Sodium imaging of intervertebral disc using weighted signal averaging: application to age-related degeneration
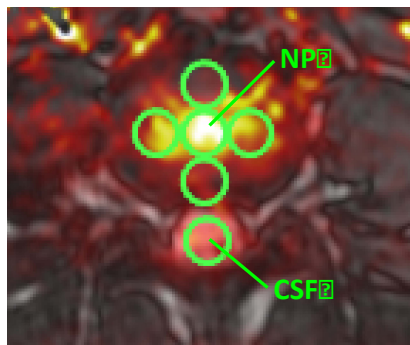
Gopal Varma[1], Alexander Ivanishev[1,2], Robert L Greenman[1], Fotini Kourtelidis[1], David B Hackney[3], Robert E Lenkinski[1,2], and Elena Vinogradov[1,2]

[1]Radiology, Division of MR Research, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States, [2]Radiology, UT Southwestern Medical Center, Dallas, TX, United States, [3]Neuroradiology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States

Introduction Degeneration of intervertebral discs (IVDs) is nearly ubiquitous with aging, and is the leading cause of back pain. Clinically, the diagnosis and prognosis is based on observing morphological changes from T_2-weighted MRI. The exact biochemical processes involved are still under investigation and the progress is often hampered by the lack of a reliable imaging marker for degeneration. The onset and progress of IVD degeneration is associated with a loss of glycosaminoglycans (GAG), whose concentration is directly related to that of sodium (Na^+) [1]. Wang *et al*. related the Na concentration in IVDs from Na MRI based on signal intensity [2]. However, the SNR requirement at the necessary resolution (at least 128x128) results in a relatively long scan time. Bansal *et al*. showed that weighted signal averaging might be used to improve SNR in Na MRI [3]. In this study, we develop sodium MRI with weighted averaging as a means to study IVD degeneration, with emphasis on monitoring age-associated changes.
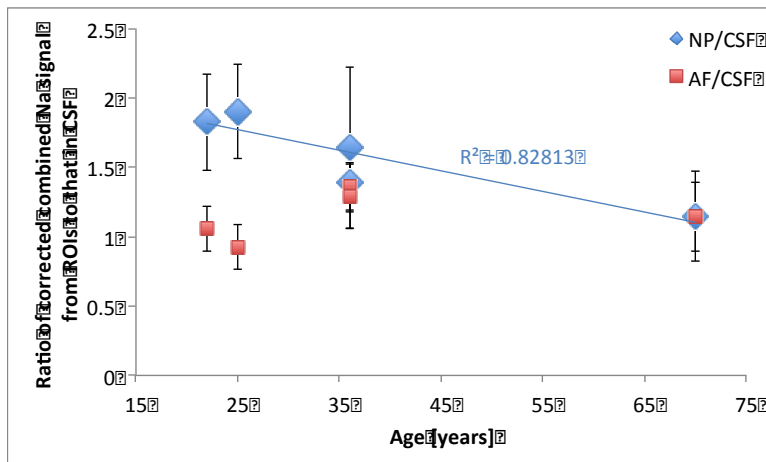

Figure 1 a) Anatomical reference and zoomed in Na MR image from: b) 32x32 filtered acquisition, c) weighted signal averaging.

Methods MR data was acquired in a 3T GE scanner using a custom-built transmit/receive surface coil for Na imaging. A 3D fast-gradient-echo sequence (FA=60°; FOV=40x40x24cm³; slice thickness=1.5cm; TE/TR≈1/30ms) was applied. Three separate acquisitions were used to acquire data for weighted signal averaging with matrix sizes: 32x32; 64x64; 128x128; and NEX: 56; 12; 4, respectively. The signal was combined by addition of k-space data. The sequences were applied to a 60mM saline phantom, and for Na imaging of the L4/L5 IVD from 5 female volunteers of varying age. *In vivo* data signal intensities were adjusted using co-registration with the homogeneous saline phantom to correct for the surface coil's sensitivity profile [4].

Figure 2 Corrected combined Na image overlaid on anatomical reference. Four ROIs around the NP ROI are used for AF analysis.

Results & Discussion Figure 1 illustrates the effect of weighted signal averaging, in which the resultant "combined" image maintains a similar SNR as that from low-resolution data (following apodization with a Fermi filter). The increase in resolution through weighted signal averaging is used in analysis. The concentration of GAG is higher in the nucleus pulposus (NP) than in the annulus fibrosus (AF) [5]. Thus, a central region of interest (ROI) was drawn to cover the NP, with 4 ROIs outside to represent the AF (Fig.2). Assuming limited variation in the sodium content in the cerebrospinal fluid (CSF) of healthy subjects [4], a ROI was also used from within CSF to provide an internal reference for quantification. Figure 3 shows the results from volunteers of differing age. The ratio of the Na signal from the NP to the CSF (taken as an indicator of concentration) shows a negative correlation with age. AF/CSF is smaller than NP/CSF, but interestingly with age it tends towards matching the NP/CSF ratio. This might reflect the lack of definition observed between the NP and AF with degeneration [5].

Conclusions Weighted signal averaging allows higher resolution Na images to be acquired from the IVD for better distinction between the disc and surrounding structures, as well as between the NP and AF.

References [1] Urban, JMRI (2007) 25:419-32 [2] Wang, Spine (2010) 35:505-10 [3] Bansal, JMRI (1995) 5:761-7 [4] Insko, Acad Radiol (2002) 9:800-4 [5] Antoniou, J Clin Invest (1996) 98:996-1003

Figure 3 Plot of corrected combined Na signal from ROIs as ratio to CSF ROI against volunteer age, with error of standard deviation.