

QUANTITATIVE EVALUATION OF TRABECULAR BONE STRUCTURE BY CALCANEUS MR IMAGES TEXTURE ANALYSIS OF HEALTHY VOLUNTEERS AND OSTEOPOROTIC SUBJECTS

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Abstract - The aim of this study is to evaluate, in vivo, trabecular bone structure of the calcaneus of healthy volunteers and osteoporotic patients by texture analysis of MR images. Automated methods of texture analysis cover a wide range of techniques enabling quantitative analysis of grey level intensity and distribution within a region of interest (ROI).

Texture analysis is not used very frequently since the interpretation of the large number of calculated parameters is difficult. We here apply multiparametric data analyses such as Correspondence Factorial Analysis (CFA) and Hierarchical Ascending Classification (HAC) to determine the relevant parameters to differentiate between two sets of images (healthy young volunteers and osteoporotic older patients).

Keywords – Magnetic Resonance Imaging ; Texture analysis ; Correspondence Factorial Analysis ; Hierarchical Ascending Classification ; bone structure ; calcaneum ; osteoporosis.

I. INTRODUCTION

Osteoporosis diagnosis and treatment are actually two of the major priorities in public health. Since Copenhagen conference consensus in 1993, osteoporosis is defined as a skeletal diffuse disease characterized by bone mass reduction and micro architecture deterioration leading to an increase of bone fragility and fracture risk. Prevention is certainly the best way to reduce significantly the public health costs for this disease. It is most important to detect subjects at risk as soon as possible to enable a preventive therapy.

The most common method to evaluate bone mass is dual X-ray absorptiometry [1, 2]. This is a non-invasive, precise and reproducible method using low radiation but it doesn't provide any information about bone texture. On the other hand, quantitative micro architecture evaluation is possible with histomorphometry [3], but this is an invasive technique that cannot be used for diagnosis.

MR texture analysis methods, which have already been described in several papers [4, 5] seem to be a good approach to evaluate calcaneus structure for comparison between healthy and osteoporotic subjects.

This study makes part of an on going project (in-vitro and in-vivo) on trabecular bone tissue characterization combining different techniques such as MRI, histomorphometry, densitometry and ultrasonography.

The long-term purpose is to set up a calcaneus architecture analysis by MRI that could be used routinely to improve fracture risk prediction and to assess anti osteoporotic treatment efficiency.

II. METHODOLOGY

A. MR imaging

15 subjects were included in this study : 9 controls (20-30 years old healthy young women) and 6 osteoporotic patients (50-75 years old women with a decreased bone density ($Tscore^* < -2.5$) and an osteoporotic fracture or spine wedging. Images were acquired on a Signa 1.5 T whole body imaging system (GE, Buc, France).

The subject is placed supine, the non-dominant foot in a GE special antenna built for extremity imaging.

A T1-weighted Spin-Echo sequence was first used for calcaneus location in the sagittal plane (TE=13ms, TR=300ms, FOV=120*120mm, Matrix size = 256*128, 1 excitations), (Fig.1). A Gradient-Echo sequence was then applied in the axial plane (TE=14ms, TR=44ms, FOV=60*40mm, Matrix size = 512*256, 6 excitations). By this, 1 mm slices were obtained with an in-plane resolution of $117*156\mu m^2$ (Fig.2).

$$* Tscore = \frac{M - C}{SD}$$

M : measured value

C : mean value for sex-matched young control

SD : standard deviation for the mean value for sex-matched young control



Fig. 1 : Foot sagittal slice.

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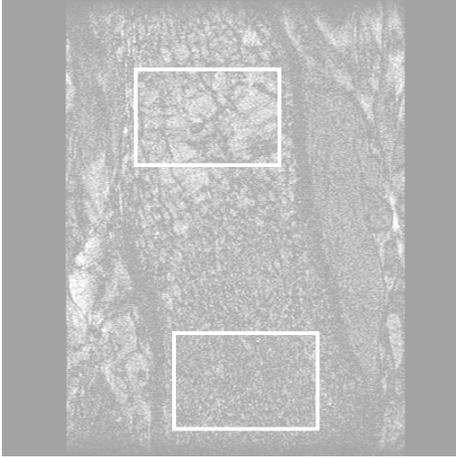


Fig. 2 : Calcaneus axial slice to be analyzed

B. Texture analysis

Firstly images have been normalized to adjust their grey levels to the 8-bit interval.

Due to the heterogeneity of the calcaneus, 2 different regions of interest (ROI2 and ROI3) have been chosen (Fig. 2) for texture analysis regarding the following criteria :

- One ROI of the whole calcaneus (ROI1) has been taken to evaluate if the global analysis of the calcaneus reports of its heterogeneity.
- ROI2 was chosen from the region of high trabecular bone density.
- ROI3 was drawn where trabecular bone was sparse.

The rectangular ROIs have been chosen as large as possible (about 5000 pixels) for the smallest part at the bottom of a patient calcaneus. Care has been taken to avoid partial volume with cortical bone. This size was then kept for all subjects and for all ROI.

Four different texture analysis methods have been applied to evaluate those ROI (histogram, gradient matrix, cooccurrence matrix and runlength matrix). Each of the three ROI was by-this characterized by a 45 texture parameters profil (Table1).

III. RESULTS

C. Data analysis

Firstly, CFA were performed to determine the most significant texture parameters for the distinction between healthy volunteers and osteoporotic patients with a confidence level of 0.95. Then a two-classes HAC was used to calculate sensitivity (true positive/(true positive+false negative)), specificity (true negative/(true negative+false positive)) and global value (number of well classified subjects) of the method for the distinction between those two populations.

TABLE I
CALCULATED TEXTURE PARAMETERS

Statistical methods	Directly calculated parameters
<i>Histogram</i>	mean, variance, skewness, kurtosis, percentile 1, 10, 50, 90, 99
<i>Cooccurrence matrix</i> (d, θ) $d=1, \theta=0^\circ, 45^\circ, 90^\circ, 135^\circ$	contrast, correlation, homogeneity, entropy
<i>Gradient matrix</i> (3*3 mask)	mean, variance, skewness, kurtosis
<i>Runlength matrix</i> $\theta=0^\circ, 45^\circ, 90^\circ, 135^\circ$	Long or short runlength emphasis Grey levels and runlength distribution Run percentage

TABLE II
RESULTS OF THE DISCRIMINATION BETWEEN THE TWO POPULATIONS
WITH THE DIFFERENT ROI

	Sensitivity	Specificity	Global value
ROI1 (whole)	67%	56%	60%
ROI2 (bottom)	100%	44%	67%
ROI3 (middle)	67%	67%	67%
ROI2+ROI3	83%	78%	80%

The most discriminant parameters evidenced with CFA were : contrast (with $0^\circ, 45^\circ, 90^\circ$ or 135° cooccurrence matrix), grey level mean (histogram) and runlength distribution (with $0^\circ, 45^\circ, 90^\circ$ or 135° runlength matrix).

Best sensitivity was obtained with ROI1, best specificity with ROI2 and 3 and best global value with ROI2 and 3.

IV. DISCUSSION

Considering ROI2 and ROI3 together in texture analysis increase the well classified subjects (80% instead of 60% or 67%) and the specificity of the study.

The initially performed analysis of the texture of the whole calcaneus showed minor discriminative power. In contrast the analysis of well defined subregions increase the global value of about 20%. So obviously different ROI (2 and 3) have to be considered in the calcaneus.

Osteoporotic patients have the same texture profil in ROI2 as they are all gathered in the same class. This is not the case for healthy subjects which are always shared in two classes whatever the region considered.

V. CONCLUSION

This study shows that relevant texture information can be extracted from calcaneus images for osteoporosis characterization. It seems that those data are more pertinent in ROI where bone structure is more homogeneous.

Such texture information could be helpful in diagnostic to improve fractures risk prediction and to assess anti osteoporotic treatment efficiency.

The perspectives for further work are the following : a) to increase the subjects number ; b) to add another population (elderly healthy women) c) to associate texture information with bone mass and ultrasonography parameters to increase the study sensitivity.and d) to correlate in-vitro texture analysis parameters with histomorphometric parameters.

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