Three-Dimensional Projection-Reconstruction (3DPR) Multiple Gradient-Echo Acquisition Scheme for ^{23}Na MRI

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INTRODUCTION Sodium magnetic resonance imaging (^{23}Na-MRI) is challenging due to the limited signal-to-noise-ratio (SNR) associated with low *in vivo* concentration. It also suffers from image blurring due to its short bi-exponential T_2^* decay. To improve SNR, the acquisition window length (T_{acq}) could be extended longer since SNR grows as square root of T_{acq}[1]. However, the resulting images suffer from blurring due to T_2^*. In this work, we introduce a new method that uses multiple shorter-duration gradient lobes (*i.e.* multiple gradient echoes) that achieves similar SNR to that of a conventional longer single-gradient lobe acquisition, **Figure 1**, but preserves image resolution by reducing T_2^* blurring.

METHODS A density-adapted three-dimensional projection-reconstruction (DA-3DPR) sequence[2] was implemented on a GE MR750 3T MRI (General Electric Healthcare, Milwaukee WI). Two implementations of this ^{23}Na DA-3DPR acquisition were performed. One scheme employed a series of 6 sequential gradient lobes per radial acquisition, each lobe being 4ms long corresponding to a total acquisition window of 24ms. A second scheme used a single gradient lobe with a length of 25ms. The following imaging parameters were used for both gradient strategies: TE/TR = 0.25/100ms, 11310 projections, isotropic resolution/FOV = 3mm/18cm, and 2 averages. Scans were performed on a knee of a healthy volunteer using a home-built 12-rung split design 18-cm-diameter birdcage transmit/receive RF coil tuned for ^{23}Na (33.786 MHz). All images were reconstructed into a matrix size of 540 × 540 × 60 corresponding to a resolution of 0.3×0.3×3-mm^3 (the images were zero-padded in-plane to produce a finer resolution) using a non-uniform fast Fourier transform (NUFFT)[3]. To quantify the extent of blurring, the full-width-at-half-maximum (FWHM) of the line profiles across the patellar, posterior femoral condyle, and femorotibial cartilage were measured and SNR was calculated on the aforementioned cartilage sections according to Madelin *et al.*[4].

RESULTS *In vivo* coronal views of the knee using the two acquisition schemes are shown in **Figure 2**. The FWHM of the line profiles measured across different sections of the articular cartilage were smaller in images acquired using the DA-3DPR multiple gradient echo scheme. Femorotibial cartilage demonstrated the greatest FWHM difference between the two schemes (approximately 3 pixels *i.e.* ~ 1 mm) as depicted in **Figure 3**. The SNR measurement in sections of cartilage is shown in **Figure 4**.

CONCLUSIONS Our new ^{23}Na MR acquisition scheme, DA-3DPR multiple gradient echo, is capable of achieving similar SNR to that of conventional single-lobed DA-3DPR while reducing T_2^* blurring for preserved image resolution.

REFERENCES **[1]** Haacke EM, et al. John Wiley and Sons; 1999. **[2]** Nagel AM, er al. Magn Reson Med. 2009;62(6):1565-1573. **[3]** Fessler J a. J Magn Reson. 2007;188(2):191-195. **[4]** Madelin G, et al. Magn Reson Med. 2012;68(3):841-849.

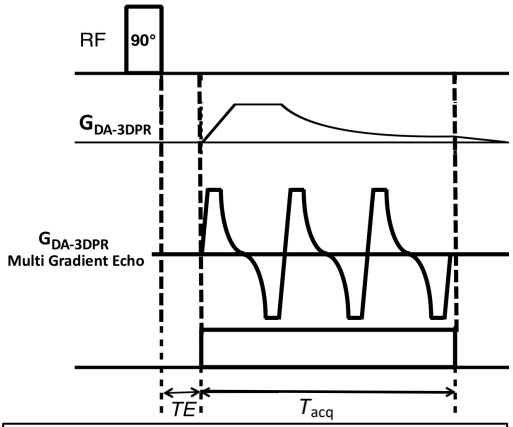

Figure 1. DA-3DPR conventional single-lobe and proposed multiple gradient echo schemes. The proposed method closely matched the conventional acquisition window length to preserve the SNR while short gradient lobes makes imaging more immune to blurring.

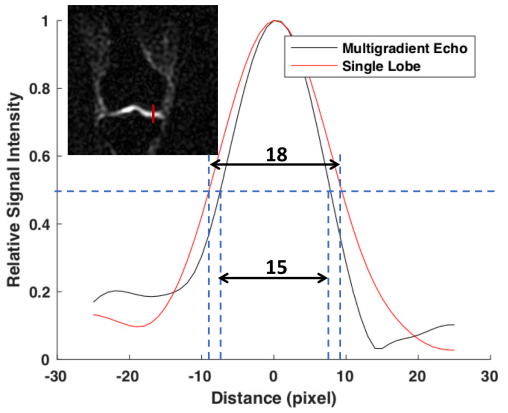

Figure 3. Line profile through femorotibial cartilage. Multiple gradient echo shows less blurring (narrower cartilage cross-section) as compared to conventional DA-3DPR. The red line on the top-left corner image indicates the location of the line profile across the cartilage section.

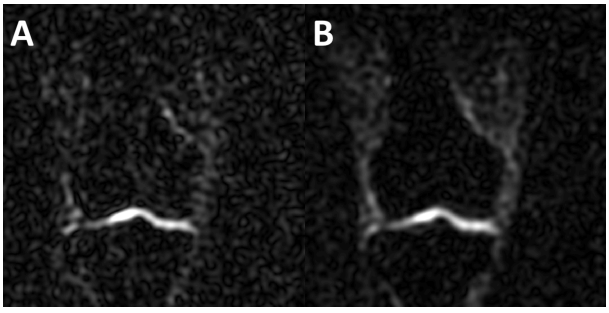

Figure 2(Left). Coronal views of ^{23}Na MR images of the knee using (A) multiple gradient echo and (B) conventional DA-3DPR.

Figure 4(Right). SNR measurements for different sections of articular cartilage. Multiple gradient echo achieved similar SNR as conventional DA-3DPR.