Fat fraction of bone marrow measured by Dixon quantitative chemical shift magnetic resonance imaging in the lumbar spine: does it have a significant correlation with bone mineral density and age or menopause?

Poster No.: C-1806
Congress: ECR 2011
Type: Scientific Paper
Authors: I.-Y. Youn, H. Y. Lee, J. Kim; Seoul/KR
Keywords: Musculoskeletal spine, Geriatric, MR, Absorptiometry / Bone densiometry, Imaging sequences
DOI: 10.1594/ecr2011/C-1806

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR’s endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method ist strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys’ fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Purpose

1. Cellularity of bone marrow decreases with age and the fat tissue replaces it instead. Osteoporosis is a disease which results in increased bone fragility and susceptibility to fracture from the following pathologic processes [1-3].

2. The most common risk factor of osteoporosis is different by sex: aging for men, and hormonal changes from menopausal status for women. There are several reports that increased visceral fat is a risk of osteoporosis in females. However, there are few studies that prove these facts through MRI [4-10, 12-24].

3. The purpose of this study is to evaluate the relationship between osteoporosis and vertebral marrow fat fraction, calculated by using Dixon quantitative chemical shift image (QCSI). And, to analyze whether there is a positive relationship between marrow fat fraction and the patient's age, menopause, and hepatic fat fraction.

Methods and Materials

A. Materials

This retrospective study included 48 healthy individuals (mean age, 50.85yrs; range, 25-76 years old; 28 men and 20 women with 11 premenopausal and 9 postmenopausal states) who underwent Dual-energy X-ray absorptiometry (DXA) of the spine and QCSI MRI. We evaluated 188 lumbar vertebrae of the enrolled patients. The 28 men were divided into two groups of people younger and older than 50 years. The women were divided by the status of menstruation. All included individuals had no history of hematologic disorder, or systemic disease such as primary malignancy or endocrine disorder, or prior history of chemotherapy or radiotherapy.

Body mass index (BMI, Kg/m²) was calculated on all individuals and if he or she had a history of vertebral operation, we excluded the involved level of spines.

In evaluating the MRI, we excluded the level with blurring, degenerative disease, wedging, compression fracture, large Schmorl's nodule, focal lesion such as intraosseous lipoma or hemangioma of spine.

B. Radiologic methods
We first conducted T2 weighted midsagittal images (TR/TE, 3300/100 msec; flip angle, 150°; section thickness, 4 mm; field of view, 450 x 450; matrix, 448 x 403; NEX, 2.0) on 1.5T MRI for evaluating conditions of lumbar vertebral bodies. The marrow fat fraction was calculated by using two point Dixon techniques (TR/double TE, 10.2/4.8 and 7.1 msec; flip angle, 10°; section thickness, 4 mm; field of view, 280 x 280; matrix, 384 x 288; NEX, 3.0) with fat only and water only images. DXA of first to forth lumbar spines and femurs was performed in all patients and diagnosed by WHO diagnostic classification of BMD using derived BMD value (g/cm²) [20,25].

**WHO diagnostic classification of BMD**

<table>
<thead>
<tr>
<th>Category</th>
<th>T-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>≈ -1.0</td>
</tr>
<tr>
<td>Osteopenia</td>
<td>-1.0 &lt; T-score &lt; -2.5</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>≈ -2.5</td>
</tr>
<tr>
<td>Severe osteoporosis</td>
<td>≈ -2.5 and fragility fracture</td>
</tr>
</tbody>
</table>

The hepatic fat fractions were calculated with chemical shift in-phase and out-of-phase gradient echo MRI (TR/TE, 110/4.9 and 2.2 msec; flip angle, 70°; section thickness, 6 mm; field of view, 370 x 270; matrix, 256 x 134; NEX, 1.0) [26].

We analyzed the association between the marrow fat fraction and T-score measured by DXA. We also evaluated whether there is a significant difference in the amount of marrow fat fraction between premenopausal and postmenopausal women, and between younger and older men (more than 50 years).

**C. Radiologic analysis**

Measurements of bone marrow fat fraction (F_f) were obtained by the same radiologists using the same MRI scanner and DXA without information of patients.

We placed polygonal "region of interest (ROI)" as large as possible on L1 to L4 vertebral bodies of water-only and fat-only images. The ROIs were located at least 3mm far from the endplates and margins of vertebral bodies to prevent effect of partial volume and secondary bony changes of degenerative disc diseases. (Fig 1) on page 4 The fat-fraction of bone marrow (F_f) was calculated as "M_f / M_f + M_w" (M_f, the pixel values in the fat-only image: M_w, the pixel values in the water only image) [12].
We placed same sized circular "region of interest (ROI)" larger than 105.3 mm$^2$ (200 pixel) in the most homogenous area of anterior, posterior segment of right lobe, left lobe, and spleen at the level of seen main portal vein on the liver parenchyma of same patient. The value of splenic ROI was used for standard of signal intensity. (Fig. 2) on page 6 The hepatic fat-fraction (LF$\_f$) was calculated as "$S_{IP} - S_{OP} / 2 S_{IP} * 100(\%)$" ($S_{IP}$, the pixel values in the in-phase image/splenic pixel value: $S_{OP}$, the pixel values in the opposed phase only image/splenic pixel value) [11,27].

D. Statistical analysis

The calculated F$\_f$ of all included lumbar spines were compared with BMI, BMD value, T-score of each vertebral levels by bivariate Spearman correlation.

We estimated differences of BMI, BMD value, T-score, F$\_f$ and LF$\_f$ in each subgroup of men and women with Mann-Whitney U test, median and mean value.

Images for this section:
Fig. 1: Lumbar Dixon QCSI image of 76-years-old man A.B. Gradient echo T1 weighted sagittal in-phase and opposed-phase Dixon sequences (TR/double TE, 10.2/4.8 and
7.1msec; flip angle, 10\(^\circ\); section thickness, 4mm; field of view, 280x280; matrix, 384x288; NEX, 3.0). C.D. Fat-only, water-only images by postprocessing with using A and B Placing polygonal "region of interest"(ROI) in L1 to L4 spinal body (IP ROI:OP ROI, L1 250 : 38, L2 260 : 36, L3 240 : 34, L4 262 : 37; Ff, L1 0.48, L2 0.52, L3 0.54, L4 .55).
Fig. 2: Chemical shift in-phase(A) and out-of-phase(B) liver MRI in 25-years-old man. Placing circular ROI (> 200 pixel) in the most homogenous area of anterior, posterior...
segment of right lobe, left lobe, and spleen at the level of seen main portal vein (in-phase ROI mean/spleen mean, 1.54; out-of-phase/spleen, 1.65; LFf, -3.5).
Results

There were no excluded patients for pre-existing disease or other histories. Four lumbar vertebral bodies of 28 men were excluded for two wedging, one fixation, and one excluded body on the image. Three bodies of 20 women were excluded for three degenerative changes and one blurring on the images.

There were no significant statistical association between the fat fraction of vertebral marrow and T-score ($p = 0.27, 0.17$) and weak positive correlation with BMI ($p = 0.05$, $r = 0.2$) in each sexes.

Demographic and data of included all patients

<table>
<thead>
<tr>
<th></th>
<th>Male (n=28)</th>
<th>Female (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>young group</td>
<td>old group</td>
</tr>
<tr>
<td>Included lumbar body</td>
<td>53</td>
<td>55</td>
</tr>
<tr>
<td>Excluded lumbar body</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Age (years) §</td>
<td>42.0 (25~50)</td>
<td>60.0 (51~76)</td>
</tr>
<tr>
<td>BMI (kg/m$^2$) +</td>
<td>25.09 ± 4.48</td>
<td>25.48 ± 3.67</td>
</tr>
<tr>
<td></td>
<td>25.3 ± 4.09</td>
<td></td>
</tr>
<tr>
<td>BMD value ( g/cm$^2$) +</td>
<td>1.15 ± 0.12</td>
<td>1.22 ± 0.21</td>
</tr>
<tr>
<td></td>
<td>1.18 ± 0.16</td>
<td></td>
</tr>
<tr>
<td>T-score +</td>
<td>-0.21 ± 0.97</td>
<td>0.39 ± 1.66</td>
</tr>
<tr>
<td></td>
<td>0.05 ± 1.27</td>
<td></td>
</tr>
<tr>
<td>Bone marrow F$_f$ +</td>
<td>0.48 ± 0.08</td>
<td>0.55 ± 0.81</td>
</tr>
<tr>
<td></td>
<td>0.52 ± 0.8</td>
<td></td>
</tr>
<tr>
<td>Liver F$_f$ (%) +</td>
<td>5.14 ± 6.17</td>
<td>5.50 ± 6.69</td>
</tr>
<tr>
<td></td>
<td>3.55 ± 9.46</td>
<td></td>
</tr>
</tbody>
</table>

§ Data were presented as mean (range)

+ Data were presented as mean ± SD
The older group of men and postmenopausal group of women show significantly higher $F_f$ than the younger group and premenopausal group ($p < 0.01$, $< 0.01$). BMD value and T-score of DXA, diagnostic criteria for osteoporosis, showed significant difference in the group of women ($p < 0.01$, $< 0.01$), but not in the men ($p = 0.09$, 0.07).

### Statistical analysis between two groups in both sexes

<table>
<thead>
<tr>
<th></th>
<th>$p$ value$^+$ in male group</th>
<th>$p$ value$^+$ in female group</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>0.368</td>
<td>$&lt; 0.01$</td>
</tr>
<tr>
<td>BMD value (g/cm$^2$)</td>
<td>0.088</td>
<td>$&lt; 0.01$</td>
</tr>
<tr>
<td>T-score</td>
<td>0.074</td>
<td>$&lt; 0.01$</td>
</tr>
<tr>
<td>Bone marrow $F_f$</td>
<td>$&lt; 0.01$</td>
<td>$&lt; 0.01$</td>
</tr>
<tr>
<td>Liver $F_f$ (%)</td>
<td>0.73</td>
<td>0.133</td>
</tr>
</tbody>
</table>

$^+$ Mann-Whitney U test among the two groups (male group divided by age, female group divided by menopausal state)

The hepatic fat fraction showed positive correlation with vertebral marrow fat fraction in female group ($3.26 \pm 1.56$, $p < 0.01$, $r = 0.55$), but not in men.

### Demographic and individual data correlation with liver fat fractions in each sexes

<table>
<thead>
<tr>
<th></th>
<th>$p$ value$^+$ in male group</th>
<th>$p$ value$^+$ in female group</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>$&lt; 0.01$ ($r = 0.7$)</td>
<td>$&lt; 0.01$ ($r = 0.7$)</td>
</tr>
<tr>
<td>BMD value (g/cm$^2$)</td>
<td>0.53</td>
<td>0.715</td>
</tr>
<tr>
<td>T-score</td>
<td>0.38</td>
<td>0.731</td>
</tr>
<tr>
<td>Bone marrow $F_f$</td>
<td>0.76</td>
<td>0.01 ($r = 0.55$)</td>
</tr>
</tbody>
</table>

$^+$ Bivariate Spearson correlation among the two groups

### Conclusion

Our data supports that post-menopausal women and older men have higher marrow fat fraction calculated by Dixon QCSI than pre-menopausal women and young men. Hepatic fat fraction and marrow fat fraction have positive correlation only in the female group.
References


Personal Information

In-young Youn MD.

Department of Radiology, Chung-Ang University College of Medicine, Seoul, Republic of Korea.