Effect of Aortic Sclerosis on Bone Mineral Measurements by Dual-Photon Absorptiometry

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Measurements of the bone mineral content (BMC) of lumbar spine by dual-photon absorptiometry (DPA) are performed mainly in the anteroposterior (AP) projection. Due to superimposition of the abdominal aorta, the BMC measured for patients with aortic calcification usually is too high. To determine the influence of aortic calcifications, DPA scans were performed in the AP-projection on 100 dissected abdominal aortae with different degrees of atherosclerosis placed on a human lumbar spine cast in lucite. The measured values were compared with those obtained in the same projection without the aortae. The average increase of the BMC values relative to the mean for the vertebrae L2 to L4 for aortae with severe complicated lesions, i.e., those containing larger amounts of calcium, was 0.03 g/cm^2, with a maximum deviation of 0.09 g/cm^2. Aortae with fatty streaks or fibrous plaques did not cause significant increases of the BMC. The mean deviation for aortae with mild complicated lesions, i.e., those containing smaller amounts of calcium, was within the range of instrument precision.

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The main indication for the measurement of bone mineral content (BMC) is the detection of osteoporosis. Since trabecular bone has a higher turnover than cortical bone (*1*), the lumbar spine represents a particularly sensitive site for BMC determination (*2*). The measurement of BMC on the lumbar spine by dual-photon absorptiometry (DPA) is usually performed in the anteroposterior (AP) projection (*3*). Due to the superimposition of the abdominal aorta and the lumbar spine, calcification of the aorta is a potential source of error in DPA measurements (*4*). The goal of our investigation was to experimentally determine the influence of aortic sclerosis on the osteodensitometry of the lumbar spine by DPA.

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MATERIALS AND METHODS

DPA measurements are obtained with a MSE (Sudbury, MA), model Osteotech 300 bone densitometer (software version 1.27), using a gadolinium-153 source that emits photons with predominant energies of 44 and 100 keV (*5,6*). The examinations were performed in the AP-projection using rectilinear paths in a field with a length of 15.0 cm and a width of 10.5 cm. The single detector had a face located 50 cm above the scanning table, and a transverse speed of 12.6 mm/sec. Contiguous transverse scans were separated by 2.5-mm increments in the longitudinal direction. The gadolinium-153 source had a collimator aperture of 3 mm and a detector collimator aperture of 25 mm. Scanning time was approximately 10 min per scan. The parameter measured is an area density which represents the BMC in g/cm^2.

One hundred dissected abdominal aortae placed on a human lumbar spine cast in lucite (LS-phantom) were scanned by DPA. The values obtained were compared with the results of measurements in the absence of the aortae. Region of interest (ROI) technique was used to determine the integral BMC of the lumbar vertebrae L2 to L4, the ROIs being identical in the control scans. The LS-phantom consisted of a lumbar spine of an 89-yr-old woman from which all the soft tissue had been removed and which had been cast into a lucite (Plexit 55, Merck, Darmstadt, FRG) block measuring 21.1 cm × 14.6 cm × 14 cm (L × W × H; Fig. 1). The dissected aortae were randomly selected from routine autopsy cases.

We studied a total of 100 dissected abdominal aortae; 55 patients were male, 45 were female. The age range was 21 to 89 yr with a median of 63 yr. The atherosclerotic lesions were grouped in five categories (Table 1): no atherosclerotic lesions (grade 0), fatty streaks (grade 1), fibrous plaques (grade 2), mild (grade 3) and severe (grade 4) complicated lesions. The category "fatty streaks" is made up of aortae with fatty deposits but without any other lesions. The fatty deposits can be recognized by the yellow color of the lipids in the intima. The category "fibrous plaques" is comprised of vessels with focally raised atherosclerotic lesions but without ulcerations and calcium deposits. "Complicated lesions" are atherosclerotic changes made of varying combinations of fatty deposits, proliferations of connective tissue, necroses, and calcium deposits. Atherosclerotic changes were graded by an experienced pathologist using inspection and palpation of the lesions.

For each DPA measurement, the abdominal aorta was placed into a water bath above the LS-phantom allowing AP-scanning of the lumbar spine with the superimposed aorta

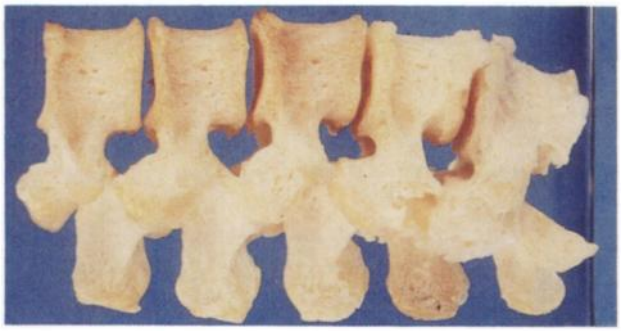

FIGURE 1
Lateral view of lumbar spine phantom.

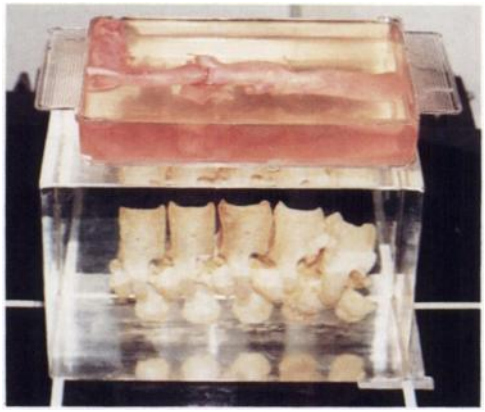

FIGURE 2
DPA measurement of LS-phantom with superimposed abdominal aorta.

(Fig. 2). The water bath contained distilled and deionized water with a constant filling height of 2.7 cm. It was left in place after the aorta was removed from it. The filling height was kept constant at 2.7 cm. To avoid artifacts produced by the passage of the beam in some regions through the water and its container, and in other regions through only the air above the lucite, the dimensions of the water bath were kept larger than the vertebrae of the LS-phantom. The values obtained were compared with control measurements performed after removal of the dissected aorta from the LS-phantom whose position remained unchanged.

For statistical evaluation, we used the Wilcoxon test for paired differentials.

RESULTS

Instrument precision for immediate repeat studies of the LS-phantom was within 0.01 g/cm^2, i.e. less than 1% relative to the measured BMC values. The average increase of the BMC values relative to the mean for the vertebrae L2–L4 as a function of different degrees of atherosclerotic lesions is shown in Table 2. The result of our studies demonstrate that for aortae with complicated lesions there is a significant ($p < 0.01$) increase in the BMC value.

As one would expect, there is no significant difference in the BMC values for aortae with fatty streaks and those with fibrous plaques. In aortae with mild complicated lesions, the mean deviations do not exceed the error of measurement and, therefore, the difference is not significant for an individual examination.

Figure 3 shows the increase of mean integral BMC values of lumbar vertebrae L2–L4 in relation to the degree of atherosclerotic changes. Relative to the mean for the vertebrae L2–L4 in controls, the average increase of the BMC values for aortae with severe complicated lesions was 0.03 g/cm^2, with a maximum deviation of 0.09 g/cm^2. With respect to the L2-L4 BMC of the LS-Phantom (1.14 g/cm^2), which is equal to the BMC of a healthy young adult, the percentage deviation is 2.4% (maximum deviation 7.4%), but in the osteoporotic range, overlying calcifications could well contribute to a relatively higher percentage change.

TABLE 1
Classification of Atherosclerotic Lesions

Grading	Classification	Samples	Mean age (yr)
0	No atherosclerotic changes	7	40
1	Fatty streaks	17	51
2	Fibrous plaques	26	64
3	Mild complicated lesions	33	69
4	Severe complicated lesions	17	72

DISCUSSION

One of the technical problems of DPA measurements of the lumbar spine performed in the AP-projection is that aortic calcification can affect the results (*3,7*). According to Krolner et al. (*8*) aortic calcification may account for overestimation of close to 10% of lumbar BMC in women with severe osteopenia.

In the North American white population, a substantial portion of autopsies of subjects of age 35 yr or older reveal atherosclerotic changes of the aorta (*9–11*). We, therefore, examined to what extent this potential and frequently occurring interfering factor may erroneously increase the BMC value of the lumbar vertebrae.

The results of our investigation on a total of 100 dissected abdominal aortae show that the presence of severe aortic calcification can cause an overestimation of the lumbar spine BMC, although the mean BMC increase for mild aortic calcification was about 0.01 g/cm^2, which is in the range of short-term reproducibility. In only 2 out of 17 cases with severe complicated lesions was the deviation of the BMC value greater than 0.05 g/cm^2. Our results are in agreement with those of Pouilles et al. (*12*), who reported on the influence of aortic calcification in six patients. They found a BMC difference of 0.006 g/cm^2, which was not statistically significant. This is probably because they studied only a small number of patients who apparently had mild aortic calcifications. In addition, they showed the small

TABLE 2
Quantitative Results of Study

Grading of atherosclerotic lesions	BMC L24* g/cm²	BMC L24A+ g/cm²	Mean BMC-increase g/cm²	Standard deviation g/cm²	Maximum deviation g/cm²	Probability value‡
0	1.14	1.15	0.01	0.01	0.02	0.1775
1	1.14	1.14	0.00	0.02	0.03	0.3967
2	1.14	1.14	0.00	0.01	0.02	0.2954
3	1.15	1.16	0.01	0.02	0.05	0.0003
4	1.14	1.17	0.03	0.02	0.09	0.0007

Note: The grading system of atherosclerotic lesions is given in Table 1.
* Mean BMC relative to the vertebrae L2–L4.
+ Mean BMC relative to the vertebrae L2–L4 with superimposed aorta.
‡ Wilcoxon test.

influence of compression fracture on BMC measurements, and the apparently large influence of osteophytes. We believe also, as Poilles has shown, that arthritic changes, and not aortic calcification or fracture, are the major source of artifacts.

Our findings are likely to be applicable to dual-energy X-ray absorptiometry studies performed in the AP-projection, due to the similar short-term reproducibility which can be achieved using gadolinium in place of X-ray sources (*13–15*). It seems likely that in the future most lumbar spine scans will be performed in the lateral projection, because a higher sensitivity to changes in bone density can be obtained by this approach and consequently the influence of the aorta would be unimportant. Unfortunately, beam-hardening and scatter, the major drawbacks of scanning in the lateral projection, have not yet been solved sufficiently. Further developments to improve the signal-to-noise ratio in lateral scanning are necessary and, therefore, measurements in the anterior projection must still be seriously considered and have not been replaced.

In summary, we have shown the relatively small influence of aortic calcification on BMC measurements done in the anterior projection.

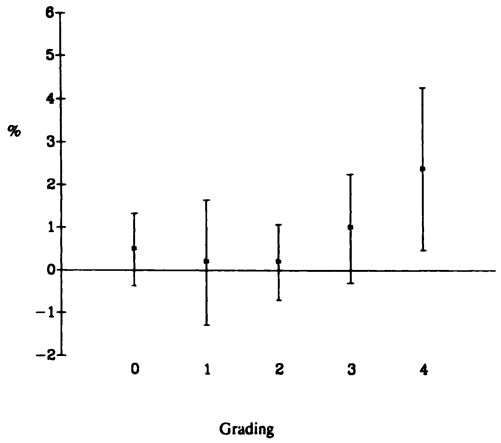

FIGURE 3
Relationship between average percentage increase of the BMC values (L2-L4) and the grading of the atherosclerotic lesions. Note: legend for grading is given in Table 1.

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