Dynamic Contrast Enhanced MR Imaging and ^{1}H MR Spectroscopy Study of Post Menopausal Osteoporosis

J. F. Griffith[1], D. Yeung[1], G. E. Antonio[1]

[1]Diagnostic Radiology and Organ Imaging, The Chinese University of Hong Kong, Shatin, Hong Kong, China, People's Republic of

Introduction: Osteoporosis is a disease characterized by reduced bone strength predisposing to fracture. Recent dynamic contrast-enhanced MR imaging (DCE-MRI) and proton (^{1}H) MR spectroscopy studies of the lumbar spine in males have shown that in line with decreasing bone density, there is a decrease in marrow perfusion indices and a corresponding increase in marrow fat (1). As gender differences have been described in vertebral body perfusion indices and fat in normal subjects (2,3) we were interested in examining whether similar changes occur in females with differing bone density. As recent studies have shown that there is a possible link between atherosclerosis and osteoporosis (4), we also wished to examine if changes in perfusion indices on DCE-MRI evident in the vertebral marrow where also apparent in extra-vertebral tissues supplied by the lumbar artery same artery (for instance, the erector spinae muscle), which is also supplied along with the lumbar vertebrae by the lumbar arteries. Our goal was to prospectively study the relationship between vertebral marrow fat content, marrow and erector spinae muscle perfusion indices in female subjects of varying bone density.

Materials and Methods: Dual x-ray absorpiometry (DXA), ^{1}H MRS, and DCE-MRI of the lumbar spine and erector spinae muscle were performed on 110 female subjects (mean, 73 years). Subjects were grouped into three categories according to T-score and WHO criteria: T score > -1.0 (normal), T score between -1.0 and -2.5 (osteopenia), and T score < -2.5 (osteoporosis). Examinations were performed on a 1.5-T whole-body system using a 20-cm diameter circular surface coil centered at L3. T1W (TR/TE, 450/1) and T2W (TR/TE, 3500/120) sagittal images of the thoracic and lumbar spine were obtained to identify vertebral fracture, to help exclude metastases. For MRS, the width (w), depth (d) and height (h) of the L3 vertebral body were measured on MR images to define a volume of interest (VOI). A VOI measuring $w/2 \times d/2 \times h/2$ cm^3 was located centrally in the vertebral body (Fig. 1). After local shimming and gradient adjustments, 64 non-water suppressed signals were obtained using a PRESS sequence (TR/TE, 3000/25). Vertebral body fat content (FC) was calculated according to the following equation: $FC = [I_{fat}/(I_{fat} + I_{wat})] \cdot 100$, where I_{fat} and I_{wat} are the peak amplitudes of fat and water, respectively (Fig. 3). No correction for relaxation losses was applied.

DCE-MRI was performed in the axial plane through the mid-L3 region. Dynamic images were obtained using a short T1-weighted gradient-echo sequence (TR/TE, 2.7/0.95; pre-pulse inversion time, 400 msec; flip angle, 15°; section thickness, 10 mm; number of slices, one; FOV 250 mm; acquisition matrix, 256 × 256; one signal acquired). A total of 160 dynamic images were obtained after a bolus of gadoteric acid at a concentration of 0.15 mmol/kg was injected at a rate of 2.5 mL/sec. On the mid-axial T1W image, ROIs separately encompassing the L3 vertebral body and the three elements of the erector spinae muscle were drawn manually (Fig 2). Time-intensity curves were recorded and processed on an offline computer to obtain two perfusion indices namely: maximum enhancement (ME) and enhancement slope (ES). ME was defined as the maximum percentage increase in signal intensity from baseline (I_{base}). ES was defined as the rate of enhancement between 10% and 90% of the maximum signal intensity difference between maximum signal intensity (I_{max}) and I_{base}. These perfusion indices parameters were calculated thus:

$$ME = \frac{(I_{max} - I_{base})}{I_{base}} \cdot 100\% \qquad ES = \frac{(I_{max} - I_{base}) \cdot 0.8}{I_{base} \cdot (t_{90\%} - t_{10\%})} \cdot 100\%$$

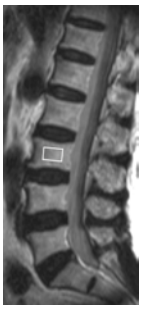

Fig. 1: position of VOI.

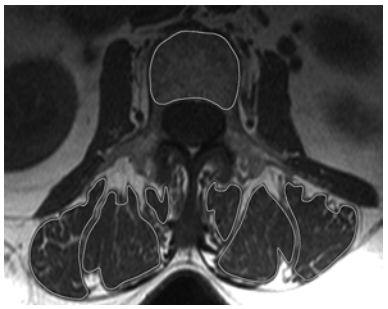

Fig. 2: ROI drawn within the boundaries of vertebral body and muscle groups.

where $t_{10\%}$ and $t_{90\%}$ are the time intervals when the rise in signal intensity reaches 10% and 90% of the maximum signal intensity difference between I_{base} and I_{max}, respectively. Both parameters were derived from the first-pass phase of signal enhancement and are considered to represent the arrival of contrast material into the arteries and capillaries and its diffusion into the extracellular space.

Results: Seven subjects were excluded yielding a final cohort of 103 subjects comprising 18 normal bone density subjects, 30 osteopenic subjects, and 55 osteoporotic subjects. Vertebral marrow fat content was significantly increased in osteoporotic subjects (67.8 ± 8.5%) compared to those with normal bone density (59.2 ± 10.0%) (P = 0.002) (Fig. 4). Vertebral marrow perfusion indices were significantly decreased in osteoporotic subjects (Fig. 6) (enhancement slope, 1.10 ± 0.51%/sec) compared to osteopenic (1.45 ± 0.51%/sec) (P = 0.01) and normal bone density subjects (Fig. 5) (1.70 ± 0.52%/sec) (P < 0.001). Erector spinae muscle perfusion indices did not decrease with decreasing bone density.

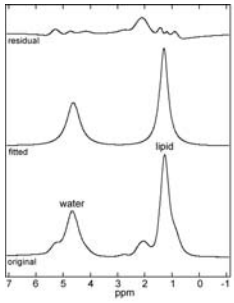

Fig. 3: fitted spectra using MRUI.

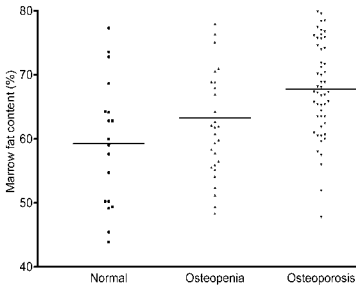

Fig. 4: distribution of marrow fat in subjects with different bone densities.

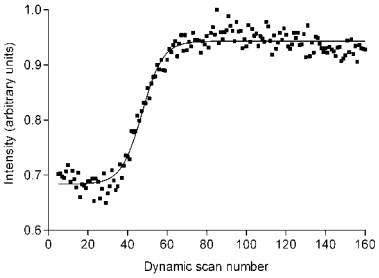

Fig. 5: example of time-intensity curve from a subject with normal bone density.

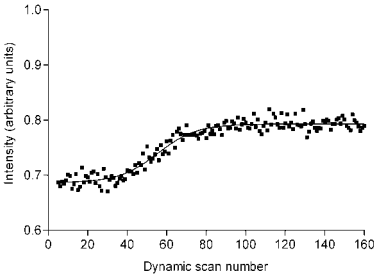

Fig. 6: example of time-intensity curve from a subject with osteoporosis.

Discussion and Conclusions: This study shows a similar trend in female subjects to male subjects with regard to vertebral bone density, marrow fat and marrow maximum enhancement and enhancement slope perfusion [1]. Reduction in bone density is associated with a corresponding increase in marrow fat [3] and a reduction in marrow perfusion indices [1,2]. The vertebral bodies and the erector spinae muscles are both supplied by the paired segmental lumbar arteries [5]. Perfusion indices within the vertebral marrow decreased in line with decreasing bone density. If this reduction in perfusion were related to general circulatory impairment or atherosclerosis in the main lumbar arteries, one would expect a similar reduction in perfusion indices to occur in the erector spinae muscle perfusion. In conclusion, our results show that females demonstrate a decrease in vertebral marrow maximum enhancement and enhancement slope and an increase in marrow fat content with decreasing bone density. The reduction in perfusion indices occurred only within the vertebral body and not in the paravertebral tissues supplied by the same artery.

References: [1] Griffith J et al. Radiology 2005, 236: 945-951. [2] Chen WT et al. Radiology 2001;220:213-218. [3] Schellinger D et al. Radiology 2000;215:910-916. [4] Hamerman D. Q J Med 2005;98:467-484. [5] Ratcliffe JF. J Anat 1980;131:57-79.