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Professional Paper

CORRELATION OF BONE MINERAL DENSITY MEASURED BY QUALITATIVE ULTRASOUND AND DUAL ENERGY X-RAY ABSORPTIOMETRY

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SUMMARY – Osteoporosis is a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with consequential increase in bone fragility and susceptibility to fracture. Bone mineral density (BMD) is an important determinant factor of fracture risk. Fifty-eight healthy postmenopausal women aged 53-91 years were included in the study. The subjects were divided into three age groups. Heel bone (calcaneus) BMD detected by qualitative ultrasound (QUS) was correlated with lumbar spine and proximal femur BMD detected by dual energy x-ray absorptiometry (DEXA). Also, subject age and anthropometric parameters (body weight and height) were correlated with BMD values in the calcaneus, spine and proximal femur. A chart was made of T-score conversion for lumbar spine according to T-score of heel bone detected by QUS. Calcaneal BMD showed best correlation in group 2 (58-67 yrs) with total femoral BMD (R=0.72) and intertrochanteric area (R=0.719), both statistically significant ($p1=0.0007$, $p1<0.001$; $p2=0.0008$, $p2<0.001$). There was no significant correlation between any of the calculated BMD values (calcaneus, lumbar spine and proximal femur) and age, body weight or body height. According to our conversion chart, when T-score calculated on ultrasound densitometry is equal or below -1 it yields a final T-score of lumbar spine between -1 and -2.5, which according to WHO criteria is diagnosed as osteopenia. This makes ultrasound densitometry an excellent screening method to identify patients at a risk of fracture.

Key words: *Bone density – diagnosis; Densitometry – x-ray; Bone diseases, metabolic – ultrasonography; Osteoporosis – diagnosis*

Introduction

Osteoporosis is a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with consequential increase in bone fragility and susceptibility to fracture[1]. The fractures tend to occur in the regions of the skeleton that are rich in trabecular bone (the wrist, spine and hip), and can result in considerable morbidity (pain, loss of height and deformity) and mortality[2]. Hip fracture is the most serious consequence of osteoporosis and it is known that the women with hip fracture are 2 to 4 times more likely to die within 12 months of the event than are the women of the same age without fracture in the general population[3]. Whether a patient suffers a fracture will depend on a number of risk factors, and bone mineral density (BMD) is an important factor. Recent studies have shown that a decrease in femoral BMD of one standard deviation (SD) leads to two- to threefold increase of fracture risk[4]. As effective therapies (HRT, SERMs, bisphosphonates) that increase BMD and reduce future fracture risk are now available, it is important that patients with osteoporosis and at risk of fractures are identified before the fractures occur[5,6].

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Over the last 25 years, several noninvasive techniques based on the attenuation of ionizing radiation have been developed in order to quantify BMD in the axial and peripheral skeleton. These techniques include single photon absorptiometry (SPA), single x-ray absorptiometry (SXA), dual energy x-ray absorptiometry (DEXA) and quantitative computed tomography (QCT). Ultrasound densitometry based on qualitative ultrasound (QUS) measurements of bone has been recently introduced as a new and radiation-free technique for screening and identifying the patients at risk of osteoporosis.

In our study, we correlated BMD of the heel bone (calcaneus) detected by QUS with BMD of the lumbar spine and proximal femur detected by DEXA. We also correlated subject age and anthropometric parameters (body weight and height) with BMD values of the calcaneus, spine and proximal femur.

Hologic (the Sahara and DEXA densitometry manufacturer) has developed a simple chart of T-score conversion (between lumbar spine and calcaneus T-score) based on the manufacturer's reference ranges according to age group, site and method (Sahara-DEXA). This conversion chart is based on average values for age and they can show significant intraindividual variation. We developed our chart of conversion, based on linear correlation diagram, for lumbar spine according to the same age groups as proposed by the manufacturer.

Subjects and Methods

The study included 58 healthy postmenopausal women aged 53-91 years. Two different methods, ultrasound measurements and DEXA, were performed in all women. Ultrasound measurements were performed on a Sahara clinical bone sonometer (Hologic) with the subject seated and her foot positioned and secured in the Sahara system using a positioning aide. After the subject's foot has been secured, a pair of soft silicone rubber pads are brought into contact with opposite sides of the patient's heel by means of a motorized caliper mechanism. Each of the silicone rubber pads is acoustically coupled to the heel and to a sound transducer using Sahara ultrasound coupling gel. Ultrasound waves (0.6 MHz), produced by one of the sound transducer, are transmitted through the heel and received by the opposite transducer. The output from Sahara clinical bone sonometer is expressed as an estimate of the BMD in g/cm^2 of the calcaneus and as a T-score. T-score is the number of standard deviations above or below the mean BMD for young women.

DEXA (Hologic, QDR 4500 W) was used to measure BMD in g/cm^2 and T-scores for lumbar spine and proximal femur. BMD of the lumbar spine was calculated as an average value of bone mineral density in L1-L4. In the proximal femur bone mineral densities from different sites were measured including femoral neck, intertrochanteric area, trochanter and Ward's triangle. Total femoral BMD was also calculated as an average value of bone mineral density for the femur sites.

Statistics

Standard parameters of descriptive statistics were calculated and relative errors of the measured BMD values were estimated. Linear correlations were used to determine the parameters of correlation diagram and correlation index. Statistical significance of the correlation index was also calculated. A model of changeable statistical weight factor for independent and dependent variable was used.

Table 1. Mean, minimum, maximum (g/cm^2) and standard deviation (SD) of bone mineral density values (BMD) for heel bone, lumbar spine, Ward' triangle, total, intertrochanteric area, trochanter and femoral neck

	Group 1 (53-57 yrs)				Group 2 (58-67 yrs)				Group 3 (>68 yrs)			
	min	mean	max	SD	min	mean	max	SD	min	mean	max	SD
Heel bone	0.25	0.36	0.46	0.07	0.17	0.39	0.77	0.11	0.20	0.35	0.45	0.08
Lumbar spine	0.77	0.88	0.97	0.05	0.52	0.81	1.13	0.15	0.50	0.80	1.08	0.14
Ward's triangle	0.39	0.60	0.76	0.12	0.17	0.51	0.82	0.15	0.23	0.48	0.82	0.16
Total	0.73	0.87	1.05	0.1	0.22	0.80	1.11	0.18	0.42	0.73	1.09	0.16
Intertrochanteric area	0.85	1.02	1.25	0.13	0.27	0.96	1.34	0.22	0.47	0.88	1.26	0.20
Trochanter	0.57	0.66	0.79	0.07	0.08	0.60	0.83	0.16	0.28	0.55	0.87	0.13
Femoral neck	0.60	0.76	0.91	0.11	0.36	0.70	0.90	0.13	0.53	0.67	0.92	0.12

Table 2. Manufacturer's and our charts of T-score conversion for lumbar spine according to T-score of heel bone detected by QUS (Sahara)

	Manufacturer's conversion	Our conversion
Group 1(53-57 yrs)	T-score (lumbar spine)= T-score (Sahara) – 0.75	T-score (lumbar spine)= 0.50xT-score (Sahara) – 0.67
Group 2 (58-67 yrs)	T-score (lumbar spine)= T-score (Sahara) – 0.85	T-score (lumbar spine)= 0.62xT-score (Sahara) – 1.1
Group 3 (>68 yrs)	T-score (lumbar spine)= T-score (Sahara) – 1.0	T-score (lumbar spine)= 0.46xT-score (Sahara) – 1.2

Student's t-test was used to test for differences associated with BMD of the right and left heel bone. Analyses were made using Statistica for Windows 5.0.

Results

The subjects were divided into three age groups, as proposed by the manufacturer. The values of the predominant leg were used on calculations, because statistical analysis yielded no statistically significant differences in BMD values between the right and left calcaneus.

In each group the minimum, maximum, mean and st. dev. SD of BMD values for the calcaneus, lumbar spine (L1-L4) and specific sites of proximal femur were calculated. Overall results are presented in Table 1.

Group 1 included ten women aged 53-57 years. According to the manufacturer's conversion chart for this age group, T-score in lumbar spine is obtained by the equation:

T-score (lumbar spine) = T-score (calcaneus) – 0.75.

In this study, we found that the correlation between these two parameters could be expressed by the following equation (Table 2):

T-score (lumbar spine) = 0.5xT-score (calcaneus) – 0.67.

For calcaneal BMD the best correlation was found with Ward's triangle, however, without statistical significance (R=0.63; p>0.05, where R=index of correlation), as shown in Table 3.

Table 3. Indices of correlation between heel bone BMD and BMD of lumbar spine and proximal femur

	R	p
Group 1, Ward's triangle	0.63	>0.05
Group 2, Total	0.72	0.0007
Group 2, Intertrochanteric area	0.719	0.0008
Group 3, Total	0.53	>0.05

In group 2 there were 30 women aged 58-67 years. According to the manufacturer's conversion chart for this age group, T-score in lumbar spine is obtained by the equation:

T-score (lumbar spine) = T-score (calcaneus) – 0.85.

In this study, we found that the correlation between these two parameters could be represented by the following equation (Table 2):

T-score (lumbar spine) = 0.62xT-score (calcaneus) – 1.1.

For calcaneal BMD the best correlation was found with total femoral BMD (R=0.72) and intertrochanteric area (R=0.719), and these both were statistically significant (p1=0.0007, p1<0.001; p2=0.0008, p2<0.001), as shown in Table 3.

Group 3 comprised 18 women aged >68 years. According to the manufacturer's conversion chart for this age group, T-score in lumbar spine is obtained by the equation:

T-score (lumbar spine) = T-score (calcaneus) – 1.0.

In this study, we found that the correlation between these two parameters could be represented by the following equation (Table 2):

T-score (lumbar spine) = 0.46xT-score (calcaneus) – 1.2.

For calcaneal BMD the best correlation was found with total femoral BMD and intertrochanteric area BMD, however, without statistical significance (R1=0.53; R2=0.51; p>0.05), as shown in Table 3.

There was no significant correlation between any of the calculated BMD values (calcaneus, lumbar spine and proximal femur) and age, body weight or body height.

Discussion and Conclusion

Ultrasound densitometry is a new diagnostic method for bone mineral density measurement. As the calcaneus is mainly composed of trabecular bone (95%), it has been extensively studied for measuring BMD. The fact that the

heel is a weight-bearing bone may be particularly useful in predicting hip fractures[4,7]. Calcaneal ultrasound measurements have been shown to correlate moderately with BMD measurements at the proximal femur[8-10].

The World Health Organization (WHO) criteria[2] classify patients with BMD values more than 2.5 SD below the young adult mean (T-score < -2.5) as having osteoporosis. Patients with BMD values between 1 and 2.5 SD below the young adult mean (T-score between -1.0 and -2.5) are classified as having osteopenia. Various studies demonstrate that the WHO criteria for osteoporosis (T-score <-2.5) that were established for hip and spine, seem questionable when measurements are made at a peripheral site, although the predictive value of the heel for fracture risk is not in question. Goldstein *et al*.[11] report that in 313 perimenopausal women, 82% of patients with hip DEXA T-score below -2.5 had Sahara T-scores less than -1. Greenspan *et al*. stress discrepancies in osteoporosis prevalence at different skeletal sites, and their impact on the WHO criteria. It is also pointed out that these differences clearly vary with age[12]. A T-score that is measured with ultrasound densitometry must be corrected by using conversion chart recommended by the manufacturer. In our study, we used a new, alternative conversion chart for lumbar spine T-score according to age group, as suggested by the manufacturer.

Despite the differences in both conversion charts, when T-score calculated on ultrasound densitometry is equal or below –1, it yield a final T- score of lumbar spine between -1 and -2.5, which is according to the WHO diagnosed as osteopenia. This makes ultrasound densitometry an excellent screening method for identifying the patients at risk of fracture, however, in our opinion, ultrasound densitometry and its outputs (BMD and T-score) still cannot be used as the only diagnostic tool for making the diagnosis of osteoporosis. We think that further diagnostic methods should be recommended for patients with T-score equal or below -1 on ultrasound densitometry.

In our investigation the best correlation, if total femoral BMD is excluded, was found with intertrochanteric area of the proximal femur, and if we consider that hip fracture is the most serious consequence of osteoporosis, it is another fact adding importance to ultrasound densitometry.

Its low cost, nonionization and portability make QUS an attractive technology for assessing the risk for osteoporotic fractures in a larger population than may be suitable or feasible for bone densitometry. Additional investigations to assess innovative QUS techniques in well-defined research settings are important to determine and utilize the full potential of this technology for the benefit of early detection and monitoring of osteoporosis.

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Sažetak

KORELACIJA KOŠTANE MINERALNE GUSTOĆE MJERENE KVALITATIVNIM ULTRAZVUKOM I DVOENERGETSKOM RENDGENSKOM APSORPCIOMETRIJOM

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Osteoporoza je sistemska skeletna bolest obilježena malom koštanom masom i mikroarhitektonskim pogoršanjem koštanoga tkiva, s posljedičnim porastom krhkosti kostiju i sklonosti za prijelome. Koštana mineralna gustoća (BMD) je važan čimbenik koji određuje rizik od prijeloma. Ispitivanje je provedeno u 58 zdravih žena u postmenopauzi, u dobi od 53 do 91 godine. Ispitanice su bile podijeljene u tri dobne skupine. BMD petne kosti (kalkaneus) izmjerena kvalitativnim ultrazvukom (QUS) korelirana je s BMD lumbalne kralješnice i proksimalnog femura izmjerenom dvoenergijskom rendgenskom apsorpciometrijom (DEXA). Također su dob i antropometrijski parametri (tjelesna težina i visina) korelirani s vrijednostima BMD za kalkaneus, kralješnicu i proksimalni femur. Izrađena je vlastita tablica za konverziju T-vrijednosti za lumbalnu kralješnicu prema T-vrijednosti za petnu kost izmjerenima pomoću QUS. Najbolja korelacija za BMD kalkaneusa nađena je u 2. skupini (58-67 godina) s ukupnim BMD femura (R=0,72) i intertrohanterskog područja (R=0,719), obje statistički značajne (p1=0,0007, p1<0,001; p2=0,0008, p2<0,001). Nije bilo značajne korelacije između bilo koje izračunate vrijednosti BMD (kalkaneus, lumbarna kralješnica i proksimalni femur) i dobi, tjelesne težine i tjelesne visine. Prema vlastitoj tablici konverzije, kada je T-vrijednost izračunat ultrazvučnom denzitometrijom jednak ili ispod -1, to daje konačnu T-vrijednost za lumbalnu kralješnicu između -1 i -2,5, što se prema kriterijima SZO dijagnosticira kao osteopenija. To čini ultrazvučnu denzitometriju izvrsnom metodom probira za prepoznavanje bolesnika s rizikom od prijeloma.

Ključne riječi: *Gustoća kosti – dijagnostika; Denzitometrija – rendgen; Bolesti kostiju, metaboličke – ultrasonografija; Osteoporoza – dijagnostika*