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Original Article

In Vivo Intrarater and Interrater Precision of Measuring Apparent Bone Mineral Density in Vertebral Subregions Using Supine Lateral Dual-Energy X-Ray Absorptiometry

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Abstract

Analysis of apparent bone mineral density (BMD) in the lumbar spine is commonly based on anteroposterior (AP) scanning using dual-energy X-ray absorptiometry (DXA). Although not widely used, clinically important information can also be derived from lateral scanning. Vertebral bone density, and therefore strength, can may vary in different subregions of the vertebral body. Therefore, subregional BMD measurements might be informative about fracture risk. However, the intrarater and interrater precision of in vivo subregional BMD assessments from lateral DXA remains unknown. Ten normal, young (mean: 24 yr) and 10 older (mean: 63 yr) individuals with low BMD were scanned on one occasion using an AP/lateral sequence. Each lateral scan was reanalyzed six times at L2 by three raters to determine the intrarater and interrater precision in selecting seven regions of interest (subregions). Precision was expressed using percentage coefficients of variation (% CV) and intraclass correlation coefficients (ICC). Intrarater precision ranged from ICC(1,1) 0.971 to 0.996 (% CV: 0.50–3.68) for the young cohort and ICC(1,1) 0.934 to 0.993 (% CV: 1.46–5.30) for the older cohort. Interrater precision ranged from ICC(2,1) 0.804 to 0.915 (% CV: 1.11–2.35) for the young cohort and ICC(2,1) 0.912 to 0.984 (% CV: 1.85–4.32) for the older cohort. Scanning a subgroup of participants twice with repositioning was used to assess short-term in vivo precision. At L2, short-term in vivo precision ranged from ICC(1,1) 0.867 to 0.962 (% CV: 3.38–9.61), at L3 from ICC(1,1) 0.961 to 0.988 (% CV: 2.02–5.57) and using an L2/L3 combination from ICC(1,1) 0.942 to 0.980 (% CV: 2.04–4.61). This study demonstrated moderate to high precision for subregional analysis of apparent BMD in the lumbar spine using lateral DXA in vivo.

Key Words: Bone mineral density (BMD); lumbar spine; subregion; precision; lateral DXA.

Introduction

Authorities on bone mineral measurement and osteoporosis recognize dual-energy X-ray absorptiometry (DXA) as the most effective method to measure apparent bone mineral density (BMD) of the lumbar spine *(1–3).* This choice reflects the high precision, accuracy, efficiency, and low radiation dosage associated with DXA *(4).* It is essential that results provided by densitometers have high precision, as important decisions about the management of patients with bone diseases are based on the derived BMD results.

Improvement in risk prediction of osteoporotic vertebral fracture using DXA would be of great benefit given the significant morbidity and mortality associated with these fractures *(5,6).* Interestingly, the prevalence of osteoporotic vertebral fracture can differ markedly among individuals with comparable BMD of the lumbar spine measured with anteroposterior/postero-anterior (AP/PA) DXA, which might suggest a lack of sensitivity and specificity with this approach

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(7–11). Results from ex vivo studies of human lumbar spine bone mineral suggest that variance exists in BMD between different subregions of trabecular bone within the vertebral centrum *(12–18).* This phenomenon might help to explain why some individuals with diagnosed osteoporosis sustain a vertebral fracture, whereas while others remain free of vertebral fracture. Deriving results of BMD using the sagittal area of the whole vertebral body disregards any variance in subregional BMD (srBMD) and clinically important information might be overlooked. Analysis of srBMD has not been investigated in a clinical population using a clinical tool. Measurement of areal srBMD might assist in monitoring the efficacy of pharmacotherapies and in more accurately identifying those individuals who are at a higher risk of sustaining an osteoporotic vertebral fracture. To be used in these contexts, the precision of srBMD analysis using DXA must first be analyzed and this parameter optimized before potential applications of the technique can be explored adequately.

With advancements in densitometry technology, supine lateral scans of the lumbar spine are possible. Precision errors associated with previously used decubitus lateral scans were unacceptably high, discouraging the use of that technique. Precision of the supine lateral technique is far superior to the decubitus method because difficulties with patient repositioning are minimized *(19)*. The advantage of performing a lateral scan over an AP or PA is that the posterior elements of the vertebra are removed from the analysis of the vertebral body, thereby avoiding the overriding influence of these structures on apparent density measurements *(2,20,21).* Lateral scans are also less affected by degenerative spinal diseases and aortic calcification *(21–23).* The results derived from a lateral scan more accurately represent the density of the metabolically active trabecular bone in the vertebral body. Research has shown that the diagnostic sensitivity of lateral DXA scans is greater than that derived with AP alone, therefore justifying their use in a clinical setting *(4,20,21,24,25).* This approach has the potential to increase the sensitivity to differentiate normal patients from those with osteoporosis. However, the clinical utility of lateral DXA could be compromised by the greater precision errors, longer scanning time, and greater radiation dosage compared to conventional AP scans *(3,4,26)*. In addition, T-scores derived from lateral DXA cannot be interpreted with World Health Organization (WHO) guidelines, as they do not consistently agree with AP spine and hip scores. However, as the clinical utility, accuracy, and precision of lateral DXA are explored further and more extensive normative data established, WHO guidelines might be expanded.

Dual-energy X-ray absorptiometry has been used for many years to measure areal BMD in the hip and spine with sufficient precision. Precision associated with srBMD analysis in the lumbar spine remains unknown. The aim of this study was to evaluate the intrarater and interrater precision of subregional analysis in the lumbar spine from lateral DXA scans. The short-term precision for the entire protocol was also evaluated.

Materials and Methods

Subjects

Ten (nine female, one male) healthy, young participants were recruited (mean age: 23.7 yr; SD: 5.4 yr). A second cohort of 10 elderly (mean age: 69.9 yr; SD: 6.0 yr) female participants with low BMD was also recruited to determine the combined effect of age and bone and joint disease on precision. Participants in both cohorts were not taking any medications known to affect bone metabolism for a period of greater than 6 mo. All subjects provided written informed consent. These studies were approved by the Human Research Ethics Committees of Melbourne Health and the University of Melbourne.

Procedure

Scanning

An Hologic QDR4500A fan-beam densitometer (Hologic Inc., Waltham, MA, USA) with operating system software version 9.10D was used for scanning. A combined lumbar AP/lateral scan was performed on each subject using the recommended patient positioning and scanning mode *(27).*

Subregional Analysis

Apparent areal BMD from the lateral scan was calculated for the whole L2 vertebral body area (defined as region of interest [ROI] 1) and in six subregions (ROI 2–7). Subregions were selected manually by changing the regions of interest during the analysis phase of the scanning process, using Hologic analysis software version 8.26f:3. The whole vertebral area (ROI 1) was defined by the four corners of the vertebral body from the lateral DXA image, including the vertebral end plate. Subregions 2 to 4 formed equal thirds in the area of ROI 1, orientated vertically. Subregions 5 to 7 formed equal thirds in area of ROI 1, orientated horizontally. The subregions are illustrated in Fig. 1.

Data Analysis

To determine intrarater precision of selecting subregions, reanalysis of each scan was performed on six consecutive occasions, 1 wk apart, by three independent and blinded investigators. Each investigator had experience using the Hologic software and performing DXA scans. Prior to each reanalysis, the unanalyzed scan data were restored from a data file and displayed to ensure that the investigator was blinded to the bone map and selected ROIs from prior analyses. The intrarater precision for selecting the vertebral subregions was expressed as the percentage co-efficient of variation (% CV). Additionally, a one-way random effects model intraclass correlation coefficient ICC(1,1) with a 95% confidence interval (95% CI) was calculated to reflect both agreement and correspondence among the six repeated measures for each rater in each cohort. Interrater precision was expressed using a two-way random effects model ICC(2,1) based on a single analysis for each rater in each subregion. All data were analyzed using SPSS version 11.5.0 for Windows (SPSS Inc., Chicago, IL, USA).