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A Newly Developed Instrument of Dual Photon Absorptiometry for Bone Mineral Analysis of the Lumbar Vertebra: Study in Control and Aged Females

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ABSTRACT. In order to determine the quantitatively bone mass, dual photon absorptiometry instrument using a scintillation camera was newly developed, and its basic performance was described. Furthermore, with this instrument, bone mineral at 3rd lumbar vertebra was measured in 57 women (31 controls: age 29.9±6.4 yrs., and 16 seniles: age 67.7±6.6 yrs.). The aged females, compared with the young control females, showed significantly low the all parameters of bone mineral such as bone mineral content (BMC), bone mineral density and total BMC at 3rd lumbar vertebra. Thus, it was shown that assessment of bone mineral with this instrument provided a useful information in the diagnosis of osteoporosis.

Key words : dual photon absorptiometry — scintillation camera — bone mineral density — lumbar vertebra — osteoporosis

With increasing proportion of the aged in the general population, there has been a steady increase in the prevalence of senile osteoporosis in Japan. Osteoporosis is a condition characterized by diminished bone mass and hence susceptibility to fracture of bone. In the aged fracture of bone often leads the patient to be confined to bed, thereby seriously deteriorating his or her quality of life. Early detection and, preferably, prevention of decreased bone mass have therefore been required. Methods by which to determine the bone mineral of the vertebra both accurately and conveniently, if available, will be of great aid in predicting the risk of compression fracture of the thoracic or lumbar vertebra, which is known as a frequent complication of senile osteoporosis, as well as in evaluating the response to treatment.

Recently we have had an opportunity to utilize DUALOMEX HC-1 (Chugai Pharmaceutical Co.), which was newly developed instrument for bone mineral analysis of the lumbar vertebra based on the principle of dual photon absorptiometry (DPA). In this report is given an outline of the instrument and its basic performance. Age-related changes in the bone mineral of the third lumbar vertebra (L_3) in healthy women, determined by the instrument, are also presented.

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BRIEF DESCRIPTION OF NEWLY DEVELOPED DPA INSTRUMENT AND ITS BASIC PERFORMANCE

DUALOMEX HC-1 is a novel DPA instrument with its detector component consisting of a scintillation camera system, instead of the scintiscanner employed in conventional instruments. The detector of the new instrument has one NaI (T1) scintillation crystal backed with a matrix of 22 photomultiplier tubes. With an effective field of view of 12.5×15.6 cm, it enables simultaneous assay of more than 3 vertebrae. The uniformity in 80% of the field size is good (less than $\pm 10\%$). The intrinsic spatial resolution is 9.0 mm (FWHM) at a 44 KeV and 5.0 mm (FWHM) at a 100 KeV photon energy. The distance between the source and detector is 100 cm. The gamma camera is positioned with the subject sitting on the chair set by the side of the detector. The entire procedure assay takes only 6 min (for body thickness of 20 cm with 50 mCi of ^{153}Gd). The precision of measurement is so satisfactory as to give 95% limits of less than $\pm 3\%$. Data collection and processing are done by personal computer. The radioactive source used is ^{153}Gd, its dose (50 mCi) being lower than in conventional instruments. The irradiation is as limited as less than 2 mR. The instrument, inclusive of the counting device, the signal processor unit and computer, is of sufficiently small size to be installed within a space of 270×270 cm.

MATERIALS AND METHODS

Forty-seven women (31 controls (age 29.9 ± 6.4 yrs.) and 16 senile (age 67.7 ± 6.6 yrs.)) were used in this study. The procedure of bone mineral analysis of L_3 with the instrument is as follows: upon termination of data acquisition an image of the lumbar vertebrae in antero-posterior view is displayed on the display device (Fig. 1). The upper and lower ends of L_3 are then identified by moving image cursors. The area (cm^2) of L_3 is determined along with other parameters such as the mean bone mineral content (BMC, g/cm), the mean bone width (BW, cm), the mean bone mineral density (BMD, g/cm^2) which is defined as the mean BMC divided by the mean BW, and the total BMC of L_3 (T-BMC, g).

BMC profiles of L_3, sliced at intervals of 1 mm from the upper to the lower end, are also displayed (Fig. 2). From the profiles are calculated parameters such as area, BMC, BMD and T-BMC over the range of BW. BW, as referred to here, means the region which is demarcated by the adjacent soft tissue and is less than 80% of total count. T-BMC is calculated by multiplying the mean BMC by the number of slices or the height of L_3. The reproducibility of measurements was satisfactory as evidenced by a CV of less than 5% for BMD. In this way the measurements were made of these parameters to compare the results obtained in the senile vs. control group of healthy women.

RESULTS

Data on the area of L_3, its BMC, BW, BMD and T-BMC in the senile and control groups as measured with the instrument are presented in Table 1. The area of L_3 was significantly smaller ($p<0.025$) in the aged (16.24 ± 4.32 cm^2) than in the control group (19.02 ± 2.95 cm^2), the former value being 85% of the

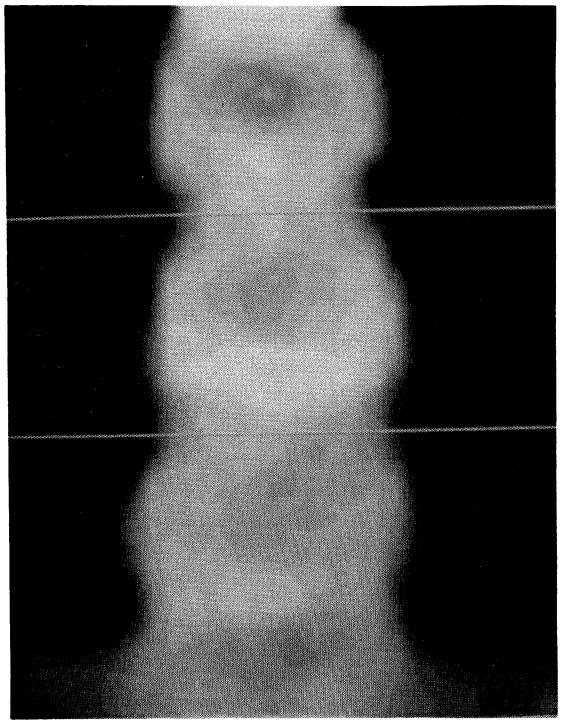

Fig. 1. Image of the lumbar vertebrae in anterio-posterior view

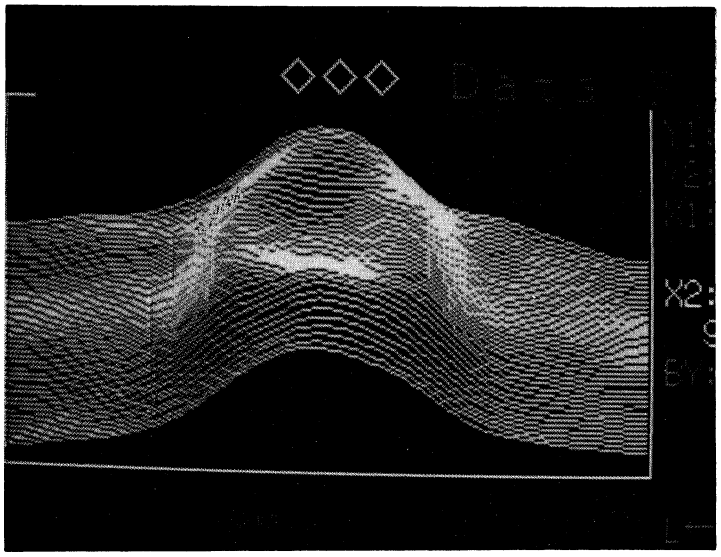

Fig. 2. BMC profile of L_3 as sliced at intervals of 1 mm from its upper to the lower margin

TABLE 1. Area of L_3, its BMC, BW, BMD and T-BMC in the control and the aged group

	N	Age (yrs.)	Area (cm^2)	BMC (g/cm)	BW (cm)	BMD (g/cm^2)	T-BMC (g)
I. Control	31	29.9 ± 6.4	19.02 ± 2.95	3.92 ±0.54	4.82 ±0.46	0.814 ±0.093	15.44 ±2.63
II. Aged	16	67.7 ± 6.6	16.24 ± 4.32	3.14 ±0.74	4.99 ±0.64	0.630 ±0.130	10.13 ±3.35
p Value (I vs. II)		<0.001	<0.025	<0.001	N.S.	<0.001	<0.001

latter. BMC was also significantly lower ($p<0.001$) in the aged group with a value of 3.14 ± 0.74 g/cm compared to 3.92 ± 0.54 g/cm for the control; the former value was 80% of the latter. No significant difference of BW was noted between the aged group (4.99 ± 0.64 cm) and the control (4.82 ± 0.46 cm), although there was a considerable variation especially in the aged group (CV of 12.8% for the aged vs. CV of 9.5% for the control). BMD was significantly lower ($p<0.001$) in the aged (0.630 ± 0.130 g/cm^2) than in the control group (0.814 ± 0.093 g/cm^2), the mean value for the former group being 77% of that for the latter group. T-BMC also was significantly lower ($p<0.001$) in the aged (10.13 ± 3.35 g) than in the control group (15.44 ± 2.63 g), the mean value for the former group was 66% of that for the latter group. It is clear that the aged group showed significantly lower values for all parameters of bone mineral.

DISCUSSION

With growing concern about osteoporosis, intensive efforts have been directed toward early detection or even prevention of the disease. Bone mineral analysis of the vertebrae, which consist predominantly of cancellous bone, is of great aid in elucidating the underlying pathologic process of the disease. In Western countries scintiscanner type of DPA has been widely used along with quantitative CT (QCT) which involves CT scanning with phantoms consisting of bone mineral equivalent materials.[1,2] In Japan, in contrast, QCT has been used almost exclusively since DPA is not yet popular enough.[3] A project has been under way in our laboratory to evaluate DPA instruments with the scintillation camera detector,[4,5] in order to overcome the disadvantages of QCT in involving a rather great risk of radiation exposure as well as yielding artifacts. It is under such circumstances that DUALOMEX HC-1, a modified DPA instrument, was developed. Being based on the scintillation camera, the instrument requires less than 1/10 the amount of radioactive source used for the scintiscanner. The data acquisition also is much less time-consuming, and can be performed even in patients who are unable to lie supine because of lumbar pain. Furthermore, radiation exposure involved is so limited as to permit repeated measurement.

The present study was done to assess comparatively the bone mineral of L_3 in healthy women as determined with the instrument. It was shown that the aged subjects had significantly lower values than the control younger subjects

with regard to the area of L_3 as well as its BMC, BMD and T-BMC. The fact that no significant difference existed between the groups in respect to BW suggests that the decreased area of L_3 in the aged might be due to a reduction in the height of L_3, which in turn might be attributed to compression fracture of mild degree. Therefore, in estimating the bone mineral of L_3 it is important to bear its height in mind. BMC will vary, with depending on the magnitude of BW. It is hence reasonable to compare the bone mineral in different subjects in terms of BMD, which is defined as BMC divided by BW. The aged often suffer from mild compression fracture of the lumbar vertebra, as mentioned above. In such individuals the height of L_3 is decreased, while BW is increased because of compression of the trabeculae. An apparent increase in BMC and BMD may hence result. In such situations T-BMC might be useful in cancelling the effect of compression fracture.

Our present study showed that the measurement of BMC, BMD and T-BMC of L_3 by this instrument is useful in estimating the bone mineral of the vertebra. The measured values for these parameters of bone mineral were decreased with age, thus providing values in the diagnosis of osteoporosis. It is hoped that this instrument will be used widely as a noninvasive methods of bone mineral analysis of the vertebra.

CONCLUSION

The usefulness of a newly developed DPA instrument with a scintillation camera detector was evaluated. The instrument requires a smaller amount of radioactive source and a shorter time for the data acquisition than those in conventional apparatuses based on the scintiscanner. The instrument also permits measurement to be made while the subject is in the sitting position.

Our present study using the instrument showed that the aged gave significantly lower values for all parameters examined of bone mineral than did the younger control subjects. It may be concluded that the instrument provides a valuable method of bone mineral analysis of the vertebra which is composed predominantly of cancellous bone.

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