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The Influence of Aortic Calcification on Spinal Bone Mineral Density *In Vitro*

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Abstract. We examined the influence of aortic calcification on the spine phantom bone mineral density (BMD). Soft X-ray photographs of human aortae were taken to calculate the percent calcification of aortic tissues. Human aorta laid on lumber spine phantom was placed in the bottom of 15 cm of water and BMD and bone mineral content (BMC) were measured in the anteroposterior view. Samples with severe aortic calcification (over 30%) caused a 2.5% increase of BMD. There might be a relatively small influence of aortic calcification on the value of L2–L4 BMD, but changes over time in a patient could falsely elevate values.

Key words: Aortic calcification — Bone mineral density — Phantom.

At the present time, it is generally thought that an increase of spinal bone mineral density (BMD)(in g/cm^2) caused by aortic calcification is negligible because the problems introduced by aortic calcification are less than those due to degenerative changes in the spine [1–4]. On the other hand, some reports show cases where severe calcification can affect results [5, 6]. However, it is unclear how much calcification is needed before there is overestimation of spinal BMD. We examined the influence of aortic calcification, which was semiquantitatively evaluated using soft X-ray photography, on the spine phantom BMD.

Materials and Methods

Specimen

Human aortae were obtained from 20 autopsy cases (11 male, 9 female). The age range was 51–95 years, mean 60 years. The aortae were cut to about 5 cm long and opened longitudinally.

Determination of Percent Calcification

Soft X-ray photographs of all 20 samples were taken to calculate the percent calcification of aortic tissues (Fig. 1). The outlines of the aorta and of the dense type plaque were then traced onto tracing paper which was overlapped on each soft X-ray photograph. The semidense plaque and light-colored plaque were ignored. Each tracing paper was cut into calcified and noncalcified segments along the tracing line. In each sample of total aortic segments (calcified and noncalcified), only calcified segments were weighed, and we defined the ratio of the weight to the weight of total aortic segments as the percent calcification.

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Measurement of Bone Mineral Density (BMD) and Bone Mineral Content (BMC)

We used a spine phantom (Lunar Corp., Madison, WI) to simulate human lumbar spine [7]. Scans (medium speed) were carried out by a DPX-L dual energy X-ray absorptiometry (Lunar) that uses an X-ray tube operating at 0.75 mA. The region of interest (ROI) was established in L2–L4. The phantom was placed at the bottom of 15 cm of water in order to simulate soft-tissue thickness, and BMD and BMC were measured in the anteroposterior view three times. After that, a human aorta was laid directly on the phantom (inside of the phantom edges) and again BMD was measured three times (Fig. 2). Mineral content of the aortae was obtained by the difference between BMC of the phantom with and without the aorta. The percent change of BMD (% Δ BMD) caused by aortic calcification was obtained as follows:

$$\% \ \Delta \ \mathrm{BMD} = \frac{(\text{spine phantom with aorta BMD} - \text{spine phantom BMD})}{\text{spine phantom BMD}}$$

A reproducibility study was made by intra-day precision (a total of six consecutive measurements within a day) and long-term precision (a total of six measurements at 9-month intervals) on phantom and phantom with aorta, respectively. The precision was expressed as the coefficient of variation (CV).

Statistical Analysis

The StatView II program on a Macintosh computer was used for the statistical analysis. The statistical correlation was determined with nonparametric statistics by the Spearman rank correlation method.

Results

The precision error ranged from 0.2 to 0.7% (Table 1). The maximum %CV was 0.740, observed for long-term precision on the phantom with aorta.

Figure 3 shows the relation between the percent calcification estimated using soft X-ray photographs and the BMC of aorta estimated by a DPX-L technique. The percent calcification significantly correlated with the BMC of aorta ($r = 0.851$, $P < 0.05$).

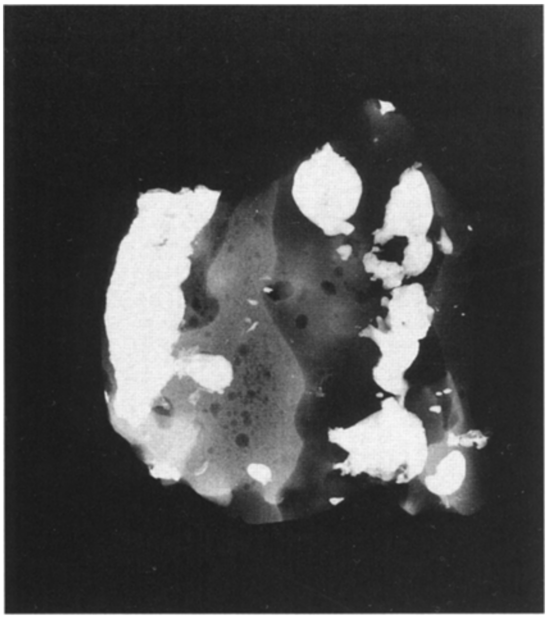

Fig. 1. Soft X-ray photograph showing aortic calcification.

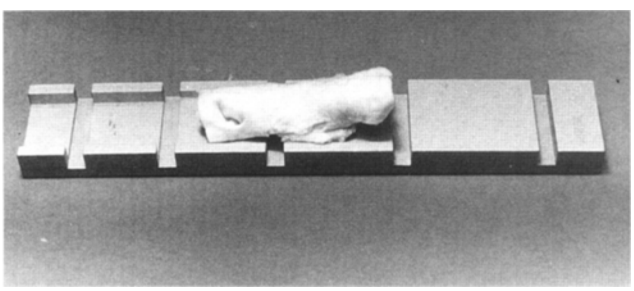

Fig. 2. Measurement of dual energy X-ray absorptiometry of spine phantom with superimposed aorta.

Figure 4 shows the relation between the percent calcification and % Δ BMD. When four samples with severe aortic calcification (percent calcification was over 30%) were laid on spine phantom, the % Δ BMD was 2.51 ± 0.75%. These values were over twice as much as that observed in long-term precision.

Table 1. Precision of the DPX-L technique

	Phantom		Phantom with aorta	
	BMD	BMC	BMD	BMC
Intra-day (%CV)	0.292	0.160	0.698	0.651
Long-term (%CV)	0.451	0.334	0.740	0.712

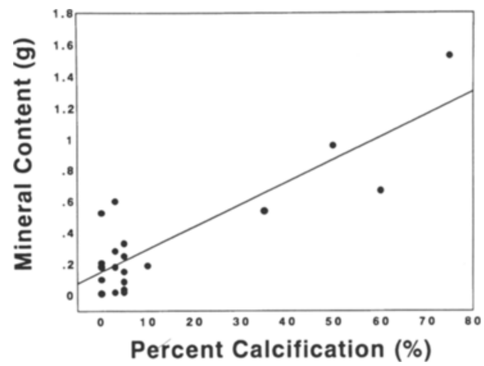

Fig. 3. The relation between the percent calcification estimated using soft X-ray photographs and the mineral content of aorta, estimated using a DPX-L technique (y = 0.014 × +0.149, r = 0.851, $P < 0.05$).

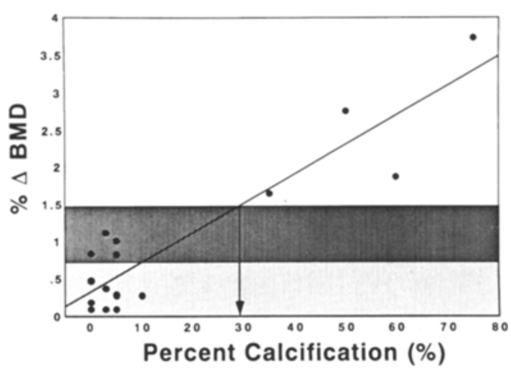

Fig. 4. The relation between the percent calcification and the percent delta of spine phantom BMD (% Δ BMD) (y = 0.040 × +0.333, r = 0.912, $P < 0.05$). The lower shadow area was the range of % Δ BMD less than 0.740% the value of which was observed in long-term precision on phantom with aorta BMD, and the upper shadow area ranged from 0.740% to 1.480% the value of which was twice as much as that observed in long-term precision on phantom with aorta BMD.

Discussion

In order to evaluate the increase or decrease of lumbar spine BMD or BMC, the estimation of the accuracy and reproducibility in the instrument are required. In this study, the intra-day precision on the phantom with aorta was about 0.7%.

In clinical and research situations, L2–L4 BMD in the anteroposterior projection is extensively used as an index of skeletal status. However, it has been suggested that BMD might be overestimated by aortic calcification; there is a high prevalence of aortic calcification in the elderly patients usually scanned. It was actually reported that in two other population samples, the prevalence of aortic calcification rose from about 10% in women aged 50–54 years to about 75% at age 80–84 years [8, 9]. There are some crude methods to evaluate aortic calcification, for example, on lateral roentgenograms, but it is difficult to evaluate quantitatively. In our study, we calculated the percent calcification and BMC using dissected aorta in order to evaluate how much calcification actually occurred. The percent calcification significantly correlated with the BMC of aorta, so it was thought that the percent calcification evaluated on the soft X-ray photograph reflected the extent of aortic calcification.

Some reports have suggested that aortic calcification could influence the measurement of integral spine BMD [5, 10]. Krølner et al. [1] found an insignificant overestimation with mild calcification but 10% overestimation when aortic calcification was severe and osteopenia pronounced. Pouilles et al. [2] found an even smaller effect in a limited number of osteoporotic subjects, and Reid et al. [4] found no such relationship in normal women. Frye et al. [6] reported that lumbar spine BMD was not significantly increased by aortic calcification generally but that it averaged about 7% greater than expected among the women with severe grades of aortic calcification. We saw only a modest effect with severe calcification. Moreover, the overestimation of BMC caused by the calcified aortae is small relative to the weight of the lumbar vertebra, particularly in view of other accuracy errors [11].

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