Are we nearly there yet? Cardiac 23Na imaging at 3T using a 3D Ultrashort TE acquisition and phased-array reception

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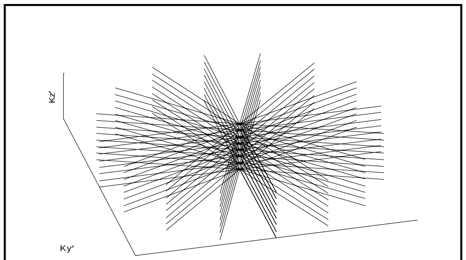
Sodium MR imaging has potential for assessing acute and chronic ischemic heart disease, due to increased sodium concentration after myocardial infarction. However, ^{23}Na imaging is challenging owing to its low sensitivity. To attempt to get high quality ^{23}Na images we have used all the tricks that are available: a 3T imaging system with higher SNR compared to 1.5T; implement phased-array reception, which has previously shown [1,2] to increase SNR, improve coil coverage, and reduce variability from patient positioning; implement a 3D acquisition with short TE, which is required for SNR efficiency; implement SSFP to further boost the SNR. The acquisition needs to be compatible with non-isotropic resolution for short-axis slicing. Our hypothesis is that the combination of these enhancements will provide us with a more powerful scientific tool for investigation of sodium in myocardial disease. We anticipate that the higher SNR will allow us to further improve image quality by correcting for respiratory motion.

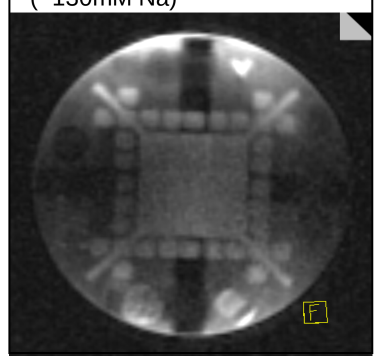
Methods Experiments were performed on a Siemens TIM Trio equipped with multinuclear capabilities. The ^{23}Na coil array has been previously described [3] (RapidBiomed) consists of two identical coil halves (anterior/posterior) that each contain 4 receive-only channels and a transmit loop driven in a Helmholtz-like configuration. The ^{23}Na receive-elements (6x20cm) are centred on the transmit loops. Rx elements are decoupled using a shared inductor design. ^{1}H traps permit the use of the Tx/Rx ^{1}H body coil.

3D Acquisition: The sequence developed for this project uses an ultra-short TE 2D readout, for each radius a series of Kz' phase-encoding gradients are employed to provide the third dimension. The Kz' loop is the inner loop and as the centre of k-space is acquired for each Kxy line this may be used for retrospective respiration correction. The excitation is non-selective, and uses a 1.5ms box-car pulse. The k-space trajectory is shown in the figure on the left. The sequence can be switched between SSFP and spoiled FLASH, and is implemented as a cardiac gated acquisition. The phase encoding gradient after excitation is added with each gradient being of minimal duration, this yields a time between the end of the RF pulse and acquisition of 40us to 220us, this approach has been previously validated. The RF pulse has a duration of 1.5ms. Imaging parameters TR=12.5ms, Resolution 4x4x25mm with an acquisition time of 8min. The Reconstruction was implemented on the scanner, which performs regridding of the centric-radial data (in 2D) and then uses a conventional Fourier Transform in the slice selection direction (reconstruction time for 8-channels is 19s at 128x128x20 resolution). Image quality was assessed on phantom (right).



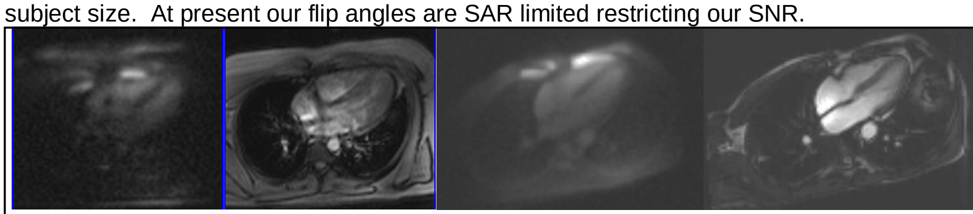
Schematic k-space trajectory showing non-isotropic k-space sampling.

10min 2.3x2.3x26mm 3D volume of 21cm GE phantom (~130mM Na)



Results Standard proton images for analysis of function using the body coil were sufficiently good for analysis. All of the sodium coil elements were found to operate correctly and the inbuilt scanner software correctly combined the signals (the Siemens adaptive combine approach providing higher SNR than the simpler sum-of-squares combination especially in low signal regions). Posterior coil elements were relevant in large subjects.

3D Acquisition: SSFP provides higher SNR in phantoms (0%-42%) and volunteers (1%-21%). Good image quality can be obtained in small subjects, image quality drops with subject size. At present our flip angles are SAR limited restricting our SNR.



Left images large subject (95kg), right images light subject (55kg). Na images (left of each pair) demonstrate strong dependence on subject weight.

Discussion At present 3T, 3D, short TE, SSFP, and phase-array receive coils are all the technologies that we are aware of for boosting the signal to noise on clinically available MRI systems. This combination provides a substantial step forward over our earlier 1.5T non-phased array approaches, and will be used for future clinical research projects on the heart. The 3D stack of spokes approach provides a method that offers rapid reconstruction, short TE and efficient coverage of k-space when sampling at non-isotropic spatial resolutions. Further efforts will focus on retrospective compensation of respiratory motion, investigating whether the trade-off of complexity for SNR of the SSFP approach is acceptable, and most importantly improving our excitation efficiency.

Conclusion Sodium imaging remains a SNR limited approach, but by combining all the standard SNR boosting methods we can achieve reasonable image quality, which we anticipate will allow ^{23}Na to be comprehensively assessed in the clinical research. This approach will never provide resolution comparable with late-enhancement methods, but still may find a role in the clinic.

References: [1] Lee et al. MRM43:269-277 (2000), [2] Lee et al. MRM55:1132-1141(2006), [3] Lanz et al. ISMRM2007:24, [4] Boada et al. MRM38:1022-1028 [5] Kharrazian et al., JMR179:73-84 (2006)