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 integrity[1)]. T2 is sensitive to water content and arrangement of collagen network structure[2,3)] 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 msec, 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 evaluated. The T2 of NP and AF in IVD was measured and the relationship between T2 value and degenerative grade was analyzed by regression analysis. One-way analysis of variance (ANOVA) was used for statistical analysis. Statistical significance was defined as $p<0.05$.

Results

IVDs were classified as; 38 for Grade I, 24 for II, 10 for III, and 9 for IV. Degenerative grade was highest at the L5/S1 level, followed by L4/5 and L3/4. Among all grade I and II IVDs, no herniation was observed. Among grade III IVDs, three (33.3%) had disc herniation (protrusion in all cases). Among grade IV IVDs, seven (77.8%) had disc herniation; two showed protrusion (22.2%), three (33.3%) showed extrusion, and two (22.2%) showed sequestration. T2 of the NP decreased with increasing degenerative grade, whereas T2 of the AP increased with increasing degenerative grade. Among grade IV IVDs, the average T2 values in the NP and AP were close to each other. With axial T2 mapping, the T2 values of NP and AF for the different degenenerative grades were almost equidistant, and there were significant differences of T2 between each degenerative grade in both NP and AF.

Discussion

In a cadaveric study, histological IVD alteration was found to begin at a very early age[4,5)], with about 20% of teens having IVDs with mild signs of degeneration; degeneration increased with age[6)]. In the current study, more than 20% of IVDs in volunteers in their twenties had degenerative IVD per axial T2 mapping. This incidence rate is comparable with those of previous reports using histological assessment, and the correlation between histological and axial T2 mapping results may support the hypothesis that axial T2 mapping detects early degeneration better than the other classification systems.

The ability to detect degeneration in the AF may contribute to investigation of the pathogenesis of low-back pain; degeneration of AF nerve endings has been found only in the outer AF and the degeneration is likely to be responsible for disc-related pain. Use of axial T2 mapping may also contribute to evaluation of the effect of conservative and operative treatments for IVDs, especially for new treatments such as NP replacement, gene therapy, and stem cell transplantation therapy[7,8)]. In conclusion, our results demonstrate the potential of axial T2 mapping as a classification system for detection of early degenerative IVDs. Axial T2 mapping can provide a useful noninvasive evaluation of matrix status in IVDs and can be a useful indicator of IVD function.

Table 1. Classification of intervertebral disc degeneration (Axial T2 mapping)

Grade	T2 value of NP	T2 value of AF	Distinction of NP and AF
I	High T2, homogeneous	Low T2, homogeneous	Clear with regular border
II	Mild decrease of T2, mildly inhomogeneous	Mild increase of T2, mildly inhomogeneous	Clear with irregular border
III	Moderate decrease of T2, moderately inhomogeneous	Moderate increase of T2, moderately inhomogeneous	Unclear
IV	Severe decrease of T2, severely inhomogeneous	Severe increase of T2, severely inhomogeneous	Lost

NP; Nucleus pulposus, AF; Annulus fibrosus

Figure 1

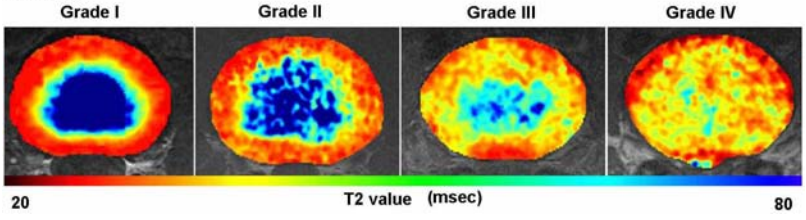

Figure 1
Representative color-coded T2 maps of intervertebral discs obtained with the axial T2 mapping classification system. A: grade I; B: grade II; C: grade III; D: grade IV.

References

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