Using 3-dim Scaling Properties in Magnetic Resonance Images for the Prediction of Osteoporotic Fractures

Bone structure, in addition to bone mineral density, is an important component in determining bone strength and risk of fracture. High resolution magnetic resonance imaging (HR-MRI) has recently been introduced to assess bone structure. In this project we are using a newly developed 3D-based scaling index method in comparison with standard 2D-techniques based on bone histomorphometry to analyze HR-MR images of the distal radius to investigate the trabecular structure in patients with and without osteoporotic spine fractures. These structure analysis techniques were compared with BMD in their diagnostic performance to differentiate patients with and without fractures.

Methods and Materials:

Axial HR-MR images of the distal radius were obtained at 1.5 T in 66 women (28 postmenopausal women with osteoporotic spine fractures and 38 postmenopausal controls). A three-dimensional gradient-echo sequence was used with a voxel size of 500x195x195 µm. Trabecular structure analysis was performed using algorithms based on our new local 3D scaling index method as well as standard morphological 2D parameters. In addition BMD measurements of the spine using quantitative CT (QCT) and dual energy X-ray absorptiometry (DXA) were obtained in all patients. Receiver operating characteristics (ROC) analyses were used to determine the diagnostic performance in differentiating patients with and without fractures. The results were statistically validated using bootstrapping and jackknifing techniques.

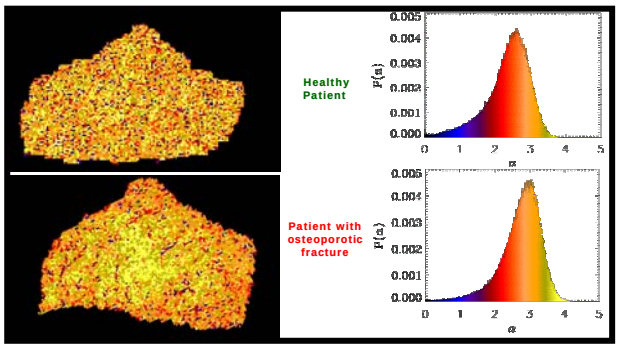

Figure 1: Color coded images of the segmented part of axial HR MR images of the distal radius. The colour coding corresponds to the α-value of each pixel The different filter response to different structural elements is obvious.

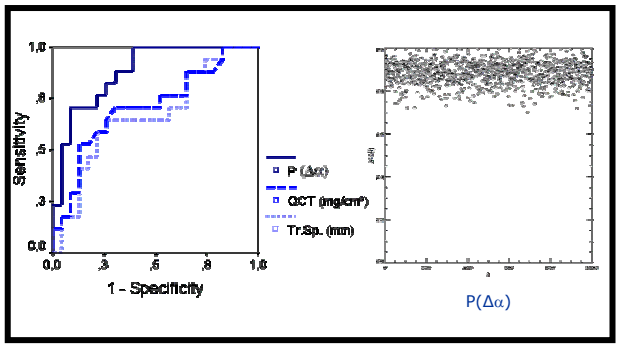

Figure 2: Left: ROC-curves comparing P(Δ α) (Az=0,88), BMD (Az=0,71) and apparent trabecular separation as the best 2D-Parameter (Az=0,69). Right: The diagram represent the Az-(AUC)-results of the bootstrap method for P(Δα).

Results:

Significant differences between both patient groups were obtained using structure analysis and spine BMD ($p<0.01$). In comparison with BMD of the spine (Area under curve (AUC)= 0.72) and the 2D based structure parameters (AUC up to 0.69) the best results were found for the local 3D scaling index method (AUC=0.87). For the bootstrapping technique the AUC-values calculated for the scaling index method (mean value: 0.862, standard deviation: ± 0.009) were significantly better ($p<0.001$) than those measured with BMD (0.721, ± 0.016) or the standard 2 D parameters (0.693, ± 0.015).

Conclusion:

The results of our study show that trabecular structure measures derived from HR-MRI of the radius using a newly developed algorithm based on a local 3D scaling index method can improve the diagnostic performance in differentiating postmenopausal women with and without osteoporotic spine fractures.

References:
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•2.Rath, C et al., Analysing large-scale structure - I. Weighted scaling indices and constrained randomization. Mon Not R Astron Soc 2002

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