T2*-relaxometry and 1H-MRS at 3T applied to healthy and osteoporotic subjects: preliminary data supporting a new procedure to evaluate bone fracture risk.

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Introduction: Bone Mineral Density (BMD) accounts only for about 60% of the global risk of bone fracture. This lack of sensitivity is due to the partial information that BMD provides on spongy bone characteristics, assessing exclusively its mineral component quantification. Other components, such as bone marrow, collagen, and proteins, are present in spongy bone tissue, and may contribute in determining its resistance to fracture. Previous MR studies have showed that MR interferometry [1,2] approach, based on T_2^* measurements, might be a useful tool for the evaluation of osteoporosis. This is because T_2^* is sensitive to the difference in magnetic susceptibility between trabecular bone and bone marrow. The dephasing of the transverse magnetisation due to susceptibility differences produces a T_2^* shortening. An increase in trabecular spacing (i.e. a decrease in trabecular bone density), for instance induced by osteoporosis, reduces the spatial field inhomogeneity and prolongs T_2^* [3]. However the large standard deviation associated to the mean T_2^* value of both healthy and osteoporotic subjects, do not allow to use this method in clinical practice. Finally, recent studies suggest a correlation between the increase of bone marrow fat and the decrease in trabecular bone density [4] In this study we evaluated T_2^* as function of both lipids-water content and trabecular bone density in healthy and osteoporotic calcanei to investigate the source of individual variability which affects T_2* measurements.

Methods: This study was approved by the local Ethics Committee and written informed consent was obtained in all cases. Eight women with osteoporosis (T-score -2.6 or less); age range: 60-70 years), eight age-matched healthy and osteopenic women (T-score -2.4 or more) and eight young (age 24±2 years) healthy women were investigated at 3.0T. T_2* from FLASH images and bone marrow ^{1}H-spectra (Single-Voxel Spectroscopy) were collected from calcanei of each subject. For every volunteer, sagittal view images obtained on the same slice (5 mm thickness) and by using the same foot position were acquired at various *TEs* (5,7,10,20 ms), TR=1500ms, NS=1, square FOV=192mm, Matrix 128X128. No chemical presaturation pulses were used for either fat and water protons. Relaxation decay curves were analysed by assuming mono-exponential decay behaviour. ^{1}H-spectra obtained with TE=22ms, TR=5 s, NS=32 and voxel size of 15x15x15 mm positioned in the centre of the calcaneus, were used to calculate individual percentages of bone marrow fat content by assessing the Methylene-Methyl to water peaks area ratios.

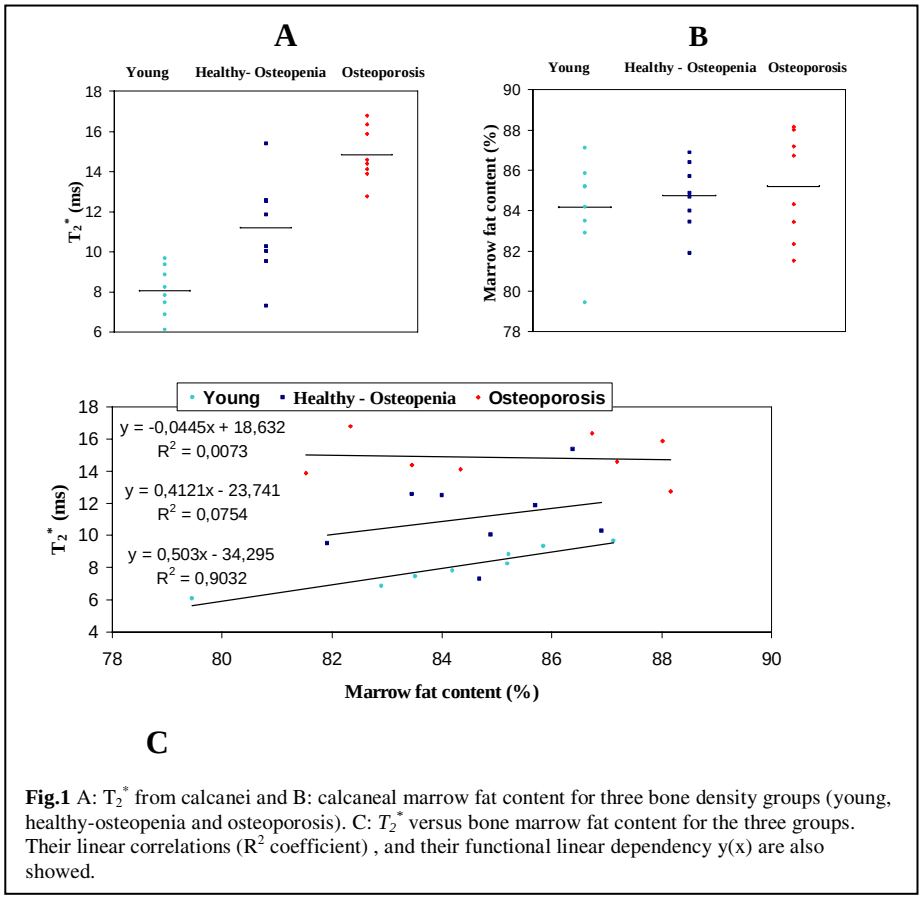

Fig.1 A: T_2^* from calcanei and B: calcaneal marrow fat content for three bone density groups (young, healthy-osteopenia and osteoporosis). C: T_2^* versus bone marrow fat content for the three groups. Their linear correlations (R^2 coefficient) , and their functional linear dependency y(x) are also showed.

Results: T_2^* values were significantly higher in osteoporotic compared to healthy-osteopenic women (T_2^* values: [14.8±1.4]ms and [11.2±2.4] ms respectively; p=0.0005). Moreover T_2^* values of young healthy women were the lowest (T_2^* values: [8.1±1.2]ms, p=0.0001), Fig.1A. A wide variability of bone marrow fat content even in the bone marrow of young healthy women (in a very short range age) was observed (Fig.1B) and high linear correlation was found between the T_2^* and the marrow fat content of young women. Conversely, a feeble trend towards linear correlation and no linear correlation were found between the T_2^* and the marrow fat content of healthy-osteopenic and osteoporotic women respectively, Fig.1C.

Discussion and Conclusion: Preliminary results reported here indicate that the large T_2* mean values standard deviation is mainly due to the wide individual variability in fat and water content of the bone marrow. Data obtained in young subjects demonstrate that the T_2* mean values standard deviation is not related to trabecular bone density but is linked with the wide individual variability in bone marrow fat content. Data obtained in healthy-osteopenic and osteoporotic subjects confirm the potentiality of T_2* measurements in discriminate subjects characterized by different trabecular bone density. Plots in Fig.1C show a similar slope for both young healthy and postmenopausal healthy-osteopenic women. The poor linear correlation of the postmenopausal healthy-osteopenic group is probably due to the presence of osteopenic subjects. Because of a dramatic alteration of trabecular bone density and microstructure, together with an alteration of bone marrow fat content in osteoporotic subjects, no linear correlation was found between T_2^* and marrow fat content of osteoporotic women. These preliminary findings indicate that calcaneal T_2* as function of bone marrow fat content is a sensitive measure to discriminate between healthy and osteoporotic women. As a consequence the combination of T_2* and ^{1}H-spectroscopy assessment might contribute in a better prediction of bone fracture risk.

References: [1] Wehrli FW et al. Radiology 1991;179:615-621. [2] Link TM, et al. Radiology 1998;209:531-536. [3] Chung H, et al. PNAS 1993;90:10250 10254. [4] Yeung DKW, JMRI 2005;22:279-285.