The Ability of Flat-Panel Fluoroscopy CT to Quantify Vertebral Trabecular Architecture

INTRODUCTION

Osteoporosis is an affection of the skeleton in elderly leading to loss of bone mass and strength and, consequently, to an increased bone fracture risk. These fractures should be prevented rather than treated. This requires an accurate diagnosis of bone strength. The overall aim of the EU-funded VPHOP research project is to obtain an improved patient-specific assessment of the current and future risk of fractures by using multiscale hypermodels based on multi-level imaging methods that also include the bone micro-architecture. These images are used to determine bone strength either directly (using micro-finite element methods) or indirectly from structural parameters [1]. The latter requires imaging methods that can resolve trabecular architecture in vivo, but current imaging methods do not provide sufficient detail at sites that suffer most from osteoporotic fractures: hip and vertebra. Recently, high-resolution flat-panel fluoroscopy with CT applicability has been developed. These devices can potentially be used to resolve the bone architecture at the hip and vertebra and the main goal of this study is to assess the potential of using such a device, XperCT (Philips Healthcare) to quantify bone structural and mechanical parameters.

MATERIALS AND METHODS

Ten sets of human cervical vertebrae (47-95 yr) were scanned while submerged in embalming fluid with an XperCT prototype resulting in reconstructions with a voxel size of 150 μm and with a microCT 80 (Scanco Medical AG, Switzerland), voxel size: 37 μm (Fig. 1). The reconstructions of C3 of both scans were aligned using image registration (Fig. 2) to enable the selection of identical cylindrical volumes of interest in the vertebral body. To segment the bone tissue, a global threshold was used on the original data and after a) Laplace Hamming filtering ( LH), b) resolution doubling and LH filtering (x2+LH) c) resolution doubling and unsharpen filtering (x2+US). The segmented volumes were used for the calculation of standard morphological parameters and were transformed into finite element models to predict bone stiffness (E). Paired-sample t-tests were applied to compare the XperCT values to the microCT ones (SPSS 16.0).

RESULTS

Image registration of the C3 vertebrae resulted in a good match (Fig. 2). This is especially appreciated when comparing matching slice reconstructions from both scans (Fig. 3) in which individual trabeculae can be easily recognized. The different filtering processes improved the quantitative results, especially the Laplace Hamming filter without and the unsharpen filter with resolution doubling: bone volume fraction, trabecular number and separation, anisotropy, and stiffness were quantified accurately by showing values that were statistically the same as the microCT values (Table 1, P > 0.05). Trabecular thickness and connectivity could not be measured accurately.

DISCUSSION AND CONCLUSION

These results show that quantitative assessment of various architectural parameters is feasible with XperCT. The Laplace-Hamming and unsharpen filtering implemented here dramatically improved the results. The resolution obtained in this study (150 μm) is close to the trabecular thickness and it is therefore obvious that this parameter cannot be measured accurately. Earlier studies with pQCT devices, however, have demonstrated that trabecular thickness can be well measured at 150 μm when correction factors are used [Laib and Rüegsegger, 1999].

Although more work is warranted to establish the accuracy of XperCT, e.g. scanning lumbar and thoracic vertebrae with a thorax phantom, this study demonstrates the potential clinical application of XperCT as a tool for assessing cancellous bone morphology and mechanical properties at the hip and vertebra.

REFERENCES


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