Comparison of techniques for assessment of age-related degeneration in intervertebral discs

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Introduction Degeneration in intervertebral discs (IVDs) is a leading cause of lower-back pain and affects millions [1]. Recent work in assessment of IVDs using MR has concentrated on changes related to the glycosaminoglycan (GAG) distribution within discs, which might be used as an early indication of degenerative disc disease. Such MR techniques, which do not require the use of contrast agents, include point-resolved spectroscopy (PRESS) [1,2], Na imaging [3], and chemical exchange saturation transfer (CEST) [4]. This work provides a preliminary *in vivo* comparison of the techniques applied to volunteers of varying age.

Methods MR data was acquired in a 3T GE scanner, using a torso array coil for the PRESS and CEST techniques in order to maximize signal from the IVD, and a custom-built loop surface coil for Na imaging. Preliminary data was taken from the L4/L5 IVD of the lumbar spine, since degeneration becomes more pronounced with age at lower disc levels. Three healthy female volunteers of varying age were recruited. Single-voxel PRESS data was acquired with and without water suppression (FOV=18x16x4mm^3, NEX=384, TE/TR=31/1000) for a total scan time of ~13mins. In this preliminary assessment, the ratio of the N-acetyl resonance peak associated with proteoglycans (~2ppm) to the water resonance peak (unsaturated) was used for quantification. Na 3D MRI was conducted with a fast-gradient-echo sequence with the following parameters: FOV=40x40x24cm^3; matrix=32x32x16; NEX=56; TE/TR=1/30ms, for a scan time of ~14mins. The Na MR data were corrected based on registration with a 60mM saline phantom acquisition, and the ratio of the signal intensity (SI) from the IVD to that from the cerebrospinal fluid (CSF) was calculated [5]. CEST data were acquired using Gaussian pulses to saturate at specific offsets prior to a single-shot fast-spin-echo sequence (FOV=30x30cm^3; matrix=128x128; TE/TR≈33/6000ms) and corrected using the WASSR technique [6]. Data were acquired at offsets of -600-+600Hz/-180-+180Hz at 50Hz/15Hz intervals using five/one 50ms pulse(s) (B_1≈1.5/0.1μT) for CEST/WASSR respectively. The total scan time for acquisition of CEST and WASSR data was ~6mins. Maps were calculated based on the MTR_{asym}: the saturated signals at a positive offset from water subtracted from that at the negative offset divided by the unsaturated signal, averaged between 0.6 and 1.4ppm [4]. A region of interest, taken to encapsulate the nucleus pulposus, was selected based on a T_2-weighted image and used to quantify the CEST contrast.

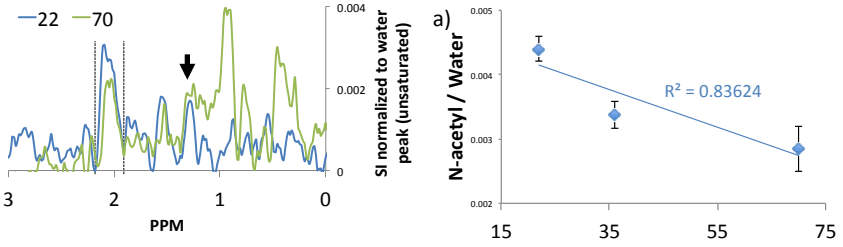

Figure 1 Normalized spectra from L4/L5 IVDs.

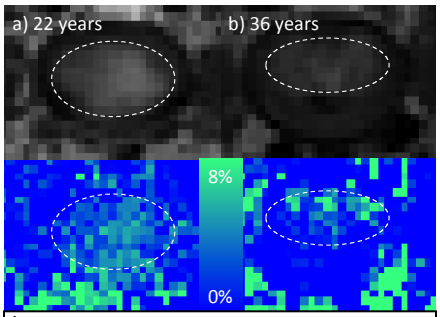

Figure 2 Hyper-intensity in T_2 image (above) correlates with CEST contrast.

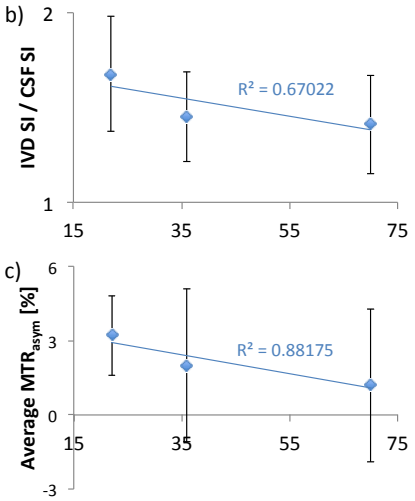

Figure 3 Plots of quantified data using different MR techniques: a) PRESS; b) Na; c) CEST, against age (horizontal axis).

Results & Discussion Figure 1 shows PRESS spectra acquired from the 22 and 70 year old volunteers. All spectra showed a peak around the expected 2ppm mark, which is associated with proteoglycan content and was shown to correlate with GAG [1,2]. Complimentary metabolite information could be utilized, e.g. relating to lipid and lactate (1.15-1.4ppm, arrow in Fig.1), if SNR allows. However low SNR remains an issue for these spectra [2]. Work is in progress on further optimization of acquisition and processing protocols for MRS. Na and CEST maps can potentially provide information on the spatial distribution of GAG. The map of CEST contrast in the IVD of the youngest volunteer shows a consistent value at the nucleus pulposus (Fig.2a). However a lower MTR_{asym} is apparent in the map from the IVD of the 36 year old, where high contrast coincides with hyper-intensity in the T_2-weighted image (Fig.2b). Comparison of the quantified data from each method presents a linear correlation with age, although with more data a plateau might be established.

Conclusions Attributes relating to the techniques are summarized in the table. In continuing this study with more volunteers, it is hoped that information regarding the sensitivity/specificity of each technique might be established.

References [1] Zuo, MRM 62:1140 [2] Zuo, Spine 2011 Jun 20 [Epub ahead of print] [3] Wang, Spine 35:505 [4] Kim, NMR Biomed 24:1137 [5] Insko, Acad Radiol 9:800 [6] Kim, MRM 61:1441

Method	Positive attributes	Negative attributes
PRESS	+ Readily available sequence + Potential information about other metabolites + Direct correlation with GAG	− Inter-volunteer water suppression varies − Data averaged over voxel; no spatial distribution − Low SNR or long scan time
Na	+ Coverage over large 3D volume + Direct correlation with GAG + Spatial distribution information	− Special hardware required − Low SNR or long scan time − Coil sensitivity correction required
CEST	+ Shortest scan time + Spatial distribution information + Utilizes proton MRI	− Sensitive to MT asymmetry − Requires B_0 correction