Internal gradient evaluation in spongy bone heel as a potential marker for osteoporosis disease

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Introduction

In osteoporotic spongy bone, the trabecular bone micro architecture is rearranged or disrupted and bone marrow quality is altered. Up to date T_2* is the most used MR parameter to evaluate the spongy bone status [1]. In fact, T_2* probes the micro-structure of the trabecular bone because it is sensitive to the microscopic field inhomogeneities caused by the magnetic susceptibility differences between the solid bone structure and the liquid bone marrow. In this study we propose an alternative way of evaluating the influence of the susceptibility differences in the spongy bone. It is based on the evaluation of the internal gradient G_i extracted from Spin-echo decay as usually performed in porous systems investigations [2]. However, the value of G_i is not only affected by magnetic susceptibility differences linked to trabecular bone density, but also by fat and water diffusion in bone marrow. Recent reports showed the ability of MRI to detect, from the calcanei of postmenopausal women, the presence of peripheral osteoporosis. Aim of this work was to assess, in vivo, the potential ability of G_i to describe the spongy bone status when applied to postmenopausal women, and to identify the most promising heel locations to assess the presence of osteoporosis. As a consequence, in the same subjects, ADC and G_i were measured from the whole calcaneus, the whole talus. Three different regions of the calcaneus were considered: the subtalar (ST) the tuber (TC) and the cavum calcanei (CC) and the talar region of talus (**Fig. 1**). ADC and G_i were correlated with the correspondent bone-mineral-density (BMD) obtained by lumbar QCT from each volunteer.

Methods and Materials

Briefly, when a spin-echo sequence is used to study a tissue characterized by strong internal gradients (G_i), the echo signal decays is described by: $S(TE) \propto \exp\left(-TE/T_2^{true} - (\gamma G)^2 D \cdot TE^3/12\right)$, which takes into account the spin diffusion between the two pulses in regions of different effective magnetic field [2,3]. By taking in consideration this contribution, it is possible to quantify G_i with a simple fitting procedure. The internal gradient was obtained from the Levengerg-Marquardt fit of the signal generated from spongy bone marrow.

Sixty women (twenty-five with osteoporosis, twenty-five with osteopenia, and ten healthy controls) were enrolled for the present study, and imaged using a 3.0T MR scanner. GE at different TEs (from 4ms to 25ms), SE sequence at different TEs (from 12ms to 100ms) and Diffusion-Weighted images (DWI) using phase diffusion gradients ("b values" 0-8000 s/mm^2) were collected from the calcanei of each recruited subject. GE, DWI and SE were used to derive T_2*, ADC and G_i values respectively. Statistical group comparisons were performed using Pearson's correlation coefficient. Correlations between T_2*, G_i, ADC and BMD, were investigated. A Multivariate linear regression was performed to establish the most sensitive MR parameter and the best location to detect osteoporosis disease.

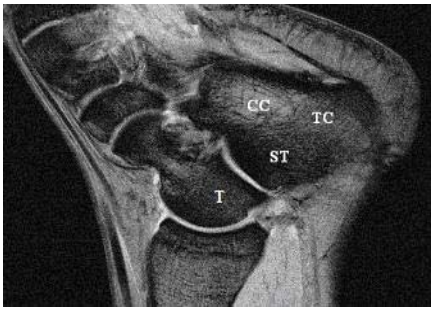

Fig. 1 Sagittal MR image of the heel with the zones considered in this study: ST, subtalar region, TC, tuber calcanei region, CC, cavum calcanei region in calcaneus; T, talar region in

Results: T_2^* values did not discriminate between osteopenic and osteoporotic women in TC. Conversely, they were significantly different, in all other locations between the three groups ($p \leq 0.05$). ADC values from ST region allowed a better discrimination ($p \leq 0.005$) between healthy and osteopenic subjects than those obtained from the whole calcaneus ($p \leq 0.01$) and T region ($p \leq 0.05$). However, ADC measured in CC region and in the whole talus did not discriminate between healthy and osteopenic subjects. G_i measured in the ST location was the most sensitive ($p \leq 0.0005$) parameter to discriminate between healthy and osteopenic subjects. The same parameter measured from the whole talus ($p \leq 0.025$) and calcaneus ($p \leq 0.05$), and from the ST region ($p \leq 0.01$) was the most sensitive to discriminate between osteopenic and osteoporotic women. A linear correlation was found between G_i and BMD in ST location (**Fig. 2**) and whole talus of healthy subjects only. Our results match with relaxation times results obtained by other authors which indicate changes in the ST region as particularly sensitive in discriminating between healthy and osteoporotic individuals [4,5].

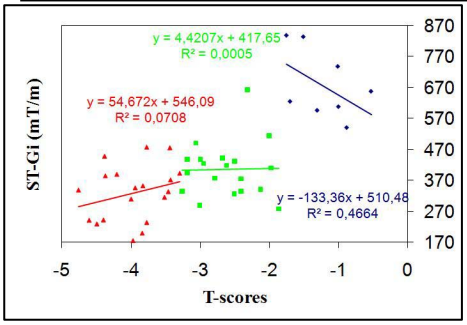

Fig. 2 Internal gradient G_i as function of T-score from ST region. Data from osteoporotic subjects in red, osteopenic subjects in green and healthy subjects in blue.

Conclusion: Our preliminary data confirm the ST as the most suitable region to detect osteoporosis, and G_i as the most sensitive parameter for an early diagnosis of osteoporosis. If confirmed on larger populations, these finding might prompt MR protocols for application in clinical routine.

References

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