

In Vivo Quantification of Delayed Gadolinium Enhancement in the Nucleus Pulposus of Human Intervertebral Disk

J. Niinimäki¹, O. Parviainen¹, J. Ruohonen¹, R. O. Ojala¹, M. Kurunlahti², J. Karppinen^{3,4}, O. Tervonen¹, M. T. Nieminen¹

¹Department of Diagnostic Radiology, Oulu University Hospital, Oulu, Finland, ²Oulu Deaconess Institute, Oulu, Finland, ³Department of Occupational Medicine, Finnish Institute of Occupational Health, Helsinki, Finland, ⁴Department of Physical Medicine and Rehabilitation, Oulu University Hospital, Oulu, Finland

INTRODUCTION

Diffusion through the end plates is the primary nutritional pathway of intervertebral disks. Deterioration of this pathway is known to be an important factor in the process of disk degeneration [1]. Transfer of nutrients through the end plate can be simulated in vivo by measuring transfer of intravenously administered paramagnetic contrast agent into the nucleus pulposus of intervertebral disk from circulation. Previous animal and human studies have investigated disk enhancement using paramagnetic contrast agents [2-5], however, these studies have only assessed signal intensity changes. The present study was conducted to quantify the delayed enhancement of the nucleus pulposus in vivo using a non-ionic contrast agent and T1 relaxation time measurements before and after contrast agent injection. Finally, the quantitative enhancement data were correlated with the Pfirrmann visual grading of disk degeneration [6].

METHODS

Twenty male volunteers (mean age 49±5, range 40-55) were studied. A routine spine examination was conducted at 1.5T (two GE Signa 1.5T scanners, Milwaukee, WI), including T2-weighted sagittal images, that were used to score the intervertebral disk degeneration according to the Pfirrmann grading [6]. For T1 relaxation time measurements of intervertebral disks (between L1 and S1 vertebrae) a series of sagittal single slice inversion recovery measurements were conducted (TR=3400ms, TI=100, 200, 400, 800, 1600 and 3200ms, 4-mm slice thickness, in-plane resolution of 0.78mm). This was followed by an intravenous injection of 0.2mM/kg of non-ionic GdDTPA-DMA (Omniscan, Amersham Health AS, Oslo, Norway) and a T1 measurement series 90min after the injection. For each disk, T1 relaxation times were averaged from elliptical regions of interest (45±4mm²) that were manually segmented into the nucleus pulposus.

RESULTS

Altogether 93 disks were analyzed. A statistically significant decrease in T1 relaxation time of nucleus pulposus was observed as a result of contrast agent intake (Wilcoxon signed ranks test, p<0.0001) (Fig. 1 and 2), the percentual change of T1 relaxation time for individual disks ranging between 0 and 60%. The T1 relaxation times varied between 440-980ms (mean 780 ± 120ms) and 350-940ms (690 ± 160ms) before and after the injection, respectively.

A positive trend was observed between the change in the T1 relaxation rate ($\Delta R1$) and the Pfirrmann grading of disk degeneration (Fig. 3). A statistically significant difference in $\Delta R1$ was observed between samples in all Pfirrmann grades except between grades II and III (Mann-Whitney U test, p<0.0001-0.02).

DISCUSSION

For a single compartment model the change in the R1 relaxivity rate ($\Delta R1$) is directly proportional to the contrast agent concentration within the pulposus if a constant relaxivity (R) is assumed, i.e. $[GdDTPA-BMA] = R \Delta R1$. Absolute concentrations could be estimated if relaxivity of the gadolinium complex in the disk was known. A previous study suggests that the relaxivity between the pulposus and annulus may be different [7]. Since there is considerable variation in the T1 relaxation time without contrast agent it may not be possible to quantify the enhancement without a T1 measurement prior to contrast agent administration.

Contrast agent intake is a dynamic process which is likely to depend on the nutritional pathway (blood vessels - vertebral sinusoids - endplate - annulus fibrosus - nucleus pulposus) and the diffusional properties of these tissues. A previous study reported a decreased enhancement (signal intensity change) in degenerated disks minutes after contrast agent injection. The present results with a longer delay are not consistent with this finding, and it is anticipated that a longer delay may be less sensitive to short time-scale differences in contrast agent intake between normal and degenerated disks. Further studies are necessary to understand the observed relationship between the significant increase of $\Delta R1$ (reflecting contrast agent concentration) and disk degeneration.

Iatridis et al. suggested that the dGEMRIC-technique (delayed Gadolinium Enhanced MRI of Cartilage), designed to indirectly quantify the fixed charge density by using an ionic contrast agent, could possibly be applied for the intervertebral disk [7]. The present results show considerable variation in the diffusion of contrast agent into the disks that may provide a competing mechanism for contrast agent intake and therefore may cause inaccuracy to the dGEMRIC measurement of the disk.

The present results suggest that delayed enhancement of the intervertebral disk may be used to study the nutritional pathway into the disk. The quantitative method to measure disk enhancement may be a sensitive parameter to assess degeneration, and may provide a means to investigate the etiology of degenerative disk disease.

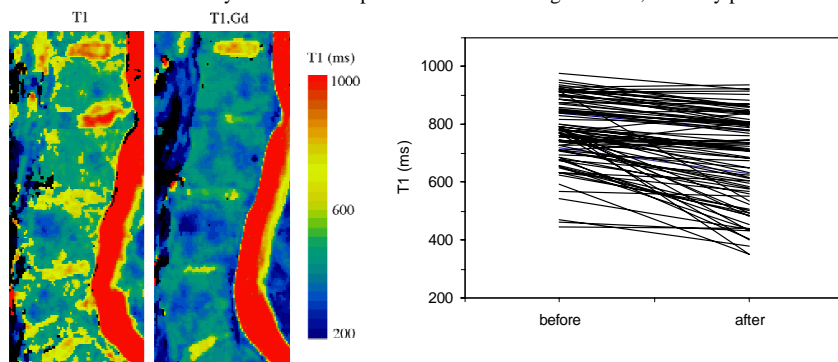


Fig. 1: T1 relaxation time maps before and 90min after injection of non-ionic GdDTPA-BMA for a representative volunteer. A significant variation in contrast agent intake between different disks is observed.

Fig. 2: T1 relaxation time before and 90min after contrast agent administration in the nucleus pulposus of intervertebral disks (n=93) in 20 volunteers.

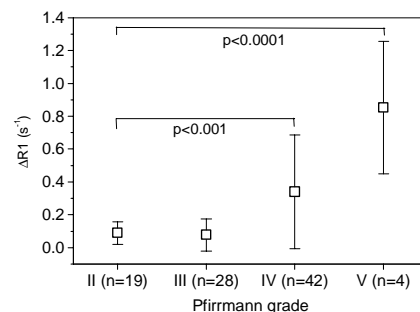


Fig. 3: The change in T1 relaxation rate ($\Delta R1$) in nucleus pulposus for different degenerative grades. A statistically significant difference (not all differences shown) in $\Delta R1$ was observed between all grades except II and III.

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