Subregional BMD and Bone Volume Fraction in the Human Vertebral Body examined by DXA and Micro-CT

INTRODUCTION:
The aim of this study was to measure Bone Mineral Density (BMD) by lateral DXA in three subregions of the L2 human vertebra, and to compare it with measurements of bone volume fraction (BV/TV) in analogous subregions obtained by micro-CT.

The evaluation of fracture risk of patients is usually conducted using dual-energy X-ray absorptiometry (DXA) of the lumbar spine. Posterolateral (PA) projections are performed, with areal bone mineral density (BMD) measurements calculated for the whole vertebral body (L2, L3). Despite BMD is significantly correlated to bone strength, using it to identify individuals who will suffer a fracture is not always reliable [1].

The bone distribution and microstructure, and thus bone strength, might vary within the vertebra [2,3]. Subregional BMD measurements, done by using lateral DXA scanning modality, might be informative about vertebral fragility [4]. The intra-vertebral BMD may be a discerning characteristic between individuals that will or will not undergo an osteoporotic vertebral fracture.

Nowadays, micro-computed tomography (micro-CT) allows three-dimensional structural characterization of entire bone segments, non-destructively and at high resolution.

To assess the capability of lateral DXA to determine subregional variations in bone distribution, the present study examined L2 human vertebrae first by DXA and then by micro-CT.

METHODS:
Eight human cadaver spines were examined (age at death 77.5±10.4 years). These were immersed in a water bath and scanned by DXA in PA projections and in lateral projections.

Approval to use the specimens for research purposes was granted by the Human Research Ethics Committee at the Royal Adelaide Hospital, South Australia, and Curtin University of Technology, Western Australia, in accordance with the Declaration of Helsinki, 1975.

Subregional areal BMD analysis (densitometer Hologic QDR4500, Hologic, Waltham, MA, USA) was performed in lateral projection of the L2 vertebra. Three subregions (superior, central, inferior) of interest were defined manually using Hologic software, and precision has been established previously [4].

The L2 vertebrae were then dissected and entirely scanned by micro-CT (17.4 µm pixel size, Skyscan 1076, Skyscan Kontich, Belgium). The micro-CT volume of interest comprised the trabecular bone of the entire vertebral body, built as a stack of axial cross-sections. This volume was divided via software into three analogous subregions with equal height (superior, central, inferior) from which BV/TV was measured.

Statistical analysis: a one way repeated measures ANOVA was performed on each outcome measure, to investigate whether there were significant differences between these. Pairwise comparisons were used to explore differences between subregions. Linear regression was used to investigate the correspondences between DXA and micro-CT variables.

RESULTS:
For both DXA and micro-CT, the values of the subregions differed significantly from the values over the whole vertebral body (p<0.01).

Significant differences between the subregions were found for both BMD and BV/TV (p<0.01), both showing higher values in the inferior subregion than in the superior subregion (p<0.05).

While the BMD measured laterally over the whole vertebrae was significantly related to the total BV/TV (R² =0.59, p<0.05), the BMD measured in the PA projection was not (p=0.33).

In the central subregion, the linear regression ‘BV/TV vs. BMD’ had the highest coefficient of determination (R² =0.80, p<0.01), compared to the inferior and superior subregion (figure).

DISCUSSION:
Significant differences between the parameters measured over the whole vertebra and the subregions were found by both techniques, and both DXA and micro-CT showed higher values in the inferior compared to the superior subregions.

These results suggest that, in contrast to PA BMD measurements, measurements done using lateral DXA scanning in the L2 vertebra are significantly related to trabecular BV/TV measured by micro-CT. In particular, subregional BMD measurements were highly related to trabecular bone volume fraction in the central part of the vertebral body.

These findings support lateral DXA examination as a valuable modality for improving the evaluation of vertebral fragility.

REFERENCES: