patients and Methods

Measurement Technique

The patients were asked to lie on a couch with the leg to be measured supported by a small cushion. The machine was calibrated before the start of each session using a standard phantom. The midpoint of the tibia was identified as the midpoint between the lower pole of the patella and the tip of the medial malleolus. The SOS was acquired by sampling 150 measurements over the sur-

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face of the tibia at this midpoint. The machine then took the mean of the five highest readings and this was the value used, expressed in metres per second. This absolute value can also be expressed as a T score and Z score, the definition of which follows that used in bone densitometry. The whole procedure took about 10 minutes.

Precision Error

Ten subjects were measured twice each at the same site by a single operator. The intra-operator precision error expressed as CV% was calculated using the formula in Table I.

These same ten subjects were then measured once each by two separate operators. The inter-operator precision error expressed as CV% was calculated using the formula shown in Table II.

Left Side Versus Right Side

Measurements were done on both sides in 74 subjects. As the SOS is normally distributed in the population, Pearson's correlation coefficient was calculated for the left side versus the right side.

Correlation with Bone Mineral Density

Fifty subjects had SOS and BMD measurements using the Hologic QDR 2000. Pearson's correlation coefficient was calculated for SOS versus BMD at various sites, namely antero-posterior spine L2-4, neck of femur, trochanter, total hip and Ward's triangle.

Results

The inter-operator precision error was 0.3% and the intra-operator precision error was also 0.3% (Tables I and II).

TABLE I: INTRA-OPERATOR PRECISION EXPRESSED AS CV%

Subject number	First (X1i)	2nd (X2i)	(X1i-X2i)	(X1i-X2i) ²
	4079.1	4079.1	0.00	0.00
2	3954.3	3963.4	-9.1	82.81
3	3860.1	3877.4	-17.3	299.29
4	3901.6	3917.2	-15.6	243.36
5	3963.5	3982.1	-18.6	345.96
6	3993.9	3979.5	14.4	207.36
	4059.6	4045.0	14.6	213.16
8	3890.5	3895.6	-5.1	26.01
9	4075.1	4046.8	28.3	800.89
10	3858.3	3882.7	-24.4	595.36
Sum	39636.0	39668.8		2814.2

Average
 $(39636.0 + 39668.8) / (2 \times 10)$
 $= 79304.8 / 20$
 $= 3965.24$

CV% (Precision)
 $(11.86 / 3965.24) \times 100$
 $= 0.3\%$

Comparing the left and right sides, $r = 0.83$ and the points cluster closely around the line of identity (Fig. 1).

SOS correlated significantly with BMD at various sites (Table III). Pearson's correlation coefficients between these various sites and SOS were as follows: SOS versus BMD AI' spine $r = 0.61$, $P < 0.0001$; SOS versus neck of femur $r = 0.68$, $P < 0.0001$; SOS versus trochanter $r = 0.71$, $P < 0.0001$; SOS versus Ward's triangle $r = 0.7$, $P < 0.0001$; SOS versus total hip $r = 0.67$, $P < 0.0001$.

Discussion

Ultrasound techniques show considerable promise in the assessment of osteoporosis. Ultrasound of the tibia measures the speed of sound passing through a defined

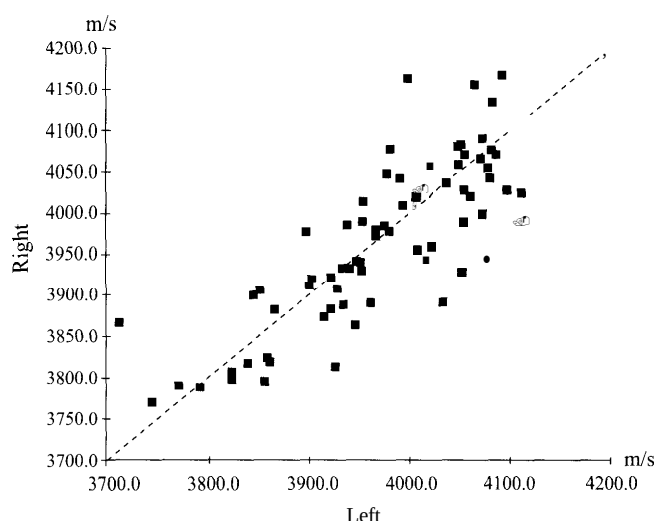


Fig. 1. Correlation of speed of sound of the right tibia with the left side

TABLE II: INTER-OPERATOR PRECISION AS CV%

Subject number	First (X1i)	Second (X2i)	(X1i-X2i)	(X1i-X2i) ²
1	4079.1	4072.0	7.1	50.41
2	3963.4	3993.4	-30.0	900.0
3	3877.4	3848.7	28.7	823.69
4	3982.1	3985.4	-3.3	10.89
5	3979.5	3974.7	4.8	23.04
6	4045.0	4074.9	-29.9	894.01
7	3995.9	4004.1	-8.2	67.24
8	3895.6	3907.8	-12.2	148.84
9	4046.8	4032.3	14.5	210.25
10	4069.4	4058.5	10.9	118.81
Sum	39934.2	3995.18		3247.18

Average
 $(39934.2 + 3995.18) / (2 \times 10)$
 $= 3994.3$

CV% (Precision)
 $(12.74 / 3994.3) \times 100$
 $= 0.3\%$

TABLE III: CORRELATION OF SPEED OF SOUND AT THE TIBIA WITH BONE MINERAL DENSITY (BMD) AT VARIOUS SITES

BMD site	Pearson's correlation (<i>r</i> value)	Significance (<i>P</i> value)
Antero-posterior: Spine L2-4	0.61	<0.0001
Neck of femur	0.68	<0.0001
Trochanter	0.71	<0.0001
Total hip	0.67	<0.0001
Ward's triangle	0.70	<0.0001

and fixed longitudinal distance of the cortical layer of the tibia parallel to its long axis. A 250 kHz pulse is propagated along a defined 50 mm distance and the speed of sound is calculated as the transit time divided by 50 mm, expressed in metres per second. The instrument is accurate to 4 m/s.

The precision error we obtained is comparable to that found in other studies. Orgee et al⁵ obtained an intra-operator CV% of 0.35% and inter-operator CV% of 0.50%. Stegman et al⁶ found both to be in the order of 0.5%. When compared to precision of other ultrasound techniques, ultrasound tibia fared favourably. At the heel, velocity CV% ranges from 0.3% to 2.7% with the better machines;^{7,8} broad band attenuation at the heel has CV% ranging from 2.3% to 10%.^{9,10} Comparing with DEXA, spine measurements have a CV% of 0.8% to 2.6%, the hip has CV% of 0.7% to 3.9% and single energy X-ray absorptiometry (SXA) of the forearm has CV% of 0.6% to 2.0%.

Hence, ultrasound tibia is a highly precise and reproducible technique. This, however, is not the sole factor in assessing its clinical usefulness. The measurements must be shown to discriminate between normal and osteoporotic subjects. If there is little variation in the parameter when measured in normal and abnormal subjects, then even a highly precise tool is not useful. This state of affairs was found to be the case for ultrasound velocity at the patella.¹¹

In our study, we found that SOS correlates highly with BMD measured at the spine and various sites at the hip. This may be an indication of its potential clinical utility but studies are needed which document its role in predicting risk of fractures and also its sensitivity to change after pharmacological interventions. Orgee et al⁵ showed that ultrasound velocity at the tibia was significantly higher in 73 premenopausal women than in 129 postmenopausal women, 26 women with steroid-induced osteoporosis and in 4 women with hyperparathyroidism. Stegman et al⁶ found that low tibial velocity was associ-

ated with the presence of low energy appendicular fractures. There was, however, no association with vertebral fractures nor with the category "all fractures". Currently, studies assessing the use of ultrasound tibia longitudinally are lacking.

Measurements on the left correlated significantly with those on the right in 74 patients. The *r* value of 0.83 and the clustering around the line of identity suggest that it does not matter which side is used for measurement. This is relevant for subjects who have suffered previous trauma to the tibia on one side. In such a situation, measuring the contralateral tibia will be useful.

In conclusion, ultrasound of the tibia is a precise and promising tool in the assessment of osteoporosis. Further studies are needed to document its clinical usefulness.

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