Optimization of Acquisition and Post-processing Strategies for Na-23 Imaging of the Human Kidney

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Introduction: We have recently shown that it is possible to acquire ^{23}Na images of the human kidney at 3T [1]. Using a quadrature surface coil centered over the right kidney we were able to acquire images with a signal-to-noise ratio (SNR) of about 40:1 in the medulla at a pixel resolution of about 3 mm in 24 minutes at 3T [1]. These images were reconstructed off-line using a Fermi filter to improve SNR while preserving spatial resolution (see [2] for a description of the filter and its optimization). We believe that the methods described in our report establish a baseline for any improvements in either hardware (RF coils) or acquisition/post-processing schemes. In this work we explore four different approaches to improve upon our previously published results. These are: 1. Non-uniform k-space sampling methods, 2. Matched filtering post-processing algorithms, 3. Block averaging vs. a single acquisition and, 4. Multi-coil transmit and receive arrays for bilateral kidney examinations. Recently there have been reports comparing several k-space sampling methods for ^{23}Na including acquisition weighted and density weighted methods which oversample the center of k-space with respect to its edges [3, 4] leading to increased SNR. Acquisition weighted methods employing Hanning or cosine weighting factors have been previously described [4-6]. Here we explored the effects of employing acquisition weighting with a matched Fermi filtering scheme on the SNR and resolution of ^{23}Na and ^{1}H images of phantoms. We also compared the results of block averaging (i.e. combining up to four separate six minute acquisitions) to a single 24 minute scan. The rationale for block averaging is to develop acquisition strategies that can be used in cases where patient compliance may be doubtful. In our previous study we used a quadrature surface coil to image a single kidney. Here we compare the results using two quadrature pairs with the single quadrature coil described in our previous studies.

Materials and Methods: ^{23}Na MRI was performed using a 3D-GRE sequence modified for multinuclear imaging, with FOV=38×38×24 cm, matrix size=128×128×16, TE/TR =1.8/30 ms. The short TE was achieved by applying a 66% partial Fourier echo, along with a hard, non-slice selective, 300 μsec RF excitation pulse. A standard acquisition of 8 averages was compared to a weighted k-space sampling in the phase encoding direction according to the diagram in Figure 1, maintaining the same amount of total phase-encoding steps. Block averaging and coil design were tested using a standard 24 averages acquisition. ^{23}Na imaging was conducted on a phantom containing 60 mM NaCl dissolved in 2% agarose. The geometry and design of the quadrature coils is described in reference 1. For the four coil comparison studies we employed two identical quadrature surface coils of the same dimensions. In one configuration we used both pairs with a single channel transmit and receive channel by employing a hi-power 3dB power splitter on the transmit line and a zero-loss combiner on the receive side. A second configuration is to employ the same scheme for transmission but use four separate channels and preamplifiers for receive.

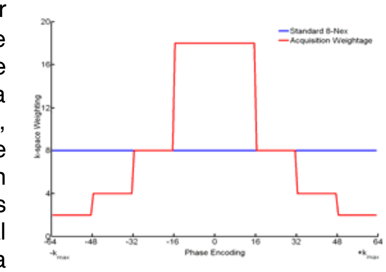

Figure 1. The weighted k-space sampling in the phase encoding direction vs. a standard acquisition of matched total phase-encoding steps.

Results: The SNR and resolution results are shown in Figure 2. Note the significant improvement in SNR obtained by using the acquisition weighting with a Fermi filter. Also note that there is a small loss in resolution with this approach.

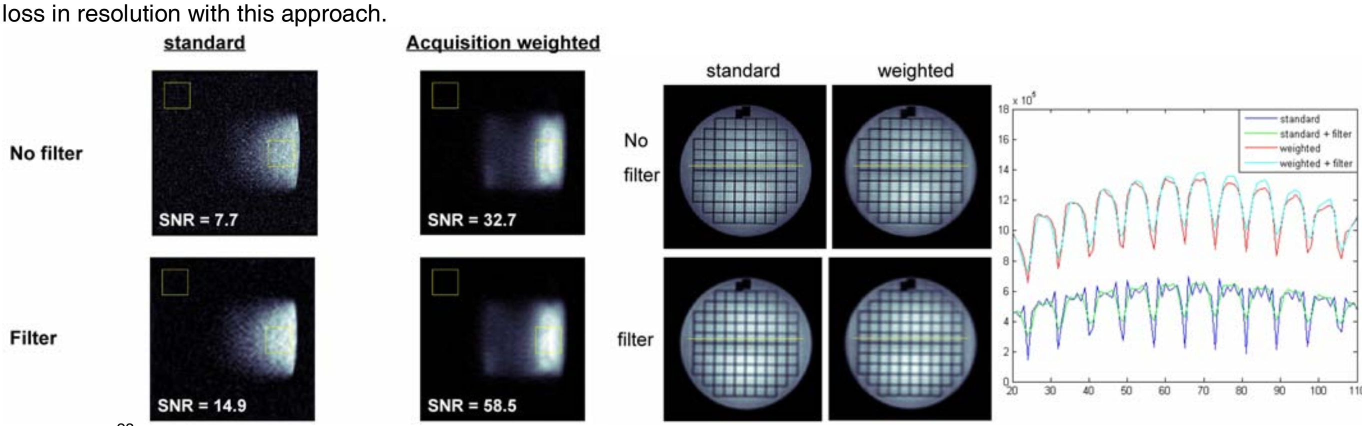

Figure 2. ^{23}Na images on the left acquired in 8 minutes using a standard sequence and an acquisition weighted sequence. The effects on resolution are illustrated on the right in the line plots across proton images obtained on a resolution phantom.

We also found that the SNR obtained using block-averaging was equivalent to that obtained from a single acquisition.
The SNR obtained using the two quadrature pairs of coils was identical to that obtained for a single quadrature surface coil.

Conclusions: Based on these results we conclude that it is possible to significantly improve the SNR of ^{23}Na imaging of the kidney with a minimal penalty in resolution by employing a weighted acquisition scheme in combination with Fermi filtering. Since block averaging has no SNR penalty we suggest that this should become the default acquisition strategy in patients. By using the appropriate RF coil arrays it is also possible to image both kidneys simultaneously without compromising SNR.

References:

1) Maril N et al. Magn Reson Med, 2006 Nov 6; [Epub] **2)** Maril N et al, Magn Reson Med 53(3): 545-52,2005. **3)** Greiser A et al, J Magn Reson Imaging 21(1): 78-81,2005. **4)** Greiser A et al, Magn Reson Med 50(6): 1266-75,2003. **5)** Mareci TH et al, Journal of Magnetic Resonance 92(2): 229-246,1991. **6)** Webb AG et al, Journal of Magnetic Resonance, Series B 103(3): 274-277,1994.