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EDITORIAL

Lateral Dual X-ray Absorptiometry of the Lumbar Spine: Current Status

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Introduction

Dual X-ray absorptiometry(DXA) is a widely accepted method for the in vivo assessment of bone mineral density (BMD).[5,12,17,20] The spine is generally the preferred site for measurements of BMD, and examinations are routinely performed in the posteroanterior (PA) projection. However, owing to its nature as a projectional technique the PA scan of the lumbar spine includes not only the metabolically active trabecular bone of the vertebral body but also a substantial amount of cortical bone, particularly in the posterior elements. Degenerative and hypertrophic changes in the spine (e.g., osteoarthritis of the articular facets, hyperthrophy of the spinous processes, and degenerative sclerosis of the end plates) may falsely increase BMD as measured by PA DXA.[6,15,26,38] DXA of the lumbar spine in the lateral projection was used by several authors shortly after the inception of DXA.[9,18,27,28,31,35] Compared to the PA DXA measurement, lateral measurement allows for an exclusive evaluation of BMD of the vertebral body, and thus for measurement of a proportionally greater amount of trabecular bone.

The early standard DXA densitometers used a fixed tube-detector system. To study the spine in the lateral projection, the subject has to be positioned in the lateral decubitus. This repositioning of the patient is quite difficult, and even using special positioning devices and a belly belt, the lateral decubitus position is unreliable. Since scanning had to be started anew, the assignment of vertebral levels is difficult on the lateral scans, because the anatomical landmarks are more variable or less distinguishable than on standard PA scans. Aside from the obvious implications for the reproducibility, from a sheer practical point of view and compared to other DXA measurements of other anatomical locations, lateral decubitus DXA is not as simple to perform. Furthermore, it is more time-consuming, even more so considering that the examination time with the early densitometers was 10–15 min/scan. Thus, lateral scanning has never found widespread acceptance in clinical practice.

With the introduction of DXA densitometers using a C-arm design that allows for a 90° rotation of the tube detector system around the person scanned, lateral DXA became more easy to perform.[32] With these devices, the patient may remain in supine position, and the technician has only to move the C arm into the right position for lateral supine scanning. Another innovation, the fan beam and detector array design of these scanners, reduced acquisition time for the scan by a factor of ten or more in comparison to its predecessors,[20] and with lateral scans being easier to perform, interest in this technique has grown.

As mentioned before, the rationale for assessing BMD of lumbar spine in the lateral projection is the ability to measure mostly trabecular bone in the vertebral body. Thus, in comparison to standard PA DXA, lateral BMD should provide better correlation with compressive strength, stronger association with age, a better discrimination between osteoporotic and nonosteoporotic persons, and more rapid-response therapeutic interventions.

Several researchers have studied the correlation between lateral BMD of lumbar vertebrae and biomechanical parameters. Wilson et al.[37] found similar correlation coefficients for both PA and lateral BMD with compressive strength. These authors also reported a good correlation between the vertebral body bone mass and the bone mass of the posterior elements. These results are in contrast to those of Myers et al.,[24] who found that lateral BMD correlated significantly better with the compressive strength of vertebral bodies than did PA BMD ($r^2 = 0.615$ and $r^2 = 0.444$, respectively). In this study, the authors reported that there was no correlation between bone mineral contained in the posterior elements and PA BMD. Bjarnason et al.[2] performed the bone density measurements initially in situ before excising the vertebral bodies and measuring bone density again, and then performing biomechanical testing. They actually found that lateral BMD measured in situ correlated less well with compressive strength than did PA BMD, while after excision lateral BMD correlated better with compressive strength than did PA BMD. The authors assumed that the latter results may have been largely influenced by the effect of overlying soft tissue on the accuracy of the lateral measurement. In these three studies, biomechanical testing was performed on single vertebrae. Only Moro et al.[23] used complete motion segments (T10–12 or L1–3) for compression testing. Bone density was only measured for L-2, and both PA and lateral L-2 BMD correlated significantly with the compressive strengths of both target vertebrae (T-11 and L-2). In contrast to the study by Myers et al., the authors did not find significant differences between lateral and PA BMD in the prediction of compressive strength. The authors concluded that the number of vertebrae studied may have been too small to

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Table 1. Discrimination between fractured and nonfractured women using posteroanterior (PA) and lateral DXA of the lumbar spine as found in various studies

	PA BMD		Lateral BMD	
Authors	% difference	z score	% difference	z score
Uebelhart et al.[35]	−22.8	−1.6	−27.8	−0.88
Slosman et al.[31]	−15.9	−0.83	−23.0	−0.61
Peel et al.[25]	−23.0	−1.47	−34.3	−1.33
Duboeuf et al.[7]	−9	−0.66	−21	−1.08
Guglielmi et al.[13]	−16.8	−0.99	−24.7	−1.01
Bjarnason et al.[3]	−16	−0.80	−17.4	−0.65
Yu et al.[39]	−8.02	−0.5	−10.9	−0.79

Data are given as percent difference between the means, as well as the respective z scores. Guglielmi et al.[13] and Yu et al.[39] performed ROC analyses and found significant differences between PA and lateral BMD.

observe a significant difference between bone density in the two projections. The latter two studies also prove that in vitro, the compressive strength of a vertebra not studied directly by DXA may be predicted by BMD of another vertebra. In all studies there seems to be a trend that lateral BMD is associated somewhat stronger with compressive strength than is PA BMD. In most studies this difference is marginal. However, there is no consistent methodology which makes the variable results hard to compare.

Similarly, there have been controversial results when looking at in vivo studies to assess the association between lateral DXA and prevalent vertebral fractures. In a number of studies of supine lateral DXA, a stronger association between lateral DXA and prevalent vertebral fractures has been observed (**Table 1**).[7,13,39] In particular, studies using the lateral decubitus position for measuring lateral BMD and/or a limited number of vertebrae (L-2 and L-3, or L-3 only) have not found significant differences between fractured and nonfractured patients. As can be seen from Table 1, the differences between PA and lateral BMD for fractured and nonfractured patients are sometimes quite substantial when looking at the percentage difference. However, using the z-score that takes into account the standard deviation of the nonfractured patients, this difference often becomes negligible. However, it is a disadvantage of the z score in that it only takes the standard deviation of the normal population into account, and only a few authors have used additional tests or more advanced statistical methodology such as receiver operating characteristics (ROC) analyses or age-adjusted logistic regression analyses to test the hypothesis that lateral DXA is more strongly associated with prevalent vertebral fractures than is PA DXA. Another drawback of comparing the results from different studies becomes obvious when looking at the numbers given. There is considerable variation in the results indicating differences in the selection of patients or the application of different methods for vertebral fracture definition. For example, some authors have also included premenopausal women in the nonfractured cohort, while others have used age-matched controls. Nevertheless, comparing the two methods in terms of the z scores, one can see that the differences between PA and lateral DXA are relatively small, and they may be negligible in clinical practice. To date, there are no prospective studies relating lateral DXA to fracture occurrence.

Consistent in a number of studies has been the finding that age is more strongly correlated with lateral BMD than with PA BMD. The decrease in lateral BMD with age in postmenopausal women was found to be between 50 and 80% greater than that of PA BMD.[7,9,13,25,28,31,35] Mazess and colleagues[21] recently reported an annual decline in bone mass of 1.4% for lateral BMD, 0.6% for PA BMD, and between 0.3 and 1.1% for various subregions of the proximal femur in women between ages 50 and 80. Formica and colleagues[10] recently studied the body composition used for the soft-tissue baseline of DXA scans and compared it to the composition over the measured bone. They found that there was substantial inhomogeneity in fat distribution, especially for the lateral spine scan. In the latter study, the difference in bone mass between PA and lateral BMD in the elderly could be fully explained by the difference in percent fat in the respective soft-tissue regions.

Reid et al.[27] studied lateral DXA in women receiving long-term glucocorticoid treatment in a cross-sectional fashion. In terms of z scores, lateral BMDs were significantly lower than PA BMDs (−1.42 vs. −0.91). A larger number of patients were categorized osteopenic on the basis of lateral BMD than on the basis of PA BMD (19 vs. 12 patients). Thus, the reduction in bone mass was relatively enhanced for lateral BMD compared to PA BMD. Similar results were reported by Finkelstein et al.,[9] who observed a decrease of 33% by lateral BMD compared to 21% by PA BMD in 30 glucocorticoid-treated women using a comparison to the manufacturer's normal population. Blake and colleagues recently published first results from a longitudinal study with 152 women enrolled in a clinical trial of cyclical etidronate therapy.[1] The authors found that the treatment effect was larger for lateral DXA than for PA DXA. However, the advantage of lateral DXA was offset by the greater precision error of this method.

For longitudinal measurements, the precision of a given technique and also the rate of bone loss to be expected at the site measured have to be considered. The stronger association of lateral BMD with age as well as with glucocorticoid therapy in comparison to standard PA BMD makes lateral DXA an attractive method for monitoring bone loss or bone gain in patients using drugs known to affect bone mineral metabolism. However, as indicated above, the precision of lateral DXA measurements has not always been found to be that favorable, especially with patients being measured in the lateral decubitus position.[4,7,16] Reports of the in vivo precision error for measurements in the lateral decubitus position vary between 1.6 and 6.8%.[18,22,28,31,35] The precision error of lateral BMD obtained with the patient in supine position are reportedly between 1.2 and 2% for measurements, including multiple vertebral levels. Precision errors, especially for the levels L-2 and L-4, are somewhat higher when single vertebral levels are measured (Table 1).[16] Besides the effect that is introduced by the sampling of more data when multiple levels are measured, the improvement in the precision error for multiple levels is in part due to the soft-tissue baseline that is averaged and to the "baseline compensation" one of the manufacturers (Hologics, Waltham, MA) applies to the scan data.[36] Blake and colleagues[4] found the precision of lateral BMD measurements without baseline compensation to be worse than with baseline compensation (e.g., 1.2 vs. 2.11% for L2–4, 1.81 vs. 2.72% for L-3 only). The effects of baseline compensation on the variation of serial measurements have to be further studied. At present, the precision error of the so-called vertebral midregions, smaller subregions in the central part of the vertebral body containing mainly trabecular bone, still seems too high to ensure a reliable serial assessment of bone density (**Table 2**).

The comparison of these precision figures is somewhat problematic owing to the different ways the authors of the studies calculate their precision errors, and maybe even more because the techniques vary sometimes between the studies with respect to the number of vertebrae included. Because of the overlap of

Table 2. Short-term precision errors (root mean square average) for BMD measurements as derived from posteroanterior (PA) and lateral DXA measurements in 60 women

		Lateral DXA	
Level	PA-DXA	Entire body	Mid region
L2	1.90	4.76	8.57
L3	1.88	3.27	6.97
L4	1.87	4.86	8.35
L2–3	1.49	2.58	5.03
L3–4	1.43	2.77	5.33
L2–4	1.31	1.98	4.18

The precision errors are given for each vertebral level and a combination thereof. For lateral spine scans, precision errors are given for the whole vertebral body and a smaller subregion in the central part of the vertebral body (midregion).[16]

the ribs and the pelvis, lateral BMD measurements of the lumbar vertebrae L-2 and L-4 are regarded as unreliable by some authors.[29] Hence, the lateral measurement of only L-3, or a combination of L-2 and L-3, has been used in several studies.[3,19,22,25,27] However, the impact of the overlap of L-2 or L-3 by ribs on the accuracy of the BMD measurement and the diagnostic sensitivity of the method may be negligible.[16] The precision error, however, is reduced considerably when a combination of L-2 and L-3 is measured, as opposed to L-3 alone. Including L-4, which is overlapped by the pelvis in approximately 30–50% of the patients, into the lateral BMD measurement is more difficult, since the overlap of the pelvis may falsely increase L-4 BMD, and thus, it also influences the diagnostic sensitivity of the lateral measurement itself. On the other hand, Jergas and colleagues[16] found that the inclusion of L-4 into the analysis when not overlapped by the pelvis could improve diagnostic sensitivity of lateral DXA, and choosing a region of interest including the levels L2–4 also provided the best precision.

There are limitations that apply generally to lateral DXA and should be considered when using this technique in studies in which the normality of a patient is assessed as well as in serial measurements. Owing to the greater nonuniformity of the fat distribution in lateral DXA scans compared with PA scans, the accuracy of a lateral measurement can be compromised, and thus lead to misinterpretations.[14,34] Alterations in the fat error (e.g. owing to weight change) may affect the long-term precision in lateral studies.[33] Inconsistencies in the soft tissue in front of the vertebral bodies represent a further important source of variability for lateral DXA measurements, all the more as this region is used for the calculation of the soft-tissue baseline and may frequently contain some calcifications.[8]

As can be seen from the studies cited, the results for fracture/nonfracture discrimination are still controversial, even though there is a trend for a slightly better performance. Thus, for the purpose of determining a person's risk osteoporotic fracture, no general recommendations for the use of lateral over PA DXA can be given at this time. The association of lateral BMD with age is certainly stronger than that of PA DXA, and the same may apply for the detection of estrogen deprivation effects as well as monitoring glucocorticoid therapy and potentially other drugs affecting bone mineral metabolism. It has been shown that lateral supine DXA provides a reproducible assessment of vertebral body BMD, especially if a maximum number of vertebral levels (i.e., L2–4) is included in the analysis. L-4, however, must be excluded if it is overlapped by the pelvis, because bone density will be falsely increased. Some studies also suggest that lateral DXA is more strongly influenced by the overlapping soft tissue than is PA DXA.

Finally, the impact of the inclusion of the posterior elements in the PA lumbar spine measurement as compared to lateral DXA of the vertebral body has been studied by few researchers.[11,30] Both studies find that the contribution of the posterior processes to total PA BMC is approximately 50%. However, with regard to other results, there are substantial differences between these two studies. Fournier and colleagues[11] did not find a significant association between vertebral body BMC and vertebral arch BMC. Seeman et al.[30] reported a significant relationship between those two variables. The implications of these findings are of great importance to the clinical application of PA and lateral DXA. If vertebral body BMC and vertebral arch BMC lost bone mass to an equal extent with aging, the PA measurement would reflect lateral vertebral body BMC or BMD as well, and one might not expect lateral BMD to be superior to PA BMD in diagnosing osteoporosis. However, if there is no strong relationship between vertebral body BMC and vertebral arch BMC, the PA measurement might not reliably reflect changes in vertebral body BMC or BMD. At this point, one has to consider that the inclusion criteria for both studies were quite different: Fournier studied bone PA and lateral bone mineral content and density in young men and women, and Seeman et al. studied bone mineral content and density in pre- and postmenopausal women as well as in specimens. However, Seeman et al. excluded women with degenerative disease of the spine from the study. The controversial results presented in those studies emphasize the need for further basic research work in this field.

In conclusion, some years after its inception, lateral DXA has not yet been established as a standard measurement of bone density. However, there may be specific indications for lateral DXA, including its application as a research tool in epidemiological studies and clinical drug trials. The same may also apply to monitoring patients who receive drugs known to affect bone mineral metabolism, although the precision error may offset the benefits of measuring only the vertebral body. At present, it is certain to say that there is a lack of prospective studies with clearly defined patient cohorts to help define the status of lateral DXA in clinical bone densitometry.

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