Comparison of the magnetic relaxation times between in vivo and extracted femoral head

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Aims and objectives

Magnetic resonance imaging (MRI) of the hip joint has been used to visualize and evaluate femoral disease, such as osteonecrosis and osteoarthritis [1]. Magnetic relaxation times represent tissue characteristics that can be quantified for specific components [2]. T1 and T2 relaxation time measurements of the hip joint have been reported [3-5]. However, there are no reports of the comparison between in vivo and ex vivo femoral head. Moreover, it is uncertain how the magnetic relaxation times of femoral bone is affected by freezing. The purpose of this study was to compare the magnetic relaxation time of the femoral bone between in vivo and extracted femoral head and to investigate the dependence on the effects of freeze-thaw after their extraction from the femur bone.

Methods and materials

Patients

Fourteen patients (in vivo n=14, fresh femoral head n=4, frozen / thawed femoral head n=6) who had planned total hip arthroplasty and underwent an MRI examination were investigated. This study was approved by the institutional review board of our institution.

Specimens

Six femoral head specimens were obtained from total hip arthroplasty surgery. In order to evaluate the effect of temperature change, specimens were divided into two groups, one for use in fresh (fresh; n=4) and the other to be processed by freezing (frozen / thawed; n=6). Two of six fresh specimens ended up not being used due to operating procedures. The extracted femoral heads were covered with normal saline-soaked gauze and placed in plastic vessels. Four of six fresh specimens were carried to the MRI room directly after extraction. After the MRI acquisition, the specimens were stored frozen at -80 °C. The frozen / thawed specimens were frozen at -80 °C immediately after extraction and were thawed to room temperature before the MRI acquisition.

MRI data acquisition

All imaging was performed using a 3-tesla whole-body clinical scanner (Achieva TX-series, Philips Healthcare, Best, The Netherlands) with a maximum gradient performance of 40 mT/m and a maximum slew rate of 200 mT/m/ms. The hip joint of each subject was centered in a 32-channel torso coil in the supine position. The specimens were also placed in a 32-channel torso coil.
After an orthogonal three-plane (axial, coronal, and sagittal) localizer image, axial and oblique-coronal T1-weighted images were acquired for the purpose of anatomically defining the femoral head using a two-dimensional turbo spin echo (TSE) sequence with field of view (FOV) = 128mm, repetition time (TR) = 700ms, echo time (TE) = 12ms, TSE factor = 4, matrix size = 72×96, slice thickness = 3mm, number of slices = 19, and acquisition time = 29s. For calculation of T1 relaxation times, oblique-coronal images were acquired using the two-dimensional Look-Locker inversion recovery sequence with FOV = 128mm, TR = 7ms, TE = 2.1ms, flip angle = 7 degrees, matrix size = 128×128, slice thickness = 8mm, number of slices = 1, and acquisition time = 44s.

For calculation of T2 relaxation times, oblique-coronal images were acquired using a two-dimensional multiple spin echo sequence with FOV = 128mm, TR = 5000ms, TE = 11.5, 23.0, 34.5, 46.0, 57.5, 69.0, 80.5 and 88.0ms, flip angle = 90 degrees, matrix size = 96×96, slice thickness = 8mm, number of slices = 1, and acquisition time = 16min 5s.

Image analysis

T1 and T2 maps (Figure 1) were calculated by using in-house developed software written in MATLAB (The MathWorks, Natick, MA, USA). Both T1 and T2 were fit using the Levenberg-Marquardt non-linear least squares method. T1 and T2 relaxation time measurements were performed by manually placing regions of interest on osteonecrosis, bone marrow edema, greater trochanter, femoral head and femur (Figure 2). The regions of interest (ROIs) were manually drawn using ImageJ software (ImageJ, National Institutes of Health, Bethesda, Maryland, USA).

Statistical analysis

Measurement data were expressed as means ± standard deviation (SD). The Steel-Dwass multiple comparison analysis test was used to compare the magnetic relaxation time for each region. All statistical analyses were performed with JMP software (version 11; SAS Institute Inc., Cary, NC, USA). Statistical significance was accepted for P < 0.05.

Images for this section:
Fig. 1: Calculated maps of T1 and T2. (a) T1 map of in vivo; (b) T1 map of the specimen; (c) T2 map of in vivo; (d) T2 map of the specimen.
Fig. 2: Region of interests (ROIs) placement on the femoral bone.
Results

Table 1 showed the T1 and T2 relaxation times of the femoral bone at each region. The mean T1 relaxation time of in vivo was longer than that of fresh and frozen/thawed specimens. The mean T2 relaxation time of in vivo was shorter than that of fresh and frozen/thawed specimens. There were significant differences between in vivo and fresh femoral head T1 relaxation times, in vivo and frozen/thawed femoral head T1 relaxation times, respectively (P<0.005). There was significant difference between in vivo and frozen/thawed femoral head T2 relaxation times (P<0.005).

Images for this section:

<table>
<thead>
<tr>
<th>Region</th>
<th>Status</th>
<th>T1 relaxation time[ms]</th>
<th>T2 relaxation time[ms]</th>
</tr>
</thead>
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<tr>
<td>osteonecrosis</td>
<td>in vivo</td>
<td>1666.1±577.8</td>
<td>73.1±32.8</td>
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<tr>
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<td>fresh</td>
<td>1294.3±507.8</td>
<td>163.8±172.5</td>
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<tr>
<td></td>
<td>frozen / thawed</td>
<td>1361.7±386.7</td>
<td>147.5±83.6</td>
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<td>bone marrow edema</td>
<td>in vivo</td>
<td>1272.2±434.4</td>
<td>72.5±20</td>
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<tr>
<td></td>
<td>fresh</td>
<td>1021.3±305.5</td>
<td>114±30.8</td>
</tr>
<tr>
<td></td>
<td>frozen / thawed</td>
<td>1147.5±296.7</td>
<td>122.7±22</td>
</tr>
<tr>
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<td>482.7±51.8</td>
<td>64.1±12</td>
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<tr>
<td></td>
<td>fresh</td>
<td>366.2±41.4</td>
<td>73.8±7</td>
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<td>74.2±18.2</td>
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<tr>
<td>greater trochanter</td>
<td>in vivo</td>
<td>425.9±20.6</td>
<td>82.6±14.5</td>
</tr>
</tbody>
</table>

*Table 1: T1 and T2 relaxation time of in vivo and ex vivo for each region*
Conclusion

Discussion

This study compared the magnetic resonance relaxation times of femoral bone between in vivo and extracted femoral heads and investigated the dependence on the effects of freeze-thaw after extraction from the body. The mean T1 relaxation time in vivo was longer than that of fresh and frozen / thawed specimens. The mean T2 relaxation time in vivo was shorter than that of fresh and frozen / thawed specimens.

In regards to the difference of the femoral bone between in vivo and ex vivo, the T2 relaxation time of the bone marrow edema was affected by freezing because there was no significant difference between in vivo and frozen / thawed. This result indicated the water content of the bone marrow edema had changed by freezing and thawing process. Moreover, for the T1 relaxation time of the femoral head between in vivo and ex vivo, there was a significant difference. This result suggested that blood leakage of the specimens induced the bone T1 relaxation time to be shortened because the disruption of blood supply changed the content of blood in femoral head bone.

There were some limitations in this study. First, the number of patients was relatively small. Second, the method of thawing might have introduced minor deviations of the relaxation times of the specimens. Although the number of patients was small in this study, changes of relaxation times between in vivo and ex vivo were observed clearly at the time. The procedure of thawing in this study might have affected some of the changes to the femoral bone and tissues. However, there were no significant differences seen between fresh and frozen / thawed specimens. The results appear to show the procedure of thawing was not related to change of the relaxation time in this study.

The results seen in this study were helpful to compare the relaxation time using MRI between in vivo and ex vivo of the femoral bone.

Conclusion

This study was able to show significant differences between in vivo and extracted femoral head magnetic relaxation times.

Personal information

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References


