Assessment of In-Vivo Cartilage Sodium using Soft Inversion Recovery Fluid Suppression

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Introduction: Sodium MRI is a promising technique for assessing cartilage health in-vivo [1]. While the presence of synovial fluid in the knee joint capsule and the near-by bursa or blood vessels can make isolating the cartilage difficult, inversion recovery can be used to suppress sodium in fluid to better differentiate cartilage and perhaps aid in the assessment of sodium concentration [2, 3]. Inversion recovery techniques suffer from a degraded signal to noise ratio (SNR) in comparison to a tissue sodium concentration image acquired in the same time, and also produce signal that is highly dependent on T_1. The purpose of this abstract is to show that Soft Inversion Recovery Fluid Attenuation (SIRFLA), previously used in the brain [4], could also be used to recover image SNR for fluid suppressed sodium images of the knee and reduce signal variation with T_1.

Methods: All sodium MRI scans were acquired on a 4.7T Varian Inova. The T_1 and T_2 relaxation constants were assessed for four vials of agar (2.5%, 5%, 7.5%, and 10% mass/vol) that each had the same [^{23}Na] = 150 ± 5 mM. Images of the phantom were acquired four times using three sodium sequences: (i) a Tissue Sodium Concentration (TSC) sequence (TR = 180 ms, N_{av} = 1, time = 9.5 min, no inversion), (ii) a Hard Inversion Recovery (HIR) sequence (TI = 20 ms, TR = 90 ms, N_{av} = 2, time = 9.5 min, inversion time = 1 ms) and (iii) a SIRFLA sequence (TI = 27 ms, TR = 70 ms, N_{av} = 3, scan = 10.5 min, inversion time = 10 ms). The inversion and repetition times were chosen empirically to null signal from synovial fluid (T_1 = 35 ms measured at 4.7 T) while optimizing signal from cartilage (T_1 = 21 ms measured at 4.7 T). All images were acquired with the same twisted projection readout (TE = 0.186 ms, readout = 14 ms, FOV = 12 cm, matrix 80x80x40). Coronal sodium images of the right knee of two healthy volunteers were acquired with TSC, HIR, and SIRFLA using parameters described above. Femoral-tibial cartilage SNR was measured in regions of the joint selected to minimize fluid contamination.

Results/Discussion: While TSC showed similar signal intensities for the four agar vials (Fig 1, top left), the HIR showed a large reduction in signal intensity as well as variation among the four concentrations of agar (Fig 1, top middle) due to the range of T_1s (listed in Fig 2). Using SIRFLA, a higher signal intensity was measured in the phantom and the signal measurement was more consistent across the range of agar concentrations (Fig 1, top right and Fig 2). This is because of the short T_{2fast} of agar that creates a 'partial inversion' effect [4] during the very long 10 ms RF inversion pulse. In the knee (Fig 1, bottom), the fluid in the joint capsule (arrow) is attenuated in both HIR and SIRFLA. SIRFLA produced an image with much better SNR (21) in cartilage than HIR (12) despite similar scan times of ~10 min. Compared with hard inversion recovery parameters, soft inversion recovery yields fluid suppression but also allows the acquisition of improved sodium images with greater SNR and reduced T_1 variation.

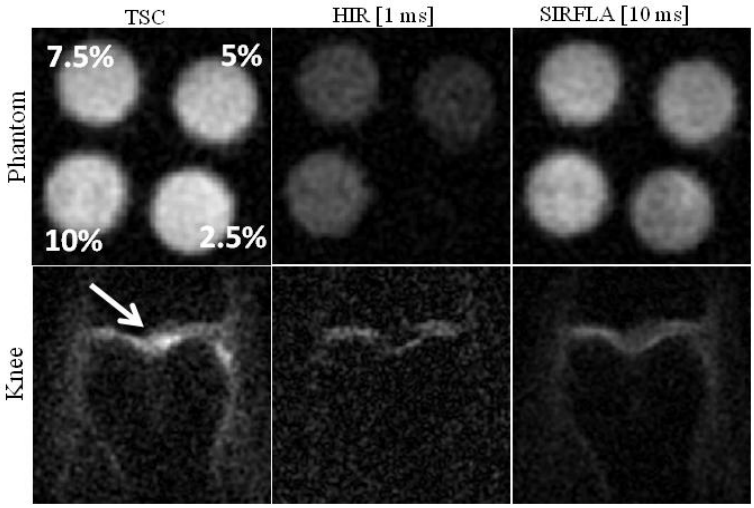

Figure 1: TSC, HIR, and SIRFLA (Top) Signal intensity from 2.5%, 5%, 7.5% and 10% agar (all with same 150 mM Na concentration). (Top middle) HIR shows reduced, variable intensity, compared to (Top right) SIRFLA. (Bottom Row) Sodium images of the knee. The arrow indicates fluid that was suppressed by the inversion recovery. Soft inversion produces better images and SNR.

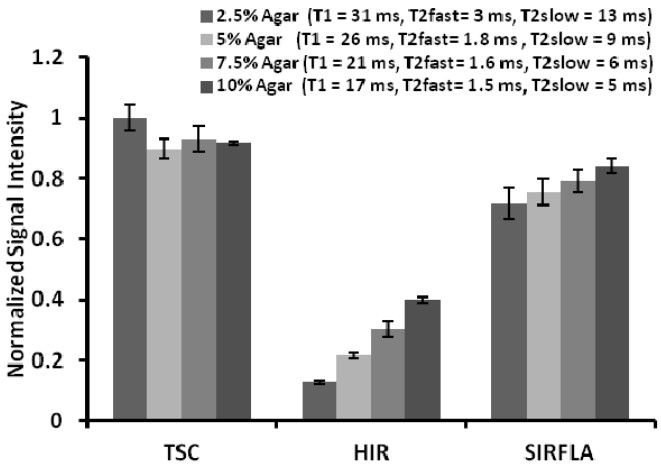

Figure 2: Average sodium signal intensity of each vial using TSC, HIR, and SIRFLA, normalized by the maximum signal intensity (± standard deviation of 4 experiments). HIR resulted in markedly less signal and a larger variation when compared to SIRFLA.

References: [1] Wheaton, Radiology 231:900(2004); [2] Madelin, JMR 207:42(2010); [3] Rong, J Magn Reson 207:193(2008) [4] Stobbe, MRM 1305:54(2005)