Osteoporosis Int (1990) 1:23–29

Osteoporosis International

Original Article

Vertebral Bone Mineral Density Measured Laterally by Dual-Energy X-ray Absorptiometry

D. O. Slosman[1], R. Rizzoli[2], A. Donath[1] and J.-Ph. Bonjour[2]

[1]Division of Nuclear Medicine, Department of Radiology and [2]Division of Clinical Pathophysiology, Department of Medicine, University Hospital, Geneva, Switzerland

Abstract. The bone mineral density (BMD) of lumbar vertebrae in the anteroposterior (AP) view may be overestimated in osteoarthritis or with aortic calcification, which are common in elderly. Furthermore, the risk of spinal crush fracture should be more closely related inversely to the BMD of the vertebral body than to that of the posterior arch. Therefore, we measured BMD of lumbar vertebrae in lateral (LAT) view (L2–L3), using a standard dual-energy X-ray absorptiometer (DEXA), thus eliminating most of the posterior spinal elements. The precision of BMD LAT measurement was determined both in vitro and in healthy volunteers. Then, we compared the capability of BMD LAT and BMD AP scans for monitoring bone loss related to age and for discriminating the BMD of postmenopausal women with nontraumatic vertebral fractures from that of young subjects. In vitro, when a spine phantom was placed in lateral position in the middle of 26 cm of water in order to simulate both soft-tissue thickness and X-ray source remoteness, the coefficient of variation (CV) of six repeated determinations of BMD was 1.0%. In vivo, the CV of paired BMD LAT measurements obtained in 20 healthy volunteers after repositioning was 2.8%. The age-related difference between a peak bone mass group estimated in a group of 27 healthy women aged 20 to 35 years and a group of 50 women aged 60 to 75 years, in whom neither vertebral fracture nor osteoporosis risk factors could be detected, were 21.7% and 37.6% in AP and LAT view, respectively. An arbitrary BMD fracture threshold was defined in AP and LAT views as the 90th percentile of the BMD value of a group of 22 osteoporotic women with vertebral fractures. The distribution of BMD AP and LAT above and below this threshold in 169 consecutively screened women without vertebral fracture was then analysed. In both AP and LAT views, 39.1% and 31.3% had BMD values above and below this threshold, respectively. Of the remaining, 16.0% had a BMD below this threshold only in AP and 13.6% only in LAT view. Thus, if BMD LAT was a better reflection of vertebral body bone mass than BMD AP, and thereby a better predictor of the resistance to crush fracture, our results would suggest that only the use of the standard AP view could under- or overestimate spinal fracture risk in about 30% of women screened for osteoporosis. In conclusion, our results indicate that BMD measurement in lateral view is feasible with a standard DEXA instrument. This mode of scanning, besides overcoming artefacts due to osteoarthritis of the posterior arch and aortic calcifications, appears to provide a greater sensitivity for assessing bone mass loss of the vertebral body than the standard anteroposterior scan.

Keywords: Bone mineral density; Dual-energy X-ray absorptiometry; Lumbar vertebrae

Correspondence and offprint requests to: Daniel O. Slosman, MD, Division of Nuclear Medicine, University Hospital, 1211 Geneva 4, Switzerland.

Introduction

During the last decade considerable technical development has been made in the methods used for the quantitative assessment of bone mineral density (BMD). Dual-photon absorptiometry (DPA) represents a major advance because it allows noninvasive measurement of BMD at critical sites such as lumbar spine and femoral neck where osteoporotic fractures are often observed. Scanning at the level of the lumbar

spine in the standard anteroposterior (AP) view provides a measurement of the overall vertebra. It includes both the vertebral body and the posterior elements. BMD of the posterior arch should not markedly contribute to crush fracture resistance of the vertebral body. Furthermore, the presence of osteoarthritis or aortic calcification, two processes that tend to increase with age, may artefactually increase the BMD values in the AP view, and thereby decrease the capability to distinguish between normal and osteoporotic subjects. The technique of quantitative computed tomography (QCT) is not influenced by such artefacts. QCT provides a quantitative cross-sectional image of the vertebral body, that allows the BMD measurement of either the trabecular or the cortical portion of bony tissue [1]. At the level of the spine, a higher age-related bone mass loss can be detected by QCT as compared to the classical measurement by DPA in the AP view. This indicates a greater sensitivity to detect age-related vertebral bone mass loss by QCT as compared to DPA [1]. QCT has, however, some shortcomings which are mainly related to cost, instrument availability in many institutions and non-negligible radiation exposure. Using the DPA technique selective information on the BMD of the vertebral body, and thus on the risk of crush fracture, could be obtained if the scanning field could avoid the posterior arch. Recently, Uebelhart et al. showed that measurement of vertebral bodies in the lateral (LAT) view was feasible using a multidetector DPA prototype equipped with a rotating arm [2].

Over the last 3 years the precision and scanning time of BMD measurement has been improved, particularly at the lumbar spine level, with the introduction of a new generation of bone densitometers that use an X-ray tube as a photon source [3–9]. This new technique eliminates the problem of radioactive source decay inherent in DPA technology [8,11,12]. It has been designated under various names such as quantitative digital radiography (QDR), dual-energy radiography (DER), or dual energy X-ray absorptiometry (DEXA) [3–9].

In this paper we first describe a method using a commercially available standard DEXA system to measure BMD of the L2–L3 vertebral bodies in the LAT view. The precision of this procedure was evaluated both in vitro and in vivo. The influence on the precision of BMD LAT measurement of soft-tissue thickness and remoteness of the X-ray source was also assessed. Secondly, we compared the capacity of BMD measurement obtained by either LAT and AP scans to detect age-related bone mass loss in a cohort of pre- and postmenopausal women.

Materials and Methods

Mode of Acquisition

Lumbar spine was scanned in vitro and in vivo with the standard QDR-1000 that has a single detector (Hologic Inc.) using two modes of acquisition: (a) normal mode with a resolution and line spacing of 1 mm; (b) high resolution mode of acquisition with a resolution and line spacing of 0.5 mm. Subjects were placed in the left lateral decubitus position with hips and knees in flexion. The pelvis was maintained perpendicular to the board of the instrument with a posterior support to insure a stable position during scanning. The arms were placed above and in front of the head to avoid superimposition of ribs on the L2 vertebral body. Using this setting BMD measurement of both L2 and L3 can be properly made, since superimposition of the anterior extremities of the ribs over the vertebral body of L2 can be avoided. The position was controlled by reference to the posterior vertical shield of the QDR-1000. Furthermore, rotation of the spine axis can be avoided with both pelvis and shoulders being maintained in a stable vertical position. For data analysis, the standard software (Version 4.1) was used throughout the study. BMD results were obtained for the overall area L2–L3 or for each vertebra independently. The standard mode of acquisition and analysis was used for the spine AP view over the areas L2–L4, L2–L3 or L2 and L3 independently. Typical AP and LAT lumbar spine scans are presented in Fig. 1.

Evaluation of Measurement Precision

The precision of vertebral body BMD measurement in the LAT view was studied in vitro and in vivo.

In vitro, we used a spine phantom placed in the LAT position. It is known that the distance between the X-ray tube and the bone structure may affect the measurement precision. In the LAT position, the lumbar spine is separated from the source by a wide and variable thickness of soft tissue. The influence of this variable was assessed by measuring repeatedly (six times) BMD LAT with the spine phantom placed first in air and then in the middle of 26 cm of water in order to simulate soft tissue.

In vivo, the precision of the measurement in the LAT view was first assessed by using the normal mode of acquisition in 10 volunteers: 4 males and 6 females. Their mean age was 24.4 ± 6.6 years and their mean body mass index (BMI, kg/m^2) was 21.2 ± 2.4. BMD LAT was determined six times in each subject with repositioning between each scan. When the precision was assessed with the high resolution mode of acquisition, pairs of measurements were done in 10 volunteers: 5 males and 5 females. Their mean age was 34.6 ± 8.6 years and their BMI was 20.9 ± 2.6 kg/m^2.

For the in vitro data the precision was expressed as the coefficient of variation (CV) of the series of six determinations. For the in vivo study, the CV for duplicate measurements was calculated as indicated below (see statistics). Note that the mean CV of the series of six measurements obtained with the normal mode of resolution was identical to that calculated for duplicate measurements using the first two BMD LAT values of each series.

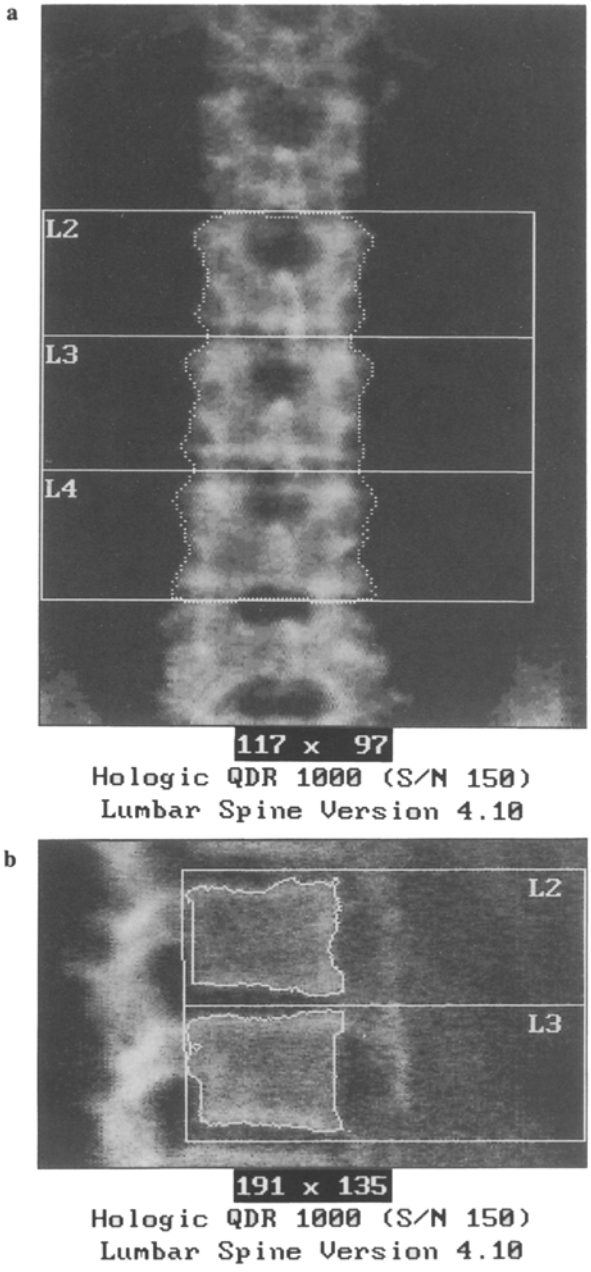

Fig. 1. Standard anteroposterior (AP) and lateral (LAT) lumbar spine scanning. AP lumbar spine BMD (Fig. 1a) was measured over L2–L4 using the normal resolution mode of 1 mm. LAT lumbar spine BMD (Fig. 1b) was measured over L2–L3 using the high resolution mode of 0.5 mm.

Comparison Between Spine AP and LAT Views

In all cases, lumbar spine in lateral view was scanned in high resolution mode, whereas in AP view it was scanned in normal resolution mode.

Lumbar spine BMD in both AP and LAT views was first determined in a group of 27 healthy women aged 20 to 35 years. Their mean age was 26.5 ± 4.2 years and their BMI was 20.6 ± 2.8 kg/m^2. The BMD AP and LAT values of this cohort of young healthy adult women were considered as reference for the peak bone mass (PBM).

Then, a series of 191 women was investigated in a prospective study during a 3-month period. BMD was determined at the level of the lumbar spine in both the AP and LAT views. The high resolution mode was used for the LAT view acquisition.

Among these 191 subjects, a subset of 22 patients displayed vertebral crush fractures as documented by X-ray examination, that were not associated with an adequate trauma. The mean age of this subset was 66.5 ± 12.3 years with a BMI of 22.8 ± 3.6 kg/m^2. Most of them had previously received treatment aimed at preventing osteoporotic fracture. The BMD values of this subgroup was used in order to determine an arbitrary fracture threshold. It was defined as the 90th percentile of the BMD measured in the AP and LAT views. The BMD in both the AP and LAT views of the remaining 169 subjects without any vertebral fracture (mean age: 58.3 ± 11.0 yrs; mean BMI: 22.9 ± 3.8 kg/m^2) was then analysed in relation with the fracture threshold defined above. Thus, BMD AP or LAT values were considered as normal or abnormal if they fell above or below their respective fracture threshold.

Age-Related Bone Mass Loss

The relative capacity of the LAT as compared to the AP view, to evaluate the age-related lumbar BMD decline was estimated as follows: among the 169 women scanned consecutively without evidence of vertebral crush fracture, we selected those aged between 60 and 75 years, who were free of any risk factors for osteoporosis, such as early menopause or glucocorticoid therapy. Fifty women fulfilled these criteria. Their mean age was 70.8 ± 5.0 years and their BMI was 23.6 ± 3.9. The difference between the mean BMD values of this postmenopausal cohort and the PBM reference group was calculated in the AP and LAT views for L2–L3 taken together as well as for each vertebra taken separately.

Statistics

Results are expressed as mean ± 1 standard deviation (SD). The coefficient of variation of multiple measurements was the ratio in percent: SD/mean. The coefficient of variation of duplicate measurements was calculated according to the following formula:

$$CV = \sqrt{(\Sigma d^2/2n)} \times 100 / [(\text{mean}_1 + \text{mean}_2)/2]$$

where d = difference between two values for a given individual.

One-way analysis of variance and the Scheffe F-test were used to evaluate significance between mean values of the four groups presented in Table 1.

Table 1. Bone mineral density (BMD) of the lumbar spine measured in both anteroposterior (AP) and lateral (LAT) views in 169 non-fractured women

Group:	1	2	3	4
BMD AP:	Normal	Abnormal	Normal	Abnormal
BMD LAT:	Normal	Normal	Abnormal	Abnormal
n (%)	66 (39.1%)	27 (16.0%)	23 (13.6%)	53 (31.3%)
Age (years)	54.6±10.0	57.0±12.6	63.0±9.5[a]	61.5±10.4[a]
BMI (kg/m^2)	23.5±3.9	21.5±4.1	24.0±3.5	22.4±3.4
Years postmenopause				
Mean	6.6	12.1	13.0	14.6
Range	0–34	0–31	0–33	0–53
BMD AP (g/cm^2)				
L2–L4	1.037±0.124	0.812±0.059[a]	0.956±0.069[a,b]	0.756±0.100[a,c]
L2–L3	1.013±0.128	0.790±0.063[a]	0.913±0.068[a,b]	0.729±0.099[a,c]
L2	0.988±0.134	0.767±0.065[a]	0.864±0.078[a,b]	0.708±0.101[a,c]
L3	1.037±0.130	0.812±0.070[a]	0.916±0.068[a,b]	0.750±0.103[a,c]
% PBM L2–L4	+0.4±12.0	−21.4±5.7[a]	−7.4±6.7[a,b]	−26.8±9.7[a,c]
BMD LAT (g/cm^2)				
L2–L3	0.625±0.102	0.566±0.049[a]	0.397±0.062[a,b]	0.353±0.098[a,b]
L2	0.605±0.117	0.525±0.061[a]	0.348±0.083[a,b]	0.316±0.107[a,b]
L3	0.644±0.113	0.607±0.076	0.446±0.068[a,b]	0.390±0.105[a,b]
% PBM L2–L3	−8.5±15.0	−17.1±7.2[a]	−41.8±9.0[a,b]	−48.3±14.4[a,b]

Values are mean±SD.
[a] $P<0.05$ as compared to group 1.
[b] $P<0.05$ as compared to group 2.
[c] $P<0.05$ as compared to group 3.
169 women were distributed in 4 groups according to their lumbar bone mineral density determined in both AP and LAT views. Values above and below the 'fracture threshold' (see text for definition) were considered as normal and abnormal, respectively.
BMI, Body Mass Index.
Peak Bone Mass (PBM), mean BMD obtained in AP (L2–L4) and LAT (L2–L3) views in a group of healthy women 20–35 years old.
% PBM, difference in percent from PBM values.

Results

Evaluation of Measurement Precision

The in vitro reproducibility of the spine phantom BMD was first tested using the normal mode of resolution. The CV of 6 repeated BMD measurements was 0.6% in air. When the spine phantom was placed in the middle of 26 cm of water, the CV increased to 2.4%. Using the high resolution mode of acquisition the CV dropped from 0.6% to 0.3% and from 2.4% to 1% when the phantom was placed in air and in 26 cm water, respectively (Fig. 2).

In vivo, in healthy volunteers, using the normal mode of acquisition, the CV of repeated measurements after repositioning was 5.5%; with the high resolution mode it fell to 2.8% (Fig. 2).

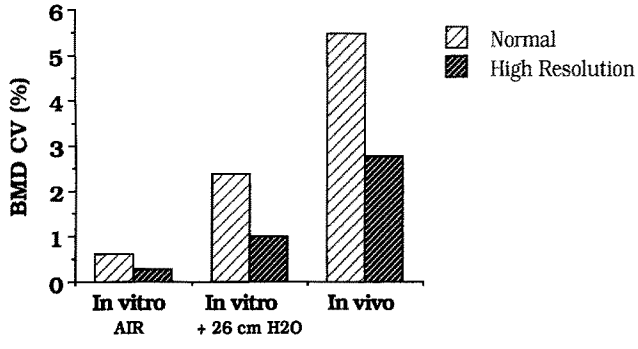

Fig. 2. Precision of lateral lumbar spine BMD measurement. In vitro, the precision (CV, coefficient of variation) of lumbar spine BMD measurement in the lateral view was assessed in vitro, both in air and in the middle of 26 cm of water to simulate the interposition of soft tissue between the source and the lumbar vertebrae. 6 repeated measurements were made under both conditions.
In vivo, the precision was assessed from paired measurements in 20 healthy volunteers after repositioning. The scans were acquired using both (▨) standard and (▩) high resolution modes (see details in the methods section).

Peak Bone Mass (PBM) Group

BMD in the AP and LAT views was determined in a group of 27 healthy young women aged from 20 to 35 years in order to estimate the peak (i.e. young adult)

bone mass. In the AP view the BMD was 1.033 ± 0.090 g/cm^2 for L2–L4 and 1.034 ± 0.099 g/cm^2 for L2–L3. In the LAT view the BMD was 0.683 ± 0.117 g/cm^2 for L2–L3, 0.658 ± 0.111 g/cm^2 for L2 and 0.708 ± 0.13 g/cm^2 for L3 (NS).

Osteoporotic Group

Among the 191 referred patients, 22 (12.1%) had X-ray documented vertebral crush fracture unexplained by an adequate trauma. The mean BMD were 0.718 ± 0.133 and 0.328 ± 0.127 g/cm^2 in the AP and LAT views, respectively. The 90th percentile of the BMD values was 0.883 g/cm^2 in the AP view and 0.481 g/cm^2 in the LAT view. These two values were arbitrarily considered as the 'fracture threshold'.

Comparison Between Spine AP and LAT Views

In the remaining 169 women of the referred cohort, 27 were premenopausal (16.0%) and 142 were postmenopausal (84%).

Among them, 66 (39.1%) subjects had BMD values in both the AP and LAT views above the 'fracture threshold' (group 1); 27 (16.0%) had a BMD value below threshold only in the AP view (group 2); 23 (13.6%) had a BMD value below threshold only in the LAT view (group 3); finally, 53 (31.3%) had BMD values below threshold in both the AP and LAT views (group 4) (Table 1). Age, years postmenopause and BMI were similar, except for the first group (BMD AP: normal; BMD LAT: normal) which was significantly younger as compared with either the third (BMD AP: normal; BMD LAT: abnormal) or the fourth (BMD–AP: abnormal; BMD LAT: abnormal) group. Note that as compared with the bone mass determined in young adult women the mean percent reduction of group 4 in the LAT view was nearly twice (−48.3%) that calculated by using the AP view measurement (−26.8%).

Age-Related Bone Loss

As compared with the mean BMD determined in the PBM group, the mean BMD measured in the group of 22 women with fracture-complicated osteoporosis was reduced by 30.5% in the AP view (L2–L4) and by 52.0% in the LAT view (L2–L3) (Fig. 3).

In the group of 50 postmenopausal women aged 60 to 75, the BMD was 0.850 ± 0.151 in the AP view (L2–L4) and 0.426 ± 0.160 g/cm^2 in the LAT view (L2–L3). When these results were compared with the respective BMD values obtained in the PBM group, they were lower by 21.7% in the AP view, but by 37.6% in the LAT view (Fig. 4). Table 2 shows identical results obtained when considering L2 or L3 separately.

To evaluate the preferential vertebral body bone loss with age, regression lines were calculated from the data obtained in the 169 women without fractures assuming a

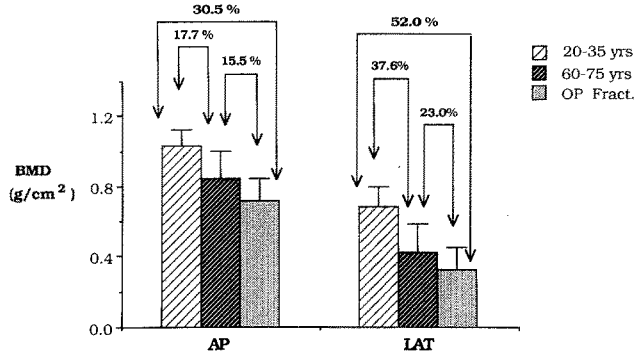

Fig. 3. Comparison of lumbar bone mass loss determined in the anteroposterior and lateral views. The mean values±SD correspond to the bone mineral density (BMD) of the lumbar vertebrae in: (▨) 27 young adult (26.5±4.2 yrs old, age range 20–35 yrs) healthy women; (▩) 50 postmenopausal women (70.8±5.0 yrs old, age range 60–75 yrs) without vertebral fracture and displaying no osteoporosis risk factor; (▤) 22 women with nontraumatic vertebral fracture (66.5±12.3 yrs old, age range 39–84 yrs). AP, anteroposterior view of L2–L4; LAT, lateral view L2–L3. The AP vs LAT comparison of the same 3 groups of subject for the BMD values corresponding to L2 and L3 take either separately or together is presented in Table 2.

Table 2. Bone mineral density of lumbar spine determined in anteroposterior and lateral view in young adult women, postmenopausal healthy women without osteoporosis risk factor, and in postmenopausal women with vertebral fracture. The 20–35 year old group corresponded to 27 healthy young women. The 60–75 year old group corresponded to 50 healthy postmenopausal women without vertebral fracture. The 'OP Fract.' corresponded to 22 postmenopausal women with vertebral fracture. See method and results sections for further details

View:	Anteroposterior			Lateral		
Age (years):	20–35	60–75	OP Fract.	20–35	60–75	OP Fract.
L2	1.024±0.107	0.777±0.152[a] (−24.1)	0.654±0.125 (−36.1)	0.658±0.111	0.394±0.166[a] (−40.1)	0.303±0.149 (−54.0)
L3	1.043±0.097	0.847±0.166[a] (−18.8)	0.711±0.150 (−31.8)	0.708±0.130	0.457±0.162[a] (−35.5)	0.352±0.130 (−50.3)
L2–L3	1.034±0.099	0.812±0.156[a] (−21.5)	0.683±0.131 (−34.0)	0.683±0.117	0.426±0.160[a] (−37.6)	0.328±0.127 (−52.0)

Values are mean±SD in g/cm^2.
[a] $P<0.0001$ as compared to the 20–35 year old group.
The three groups correspond to those presented in Fig. 3.
() Mean decrement expressed in percent of the corresponding BMD determined in the 20–35 year old group.

linear relationship between age and BMD measured in either the AP or LAT view: in the AP view the regression equation was $Y = -0.003X + 1.062$, whereas in LAT view it was $Y = -0.005X + 0.769$, where Y corresponds to the BMD in g/cm^2 for L2–L4 and L2–L3 in AP and LAT view respectively, and X is the age in years. Statistically, the difference in the two slopes was significant at $P<0.01$, indicating that the age-dependent bone mass decrement was greater when assessed in the LAT as compared with the AP view.

Discussion

A recent report from the Scientific Advisory Board of the National Osteoporosis Foundation emphasizes the importance of bone mass determination for predicting fracture risk and for selecting appropriate therapy in osteoporotic patients [10]. Four indications for bone mass measurements in clinical practice have been delineated. Three of them, namely estrogen deficiency, vertebral deformities or roentgenographic osteopenia, and long-term glucocorticoid therapy particularly concern spinal osteoporosis with the risk of fracture of the vertebral body. Although not yet fully documented it seems reasonable to consider that the predictive power for assessing risk fracture at a given site of the skeleton should be greater if bone mass can be measured at this site. Therefore, it appears important to assess the bone mass of the vertebral body in order to make the best prediction of future spinal crush or wedge fractures. The present report shows that by using a standard DEXA instrument it appears possible to measure separately the BMD of the vertebral body with a reasonable precision by lateral scanning of the lumbar spine at the level of L2–L3. Nevertheless, because of the important soft-tissue thickness present in the LAT view it was necessary to use a high resolution mode of acquisition that increases fourfold the photon flux in order to reduce the in vivo coefficient of variation from 5.5% to 2.8%. A mean CV of 2.8% is still greater than that of 1.0% we previously obtained by determining L2–L4 BMD in the AP view when using the same DEXA instrument in a comparable group of young healthy human subjects [8]. However, preliminary re-analysis of the data using new software indicates that the mean CV of our LAT view measurements made in healthy volunteers can be reduced from 2.8% to 2.1% (data not shown). It should be acknowledged that in elderly patients such a degree of precision might not be obtained. However, the future use of a movable multidetector support that will allow, like the DPA prototype mentioned above [2], the scanning of subjects in supine position, can be expected to improve the precision of the measurement.

Lumbar spine BMD measurement could be overestimated at the level of L2 by the superimposition of the distal parts of the ribs. According to investigators who use QCT for measuring lumbar spine BMD, the distal part of the ribs is often visualized in front of the L2 vertebral body. In most cases, by positioning the subjects as described in the method section, such a superimposition was avoided and ribs were not visualized at all on the images. When ribs could be seen in front of the L2 vertebral body, as sometimes happens, particularly with very thin subjects, they were excluded from the region of interest by modifying the position of the arms. Variation in the incidence of rib visualization between our own experience with DEXA and that of QCT users could be related to differences in subject positioning. Alternatively, it is possible that the presence of a distal part of ribs with very low mineral density could be missed on the DEXA-generated image. Our results indicate that, although BMD L3 is significantly higher than BMD L2 (+12%), both vertebrae display the same discriminating power as the combined BMD L2–L3 for grouping the subjects with respect to the fracture threshold. Therefore, if any rib superimposition on L2 were present in some cases, it should not introduce a significant artifactual overestimation of the vertebral body BMD determined by lateral scanning. It is of clinical importance to conserve L2 and L3 in the region of interest. Indeed, DEXA LAT scans limited to L3 would be useless when this vertebra is fractured. Furthermore, as previously observed with DPA or DEXA scans of lumbar spine in the AP view, an increase in the vertebral area improves considerably the precision of BMD measurement. Obviously, in presence of prominent thoracic and spinal deformities rib superimposition could make lateral scanning impossible.

It has been observed that in women the age-related bone loss at the lumbar spine level was greater when assessed by QCT as compared with DPA in the AP view [1]. Thus, between the age of 25 and 65, bone loss would be about 48% with QCT and 28% with DPA in the AP view [1]. Interestingly, this difference in bone loss rate is quite comparable to that we observed between the BMD measured in the LAT (52%) and AP (31%) views when the values obtained in the 20–35 and 60–75 years old groups were compared. Uebelhart et al. [2] also observed a difference in bone mass loss between AP and LAT view of the same magnitude when elderly non-osteoporotic subjects were compared with a group of young adult individuals [2]. Previous studies by Nilas et al. [13] have shown that compared with the premenopausal normal range, determination of bone mass in the distal forearm site could have a greater sensitivity in identifying patients with vertebral fractures than measurement at the spine level. In this study [13] lumbar bone mass was determined by DPA using the classical AP view. Considering the epidemiological importance of spinal crush and wedge fractures [14,15], future prospective studies aimed at assessing the relationship between bone mass and fracture risk should include the determination of lumbar BMD in both AP and LAT views in order to distinguish the contribution of the vertebral body from that of the posterior arch.

It has been reported that lumbar spine BMD values obtained by DPA in the AP view correlated rather poorly with trabecular BMD determined by QCT [1].

This is not surprising since a non-negligible part of the spine BMD measured by DPA in the AP view corresponds to the posterior arch, which predominantly consists of cortical bony tissue and is not included in the region of interest usually scanned by QCT [1]. The correlation was improved when integral density and bone mineral content were measured by QCT, thus taking into account both the cortex and the inside of the vertebral body. As suggested in a preliminary study using DPA multidetector system [16], a higher degree of correlation can be expected to be found between the integral bone density determined by QCT and the BMD measured by DEXA in the LAT view.

Discrimination between normal subjects and patients with severe osteoporosis and thus having a high risk of fracture will remain one of the most important indications for bone mass measurement in clinical practice. Raymakers et al. showed that the efficiency of QCT was superior to that of DPA for discriminating women with crush fractures from age-matched normal controls [17]. Assuming that lumbar spine BMD measured in the LAT view, as opposed to the AP view, by DEXA would better predict the risk of vertebral crush fractures, the data analysis presented in Table 2 suggests that both false 'negative' and false 'positive' results could be generated by using only the classical anteroposterior scanning. Using the arbitrary fracture threshold defined as the 90th percentile of the BMD measured in the 22 patients with evidence of osteoporotic vertebral crush fractures, the measurement of L2–L3 BMD in the LAT view allowed the recognition of 13.6% of the subjects with BMD values below this threshold that would otherwise have been considered as normal if only BMD in the AP view were measured. Furthermore, if the above mentioned hypothesis holds true, our data suggest that the risk of crush fracture could also be overestimated in some subjects (16% in our analysis) in whom low BMD in the AP view is associated with a still normal bone mass in the lateral scanning. However these conclusions should be supported by prospective studies aimed at determining the validity of this measurement for predicting the risk of fractures of the vertebral body.

In order to discriminate subjects at risk, the use of a BMD theoretical fracture threshold is probably superior to that of the z score, since this latter procedure will depend upon the variance of the normal range, which might be slightly greater in lateral than in anteroposterior view. Nevertheless a comparison between these two approaches remains to be made after the establishment of a reference range for BMD LAT in postmenopausal women.

In conclusion, our results indicate that BMD measurement in the lateral view can be made with good precision at the level of L2–L3 using a standard DEXA densitometer. The age-dependent bone mass loss detected by lateral scanning was greater than that determined by the usual anteroposterior view. These findings suggest that spinal BMD determination by lateral scanning could substantially improve the sensitivity of the DEXA technique for detecting the degree of osteoporosis and predicting the risk of wedge or crush fractures of the vertebral bodies.

Acknowledgements. We thank Mr E. Fleury for his excellent technical assistance and Mrs M.-C. Brandt for her secretarial help. This work was supported by the Swiss National Science Foundation (Grant 3200–25.535) and Sandoz–Wander Pharma AG, Berne, Switzerland. R. Rizzoli is the recipient of a Max Cloetta career development award.

References

1. Genant HK, Block JE, Steiger P, Glueer, Smith R. Quantitative computed tomography in assessment of osteoporosis. Semin Nucl Med 1987; 4: 316–33.
2. Uebelhart D, Duboeuf F, Meunier P, Delmas P. Vertebral bone mineral density (BMD) measurement assessed by lateral dual-photon absorptiometry (DPA). J Bone Min Res 1990; 5: 525–31.
3. Pacifici R, Rupich R, Vered I et al. Dual energy radiography (DER): a preliminary comparative study. Calcif Tissue Int 1988; 43: 189–91.
4. Mazess R, Collick B, Trempe J, Barden H, Hanson J. Performance evaluation of a dual-energy X-ray bone densitometer. Calcif Tissue Int 1988; 44: 228–32.
5. Kelly TL, Slovick DM, Schoenfeld DA, Neer RM. Quantitative digital radiography versus dual photon absorptiometry of the lumbar spine. J Clin Endocrinol Metab 1988; 67: 839–44.
6. Wahner HW, Dunn WL, Brown ML, Morin RL, Riggs BL. Comparison of dual-energy X-ray absorptiometry and dual photon absorptiometry for bone mineral measurements of the lumbar spine. Mayo Clin Proc 1988; 63: 1075–84.
7. Braillon P, Duboeuf F, Meary MF, Barret P, Delmas PD, Meunier PJ. Mesure du contenu minéral osseux par radiographie digitale quantitative. Presse Med 1989; 18: 1062–5.
8. Slosman DO, Rizzoli R, Donath A, Bonjour J-Ph. Quantitative digital radiography and conventional dual-photon bone densitometry: study of precision at the levels of spine, femoral neck and femoral shaft. Eur J Nucl Med in press.
9. Fogelman I. An evaluation of the contribution of bone mass measurements to clinical practice. Semin Nucl Med 1989; 19: 62–8.
10. Johnston Jr CC, Melton III LJ, Lindsay R, Eddy DM. Clinical indications for bone mass measurements. J Bone Min Res 1989; 4 (Suppl 2): 1–28.
11. Lindsay R, Fey C, Haboubi A. Dual-photon absorptiometric measurements of bone mineral density increase with source life. Calcif Tissue Int 1987; 41: 293–4.
12. Dawson-Hughes B, Deehr MS, Berger PS, Dallal GE, Sadowski LJ. Correction of the effects of source, source, source strength, and soft-tissue thickness on spine dual-photon absorptiometry measurements. Calcif Tissue Int 1989; 44: 251–7.
13. Nilas L, Gotfredsen A, Riis BJ, Christiansen C. The diagnostic validity of local and total bone mineral measurements in postmenopausal osteoporosis and osteoarthritis. Clin Endocrinol 1986; 25: 711–20.
14. Cummings SR, Kelsey JL, Nevitt MC, O'Dowd KJ. Epidemiology of osteoporosis and osteoporotic fractures. Epidemiol Rev 1985; 7:178–208.
15. Melton LJ III, Kan SH, Frye MA, Wahner HW, O'Fallon WM, Riggs BL. Epidemiology of vertebral fractures in women. Am J Epidemiology 1989; 129: 1000–11.
16. Uebelhart D, Braillon P, Meunier PJ, Delmas PD. Lateral-dual-photon absorptiometry of the spine in vertebral osteoporosis and osteoarthritis comparison with quantitative computed tomography. J Bone Min Res 1989; 4 (Suppl 1): S328.
17. Raymakers JA, Hoekstra O, van Putten J. Osteoporotic fracture prevalence and bone mineral mass measured with CT and DPA. Skeletal Radiol 1986; 15: 191–7.