In vivo quantification of lumbar intervertebral disc degeneration using axial T2 mapping

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Introduction

T2 (transverse relaxation time) mapping has the potential to quantitatively evaluate deterioration of intervertebral disc (IVD) molecular composition and structural integrity1,2. T2 is sensitive to water content and arrangement of collagen network structure3,4, and is also influenced by the dipolar interaction due to anisotropic motion of water molecules in the collagen matrix. A high T2 for the nucleus pulposus (NP) has been demonstrated in healthy IVDs; T2 decreases with the decrease of water content associated with disc degeneration. In contrast, T2 for the annulus fibrosus (AF) is low in healthy IVDs, and it increases with increased water content and loss of collagen anisotropy. The aim of this study is to assess the feasibility of using T2 mapping to detect the early degeneration of IVD.

Methods and Materials

Twenty six healthy volunteers (17 males, 10 females) without symptoms of back pain or possible sciatica within the past year and without previous medical treatment of a spinal disorder were studied. Mean age at the time of MR imaging was 30.2 ± 7.4 years [20-44] (years, mean ± SD, [range]). Axial T2 mapping was performed for the following IVDs: L3/4, L4/5, and L5/S, which are frequently involved in degeneration. MR imaging was performed using a 3.0 Tesla system (Trio; Siemens, Erlangen, Germany) with a dedicated spine coil. A multi-spin-echo (MSE) sequence was used for T2 measurement. MSE scanning parameters were 1500 msec TR, 14 TEs of 10.3-144.2 m sec, 200×200 mm field of view, 3.0-mm slice thickness, 384×384 matrix, and 1 excitation. Total scan time for this sequence was 9 minutes 41 seconds per disc. T2-calculated maps were generated using MATLAB software (Mathworks, Natick, MA) with mono-exponential curve fit.

A classification system for degenerative IVD using axial T2 mapping was developed with reference to conventional classification systems. In developing the new system, particular emphasis was laid on change of T2 and inhomogeneity of T2 in NP and AF, as well as the distinction between NP and AF. The classification system has a 4-grade scale that is summarized in Table 1 and Figure 1. Relationships between degenerative grades using axial T2 mapping and disc level, and presence or absence of disc herniation as well as type of herniation were assessed by the dipolar interaction due to anisotropic motion of water molecules in the collagen matrix. A high T2 for the nucleus pulposus (NP) has been demonstrated in healthy IVDs; T2 decreases with the decrease of water content associated with disc degeneration. In contrast, T2 for the annulus fibrosus (AF) is low in healthy IVDs, and it increases with increased water content and loss of collagen anisotropy. The aim of this study is to assess the feasibility of using T2 mapping to detect the early degeneration of IVD.

<table>
<thead>
<tr>
<th>Grade</th>
<th>T2 value of NP</th>
<th>T2 value of AF</th>
<th>Distinction of NP and AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>High T2, homogeneous</td>
<td>Low T2, homogeneous</td>
<td>Clear with regular border</td>
</tr>
<tr>
<td>II</td>
<td>Mild decrease of T2, mildly inhomogeneous</td>
<td>Mild increase of T2, mildly inhomogeneous</td>
<td>Clear with irregular border</td>
</tr>
<tr>
<td>III</td>
<td>Moderate decrease of T2, moderately inhomogeneous</td>
<td>Moderate increase of T2, moderately inhomogeneous</td>
<td>Unclear</td>
</tr>
<tr>
<td>IV</td>
<td>Severe decrease of T2, severely inhomogeneous</td>
<td>Severe increase of T2, severely inhomogeneous</td>
<td>Lost</td>
</tr>
</tbody>
</table>

Figure 1

Representative color-coded T2 maps of intervertebral discs obtained with the axial T2 mapping classification system. A: grade I; B: grade II; C: grade III; D: grade IV.

References