Predicting whole vertebral body strength from bone mineral density assessed via DXA and microarchitecture assessed via micro-CT:

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INTRODUCTION:

Strong relationships exist between areal bone mineral density (aBMD) derived from dual energy X-ray absorptiometry (DXA) and bone strength. However, the predictive validity of aBMD for osteoporotic vertebral fractures remains suboptimal.

Rather than assessing aBMD from commonly used posterior-anterior (PA) projections, the diagnostic sensitivity of DXA may be improved by assessing aBMD from lateral projections.

It is now possible using X-ray micro-computed tomography (micro-CT) to perform three-dimensional structural characterization of entire vertebral bodies, non-destructively and at high resolution, with subsequent mechanical testing to measure bone strength.

The aim of this study was to measure aBMD by lateral-projection DXA and PA-projection DXA and bone volume (BV) by micro-CT and to assess their respective capability to predict vertebral body strength determined experimentally.

METHODS:

Seven human cadaver spines (age at death 78±10 years) immersed in a water bath were scanned by DXA in PA and lateral projections, and aBMD for L2 vertebrae was determined.

Standard aBMD analysis (densitometer Hologic QDR4500, Hologic, Waltham, MA, USA) was performed using PA-projection and lateral-projection images of the L2 vertebrae.

The L2 vertebrae were then dissected and entirely scanned by micro-CT (18µm pixel size, Skyscan model1076, Skyscan Kontich, Belgium). BV was calculated over the micro-CT trabecular bone volume of the entire vertebrae.

For mechanical testing the vertebral endplates were embedded in 3mm layers of poly-methyl-methacrylate (PMMA). After polymerization the construct was placed in saline solution for 12 hours before testing. During mechanical testing the bone specimens were kept moist with saline.

Uniaxial compression tests were preformed to determine ultimate load (Fult) (TestResources, model 800L, TestResources Inc., Shakopee MN USA) with the following operating settings.

Preconditioning (load control): 5 cycles at 0.1 Hz from 150N to 350N (250N mean), then held at 250N for 5min. Test to failure (displacement control): Actuator speed: 0.15mm/s. Endpoint: manually set at 1mm displacement after peak load.

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.

Statistical analysis: Regression analysis was performed to determine the ability of aBMD or BV to predict ultimate load (bone strength). Regression analysis was performed to determine the relationships between aBMD measured from PA-projection, lateral-projection DXA and BV measured from micro-CT analysis (SAS, SAS Inc, Cary, NC, USA). P<0.05 was considered to be statistically significant.

RESULTS:

Both aBMD by lateral-projection DXA and BV by micro-CT were strongly predictive of ultimate load (r²=0.89, p<0.01, and r²=0.89, p=0.01, respectively) (Figure 1 and Figure 2, respectively). However, aBMD by PA-projection DXA was not significantly related to ultimate load (r²=0.37, p=0.15).

DISCUSSION:

These data highlight the capability of aBMD assessed using lateral-projection DXA to predict vertebral body strength, with a coefficient of determination similar to BV measured from micro-CT images. This is in contrast to the commonly used PA-projection DXA, which showed no significant relationship between aBMD and vertebral body strength.

In addition, the strong correlation between aBMD measured from lateral-projection DXA and BV measured from micro-CT images suggests that aBMD measured using lateral-projection DXA provides an effective surrogate for the volume of trabecular bone in the vertebral body, in contrast to PA-projection DXA.

These findings provide the basis for further exploring the clinical application of lateral-projection DXA analysis.

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