ORIGINAL ARTICLE

Impact of Adding Distal Forearm Bone Mineral Density Measurement to Axial Bone Mineral Density Measurement for the Diagnosis of Osteoporosis: Prevalence and Risk Factors for Diagnostic Discordance

Waralee Pongwiwattanachai, MD[1,2], Thep Chalermchai, MD, PhD[1]

[1] School of Anti-Aging and Regenerative Medicine, Mae Fah Luang University, Wattana, Bangkok, Thailand; [2] Department of Radiology, Faculty of Medicine, Chiang Mai University, Muang, Chiang Mai, Thailand

Background: Studies have demonstrated the superiority of distal forearm bone mineral density (BMD) measurement over axial BMD measurement for prediction of osteoporotic fractures of distal radius. However, distal forearm BMD measurement is not routinely performed at most centers.

Objective: To demonstrate the prevalence of discordance in diagnosis of osteoporosis using axial and distal forearm BMD measurement, and to assess whether age and other potential risk factors can predict major discordance.

Materials and Methods: Postmenopausal women aged 45 years or older and men aged 50 years or older who underwent lumbar spine, hip, and distal forearm BMD measurement at Prompt Health Center, Faculty of Associated Medical Sciences, Chiang Mai University, Thailand, between January 2021 and December 2021 were recruited. The T-scores of axial site and distal forearm were categorized based on World Health Organization classification to determine the prevalence of diagnostic discordance. Major discordance was defined as having one osteoporotic and one normal T-score. Factors potentially associated with major discordance were explored using univariate and multivariate logistic regression models.

Results: Eight hundred eighty-one participants including 621 women and 260 men with a mean age of 59.2±6.7 years were analyzed. There were 13.2% participants diagnosed with osteoporosis of the axial site, and 16.0% of the one-third (1/3) radius. The rates of major discordance, minor discordance, and concordance between axial and 1/3 radius T-scores were 3.2%, 40.5%, and 56.3%, respectively. Age of 65 years or older was significantly associated with major axial and 1/3 radius T-score discordance, with an adjusted odds ratio of 2.7 and 95% confidence interval 1.24 to 5.87 (p=0.012).

Conclusion: Diagnostic discordance is observed for at least one-third of the participants using axial and distal forearm BMD measurement. The age of 65 years or older is a risk factor for major discordance.

Keywords: Bone mineral density; Osteoporosis; Spine; Hip; Distal forearm; Discordance

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Bone mineral density (BMD) measurement is primarily used for the diagnosis of osteoporosis and the prediction of fracture risk. BMD measurements are expressed as T-scores, which are the number of standard deviation values that vary from the mean BMD for a young adult population. The World Health Organization (WHO) has defined osteoporosis as a T-score of –2.5 or less[1]. The International Society for Clinical Densitometry has recommended BMD measurements at two axial skeletal sites, the lumbar spine and hip. Osteoporosis is diagnosed on the basis of the lowest T-scores for the lumbar spine, total hip, or femoral neck. BMD measurement at the distal forearm, specifically the one-third (1/3) radius, is typically reserved for situations where hip or lumbar spine scores cannot be accurately measured or interpreted. This is particularly relevant in cases involving patients with conditions like hyperparathyroidism or extreme obesity[2]. Therefore, distal forearm BMD measurement is not routinely performed at most centers.

Typical sites of osteoporotic fractures include

Correspondence to:

Chalermchai T.

School of Anti-Aging and Regenerative Medicine, Mae Fah Luang University, 36/87-88 PS Tower 25FI, Asoke Road, Sukhumvit 21, Klong Toey Nua, Wattana, Bangkok 10110, Thailand.

Phone: +66-2-664-4360

Email: thep.cha@mfu.ac.th

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the distal radius, proximal femur, spine, and proximal humerus[3]. Axial BMD measurement is well established as the standard screening tool to estimate the risk of osteoporotic fractures[4]. However, the risk of distal radius fracture can be underestimated when axial BMD measurement is used alone[5]. Studies conducted in the past six years demonstrated the superiority of distal forearm BMD over axial BMD for the assessment of the risk of distal radius fractures[5-8]. Osteoporosis of the distal forearm has been associated with an increased risk of distal radius fractures[5-8], disability[9], and an increased mortality rate[10].

T-score discordance in osteoporosis diagnoses obtained with spine, hip, and distal forearm BMD measurement is a common occurrence[11-18]. Discordance in the diagnosis of osteoporosis is defined when dissimilar categories of T-scores as osteoporosis, osteopenia, or normal, are obtained for two different skeletal sites. Major discordance signifies one osteoporotic and one normal T-score. Minor discordance signifies one osteopenic and one normal T-score and/or one osteopenic and one osteoporotic T-score. Concordance is defined when identical scores are obtained for both sites[19]. Spine-hip T-score discordance was found to be significantly higher in elderly patients[14,16,20,21]. Various risk factors associated with discordance in osteoporosis diagnoses obtained using spine and hip BMD have been reported[13,20-23]. However, until now, the risk factors for discordance in diagnoses obtained using axial and distal forearm BMD has not been reported.

Although most centers commonly perform axial BMD measurement with the inclusion of distal forearm BMD measurement in certain circumstances, all patients in the present study health checkup program routinely undergo distal forearm BMD measurement along with standard axial BMD measurement. The aims of the present study were to demonstrate the prevalence of discordance in diagnosis of osteoporosis using axial and distal forearm BMD, and to assess whether age and other potential risk factors could predict major discordance.

Materials and Methods

Study population

The present study was a retrospective, descriptive, cross-sectional analytical study. Data for patients who participated in the health checkup program, which included BMD measurement of the lumbar spine, hip, and distal forearm, between January 2021 and December 2021 at the Prompt Health Center, Associated Medical Science Clinical Service Center, Chiang Mai University were collected and analyzed according to the selection criteria. The eligible participants were men aged 50 years or older and postmenopausal women. In the present study, postmenopausal women were defined as those aged 45 years or older and experienced at least 12 consecutive months without menstruation in the absence of any medications that could be the cause. The exclusion criteria were uncertain menopausal age, known treated osteoporosis, and underlying hyperparathyroidism.

One thousand twenty-three patients underwent lumbar spine, hip, and distal forearm BMD measurement. One hundred eight patients including 90 premenopausal women and 18 men aged younger than 50 years did not meet the eligibility criteria. Another 34 patients were excluded because 20 had previously been treated for osteoporosis and 14 had uncertain menopausal age. Underlying hyperparathyroidism was not observed in any patient. Eventually, 881 participants, including 621 women and 260 men were recruited. The mean age was 59.2, with a range of 87 to 45 years.

The present study protocol was approved by the Ethics Committee on Human Research of Mae Fah Luang University (study code: EC22109-20). The requirement for consent was waived because of the retrospective nature of the study.

Data collection

BMD measurement questionnaires and physician request forms were analyzed. Face-to-face questionnaires were administered by a technician who individually questioned each patient before the tests. Data on age, gender, body mass index (BMI), underlying hyperparathyroidism, history of osteoporotic treatment, prior fracture, parental hip fracture, steroid administration, menopausal status, and age at menopause were collected. BMI was calculated as weight (kg) divided by height squared (m^2). Height and weight were measured with the patients wearing a light hospital gown without shoes.

Bone mineral density measurement and interpretation

All patients were advised to stop taking calcium supplements for 24 hours before BMD measurement. The schedules were postponed for 7 to 10 days if the patient had a recent history of oral or intravenous contrast administration or nuclear

Table 1. Characteristics of the study population

Clinical data	Total (n=881)	Male (n=260)	Female (n=621)
Age (years); mean±SD	59.2±6.7	59.2±6.5	59.2±6.8
Age ≥65 years; n (%)	176 (20.0)	50 (19.2)	126 (20.2)
BMI (kg/m^2); mean±SD	24.0±3.7	24.6±3.8	23.7±3.6
BMI ≥30 kg/m^2; n (%)	54 (6.1)	19 (7.3)	35 (5.6)
BMI <18 kg/m^2; n (%)	23 (2.6)	8 (3.1)	15 (2.4)
Lumbar spine BMD (g/cm^2); mean±SD	1.016±0.2	1.095±0.2	0.983±0.2
Femoral neck BMD (g/cm^2); mean±SD	0.832±0.1	0.906±0.1	0.801±0.1
Total hip BMD (g/cm^2); mean±SD	0.885±0.2	0.958±0.1	0.855±0.3
One-third radius BMD (g/cm^2); mean±SD	0.772±0.1	0.901±0.0	0.717±0.1
Steroid use; n (%)	6 (0.7)	1 (0.4)	5 (0.8)
History of fracture; n (%)	12 (1.4)	-	12 (1.9)
History of parental hip fracture; n (%)	9 (1.0)	-	9 (1.4)
Age at menopause (years); mean±SD	-	-	49.8±4.0
Age at menopause <45 years; n (%)	-	-	54 (6.1)
Duration of since menopause (years); mean±SD	-	-	9.35±7.3
Menopause for ≥10 years; n (%)	-	-	254 (40.9)

BMI=body mass index; BMD=bone mineral density; SD=standard deviation

medicine procedures. Before the tests, the patients were instructed to change into a hospital gown, take off their shoes, and remove brassiere, jewelry, and metallic objects.

BMD was measured using a dual-energy X-ray absorptiometry device (Lunar DPX NT, GE Healthcare Lunar, Madison, MI, USA) by an experienced technician. The machine was calibrated daily using a standard phantom provided by the manufacturer (GE). BMD measurement was performed at the lumbar spine with a posteroanterior projection at L1-L4, left hip for the femoral neck and total hip, and non-dominant distal forearm for 1/3 radius. In cases of deformities or metallic implants over the left hip or non-dominant distal forearm, the right hip or dominant distal forearm was used for data analysis. Normative BMD values of the lumbar spine, hip, and distal forearm were obtained from the GE Lunar Asian Reference for comparison.

Based on the WHO classification, the T-scores for the lumbar spine (total L1-L4), hip (lowest T-score of the femoral neck and total hip), 1/3 radius, and axial site (lowest T-score for the lumbar spine, femoral neck, and total hip) were interpreted as osteoporosis (T-score of –2.5 or less), osteopenia (T-score between –1 and –2.5), and normal (T-score of –1 or greater).

Statistical analyses

Rates of major discordance, minor discordance, and concordance between axial-1/3 radius T-scores were calculated and presented in number and percent. To identify potential risk factors in participants with major discordance compared to the reference group, which included the minor discordance and concordance groups, multivariate backward stepwise logistic regression analyses were performed for variables with a p-value of less than 0.05 in univariate analysis. Crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were determined. All statistical analyses were performed using the IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA).

Results

Clinical characteristics of the study population

The characteristics of the 881 participants are presented in Table 1.

Classification of T-scores based on the WHO criteria

Fifty-three (6.0%), 87 (9.9%), 116 (13.2%), and 141 (16.0%) of the participants were diagnosed with osteoporosis of the hip, lumbar spine, axial site, and 1/3 radius. T-score classifications for men and women are shown in Table 2.

Diagnostic discordances based on the WHO criteria

Major discordance in the axial-1/3 radius T-scores was observed in 28 (3.2%) of the participants. The distribution of diagnostic discordance according to gender is presented in Table 3.

Table 2. Classification of T-scores based on the WHO criteria for the lumbar spine, hip, axial site, and 1/3 radius according to sex

Location	Total (n=881); n (%)			Male (n=260); n (%)			Female (n=621); n (%)		
	OP	ON	NM	OP	ON	NM	OP	ON	NM
Spine	87 (9.9)	333 (37.8)	461 (52.3)	15 (5.8)	65 (25.0)	180 (69.2)	72 (11.6)	268 (43.2)	281 (45.2)
Hip	53 (6.0)	399 (45.3)	429 (48.7)	9 (3.5)	95 (36.5)	156 (60.0)	44 (7.1)	304 (48.9)	273 (44.0)
Axial	116 (13.2)	439 (49.8)	326 (37.0)	22 (8.5)	109 (41.9)	129 (49.6)	94 (15.2)	330 (53.1)	197 (31.7)
1/3 radius	141 (16.0)	282 (32.0)	458 (52.0)	27 (10.4)	78 (30.0)	155 (59.6)	114 (18.4)	204 (32.8)	303 (48.8)

OP=osteoporosis; ON=osteopenia; NM=normal

Table 3. Distribution of diagnostic discordances based on the WHO criteria according to sex

Diagnostic site	Total (n=881); n (%)	Male (n=260); n (%)	Female (n=621); n (%)
Major discordance	28 (3.2)	7 (2.7)	21 (3.4)
Axial (osteoporosis), 1/3 radius (normal)	22 (2.5)	6 (2.3)	16 (2.6)
1/3 radius (osteoporosis), axial (normal)	6 (0.7)	1 (0.4)	5 (0.8)
Minor discordance	357 (40.5)	93 (35.8)	264 (42.5)
Axial (osteoporosis), 1/3 radius (osteopenia)	36 (4.1)	6 (2.3)	30 (4.8)
1/3 radius (osteoporosis), axial (osteopenia)	77 (8.7)	16 (6.2)	61 (9.8)
Axial (osteopenia), 1/3 radius (normal)	180 (20.4)	46 (17.7)	134 (21.6)
1/3 radius (osteopenia), axial (normal)	64 (7.3)	25 (9.6)	39 (6.3)
Concordance	496 (56.3)	160 (61.5)	336 (54.1)
Axial (osteoporosis), 1/3 radius (osteoporosis)	58 (6.6)	10 (3.8)	48 (7.7)
Axial (osteopenia), 1/3 radius (osteopenia)	182 (20.7)	47 (18.1)	135 (21.7)
Axial (normal), 1/3 radius (normal)	256 (29.1)	103 (39.6)	153 (24.6)

Table 4. Univariate and multivariate logistic regression analyses for risk factors for major discordance in T-scores between axial site and 1/3 radius

Clinical risk factors for major discordance	Adjusted OR	95% CI	p-value
Age ≥65 years	2.70	1.24 to 5.87	0.012*
Female sex	1.27	0.53 to 3.01	0.596
BMI <18 kg/m^2	3.05	0.68 to 3.88	0.146
History of fracture	4.91	0.98 to 13.7	0.052
Early menopause at <45 years of age	1.10	0.32 to 3.82	0.882
Menopause for ≥10 years	1.62	0.68 to 13.7	0.146

BMI=body mass index; OR=odds ratio; CI=confidence interval
* Significant factor ($p<0.05$) by multivariate data analysis

Risk factors for diagnostic major discordance based on univariate and multivariate logistic regression analyses

In univariate and multivariate analyses (Table 4), age of 65 years or older was significantly associated with major discordance in axial-1/3 radius T-scores. Other factors including gender, BMI of 30 kg/m^2 or more, and less than 18 kg/m^2, history of fracture and parental hip fracture, steroid use, age at menopause, early menopause at younger than 45 years of age, and menopause for 10 years or longer, were not associated with major discordance. No other risk factors were found for major discordance in axial-1/3 radius T-scores.

Discussion

Diagnostic discordances among axial and distal forearm BMD were common in the present study. Minor axial-1/3 radius T-score discordance was observed for 40.5% of the participants. Major discordance was rarely observed, with a rate of 3.2% for axial-1/3 radius T-scores. These results are in accordance with those of published studies that demonstrated the prevalence of minor discordance in 17.6% to 40% of the participants examined using axial site and distal forearm BMD. Less than 5% of the patients showed major T-score discordance between axial site and distal forearm BMD[17,18]. As the presence of discordance is commonly observed and can affect the diagnosis and therapeutic plan for an individual, clinicians should consider performing distal forearm BMD measurement in combination with axial BMD measurement.

Although major discordance is rare, this phenomenon significantly affects treatment decisions. The authors explored the various risk factors for major discordance using a multivariate regression model. Only age of 65 years or older was significantly

associated with major discordance in axial-1/3 radius T-scores. Differences in ageing-related bone loss among the various bones in the body and the proportion of cortical and cancellous bones may play an important role[16,24]. The cancellous bone is located mostly in the axial skeleton, such as the vertebrae and pelvis. The cortical bone is located in the appendicular skeleton, particularly in the diaphysis of the long bones such as the 1/3 radius[25]. Spine-hip T-score discordance is significantly higher in the elderly than in the young population[20,21,26]. In women aged 50 to 60 years, T-scores for the lumbar spine are mostly lower than T-scores for the hip, mainly because of earlier loss and a higher turnover rate for the cancellous bone[13]. However, a higher T-score for the spine than for the hip is commonly found in older patients, or patients older than 70 years, and typically caused by degenerative changes[21,22]. Accelerated bone loss in the distal forearm occurs after the age of 65 years accounts for 84% of the total bone loss in the distal forearm in women aged 50 to 85 years[27].

The discordance among spine, hip, and distal forearm T-scores may be related to multiple factors, such as physiological and pathophysiological causes, artifacts, and technical problems in measurement. Discordance due to the skeleton's natural adaptive reaction to forces, including those due to being overweight, is considered physiological discordance. Discordance due to degenerative changes such as vertebral osteophytosis, endplate sclerosis, and aortic calcification, which lead to erroneously high T-scores for the spine, is considered pathophysiological discordance. Discordance due to the presence of dense metals within the region of interest is considered artifact-related discordance. Finally, discordance due to errors in devices, variability among technicians, and patient movement is considered technical discordance[11]. Studies have reported several diseases related to lower distal forearm T-scores, such as hyperparathyroidism, chronic kidney disease, and celiac disease[28-30]. Menopause, premature ovarian insufficiency, and multiparity have also been suggested as factors affecting diagnostic discordance[12,15,20,23].

This retrospective study has limitations. First, the effect of distal forearm BMD measurement on fracture risk assessment, which is the main purpose of performing BMD measurement, could not be demonstrated because of the retrospective study design with an inadequate number of participants with a history of fracture. Second, potential risk factors for diagnostic discordance, which were not included in the BMD measurement questionnaires, could not be explored. Third, risk factors collected through participant interviews may have been influenced by recall bias or the participants' educational level and knowledge. Fourth, the present study was a single-center study, and the generalizability of the results to a larger population is limited.

As the primary objective of BMD measurement is to assess the risk of fracture, further studies with long-term follow-up designs are needed to determine the impact of including distal forearm BMD along with axial BMD on the accuracy of predicting fragility fractures. Furthermore, future studies employing robust statistical analyses and larger sample sizes are necessary to identify additional potential risk factors for discordance in T-score categories.

In summary, diagnostic discordance is observed for at least one-third of the participants underwent axial and distal forearm BMD measurement. Age ≥65 years is identified as a risk factor for major discordance. The integration of distal forearm BMD measurement with axial BMD measurement should be considered.

What is already known on this topic?

BMD measurement is primarily used for the diagnosis of osteoporosis and the prediction of fracture risk. Studies have demonstrated the superiority of distal forearm BMD over axial BMD for prediction of osteoporotic fractures of distal radius. However, distal forearm BMD measurement is not routinely performed. The prevalence and the risk factors of discordance in diagnosis of osteoporosis using axial and distal forearm BMD should be determined.

What does this study add?

Diagnostic discordance among lumbar spine, hip, and forearm BMD is common.

The rates of major discordance and minor discordance between axial and 1/3 radius T-scores were 3.2% and 40.5%, respectively.

The age of 65 years or older was a risk factor for major discordance.

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Authors' contributions

All authors participated in the present study conceptualization, data collection, data analysis, interpretation, and drafting of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

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