INTRODUCTION

With the introduction of high-resolution peripheral quantitative computed tomography (HRpQCT) scanners, detailed three-dimensional in vivo imaging of human radii has become possible. Scanning can be performed multiple times such that the exact same bone volume can be analyzed at multiple time points, and bone modeling and remodeling in individual patients can be quantified in terms of microstructural changes. In contrast, previous studies on bone micro-architectural changes have mainly relied on bone biopsies at non-fracture sites, taken from relatively small cohorts.

The aim of this study was to measure in a large cohort changes in bone micro-architecture taking place during three years and to quantify the effects on bone strength.

METHODS

In 403 men and women (age 60±15), representing an age-stratified random sample of community adults from Rochester, Minnesota, USA, one distal radius was scanned twice at an interval of approximately three years. Measurements at the first time point (TP1) were made with a prototype of the scanner with which measurements at the second time point (TP2) were made (XtremeCT, Scanco Medical AG, Brüttisellen, Switzerland). At TP1, scans were made with a voxel size of 90 * 90 * 89 μm. At TP2, this was slightly smaller; 82 μm isotropic. Three-dimensional image registration [1] was performed to determine the bone volume common to both scans. 29 paired scans had to be excluded for technical reasons, leaving 374 datasets (177 male, 197 female) for morphometry and strength analyses. Average age was 61±17 in male and 60±14 in female subjects.

The morphometry analyses were performed on the volume present at both TPs, using the otherwise standard evaluation protocol provided by the scanner manufacturer. Measures of volumetric bone mineral density (vBMD), trabecular bone volume fraction (BV/TV), trabecular number (Tb.N), trabecular separation (Tb.Sp), cortical thickness (Ct.Th) and average area per slice (area) were taken. Bone strength was determined from micro-finite element (μFE) analyses using a previously validated voxel-based modeling approach [2].

All results of the measurements at TP2 were corrected for the scanner exchange. These results were based on the results of a cross-over study between the two scanners, in which 27 subjects were measured with both systems on the same day [3].

To test for differences between TP1 and TP2, paired samples t-tests were performed for all parameters, except for Tb.Sp and area. These data did not have a normal distribution, therefore, a Wilcoxon Signed Ranks test was used instead. For all statistical tests, p<0.05 was defined as level of significance. Linear regression analyses were performed between the morphometric parameters and bone strength.

RESULTS

Significant differences between TP1 and TP2 were found for vBMD, Tb.Sp, Ct.Th and area (Table 1). Among female subjects only, all parameters differed significantly (Table 2). For male subjects, BV/TV and Tb.N were not significantly different (Table 3). The most remarkable difference between males and females was seen in bone strength: it significantly increased 1.1% in male subjects, while for females, it decreased 1.9%. Furthermore, vBMD, BV/TV and Ct.Th decreased more in women, while the increase in Tb.Sp was greater in women.

BV/TV and Tb.N had the highest correlation with bone strength (R = 0.75 and 0.72, respectively); yet, the change in BV/TV and Tb.N correlated only poorly to the change in bone strength (R = 0.57 and 0.08, respectively). Single linear regression analysis showed that the change in bone strength was best predicted by the change in vBMD and BV/TV (R = 0.57 and 0.47, respectively). A model including both the changes in BV/TV and vBMD improved the correlation to R = 0.62. A stepwise multiple linear regression analysis showed that a model including the changes in vBMD, BV/TV, area, and Tb.Sp can predict the changes in bone strength with an R value of 0.71.

DISCUSSION

Remarkable differences between men and women were seen in this cohort. Men showed no significant changes in BV/TV and Tb.N over three years, while women did. Furthermore, opposing results were found for bone strength. In men strength increased over three years, while in women it decreased. This can possibly be explained by the fact that vBMD and BV/TV, changes of which account for 39% of the change in bone strength, decreased more in women than in men.

This study also showed the importance of an individual approach for the quantification of bone modeling and remodeling; widely varying differences were seen in the microstructural parameters, shown by the high standard deviations, whereas the group averages only showed small changes between the two TPs.

In conclusion, we evaluated bone remodeling at the distal radius in a cohort. Men showed no significant changes in BV/TV and Tb.N over three years, while women did. Furthermore, opposing results were found for bone strength. In men strength increased over three years, while in women it decreased. This can possibly be explained by the fact that vBMD and BV/TV, changes of which account for 39% of the change in bone strength, decreased more in women than in men.

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