

# Optimized Resolution of Flexible Twisted Projection Imaging for Sodium MR Imaging

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## Purpose:

Quantitative sodium (<sup>23</sup>Na) magnetic resonance (MR) imaging and its derived tissue sodium concentration (TSC) bioscale have clinical applications in determining tissue viability in the human brain. The clinical interpretation of the bioscale is contingent on matching its spatial resolution to the anatomic structures being examined. In order to match the resolution to structures of a few millimeters, the acquisition resolution must balance a short readout time to avoid T2 blurring from the rapid transverse relaxation of the sodium signal against total acquisition time, which must be acceptable for human imaging. We describe an optimization for flexible twisted projection imaging (flexTPI) [1] using an ultra-short echo time that enables a specified resolution to be obtained by minimizing the effects of T2-blurring for a specified total acquisition time. The technique is demonstrated for <sup>23</sup>Na imaging of the human brain at 9.4 Tesla

## Materials and Methods

flexTPI samples a sphere of k-space using non-Cartesian trajectories. In the absence of transverse signal decay and with an optimal reconstruction strategy, the point-spread function (PSF) of the flexTPI data acquisition and reconstruction is approximately 1.5 voxels. Signal decay during readout widens the PSF and results in image blurring.

The resolution of flexTPI for quantitative sodium MR imaging was optimized under the constraints of a total acquisition time of 10 minutes (TR=175 ms to avoid T1 saturation), a maximum gradient amplitude ( $G_{MAX}$ ) of 5 mT/m, a 20 cm FOV, and an average sodium T2 of 7 ms. For each radial fraction ( $F_R$ ) and matrix size pair that met these constraints, the total PSF (including the T2-blurring due to transverse signal decay during readout) was calculated and the true resolution was computed as the full-width at half-max (FWHM) in voxels times the nominal resolution prescribed by the acquisition.

Sodium MR imaging was performed at 9.4 Tesla on a human volunteer after obtaining informed consent at three different flexTPI prescriptions (A:  $F_R=0.449$ , matrix = 49, readout time ( $T_{ADC}$ )=4.29 ms, prescribed\true resolution = 4.08\6.36 mm; B:  $F_R=0.261$ , matrix = 63,  $T_{ADC}$ =13.20 ms, prescribed\true resolution = 3.18\5.68 mm; C:  $F_R=0.184$ , matrix = 76,  $T_{ADC}$ =33.64 ms, prescribed\true resolution = 2.63\6.23 mm). All acquisitions used TR=175 ms and  $G_{MAX}$ =5 mT/m, which resulted in a total acquisition time of 10 minutes. The three datasets were reconstructed with a pixel size of 2.5 mm isotropic so that resolution differences could be appreciated.

## Results and Conclusion:

Figure 1 shows the true FWHM resolution versus the prescribed resolution for the flexTPI acquisition under the constraints of a 10 minute total acquisition time and  $G_{MAX} = 5$  mT/m and for an average T2 of 7 ms. Despite the constant acquisition time, the achieved resolution varies significantly, with the best achieved resolution of 5.68 mm isotropic obtained when the prescribed resolution = 3.175 mm and radial fraction = 0.261.

Figure 2 shows representative slices from the three human acquisitions reconstructed at the common pixel size of 2.5 mm isotropic. These data demonstrate the dependence of image resolution on acquisition parameters. Even though acquisition A has the shortest readout time (4.29 ms), and therefore the least T2 blurring, its true resolution is lower than acquisition B, which has a higher prescribed resolution and more T2-blurring. Acquisition C, which has the highest prescribed resolution, produced a lower-quality image than acquisition B due to the excessive T2-blurring due to the very long readout time (33.64 ms). This result, which is not immediately intuitive, supports the concept of incorporating the effects of T2 blurring into the selection of image acquisition parameters for quantitative sodium MRI.

## References:

[1] Lu A, Atkinson I, Claiborne T, Thulborn KR. Improved quantitative sodium imaging with a flexible twisted projection design and B0 inhomogeneity correction. Proceedings of ISMRM. #2472. 2009.

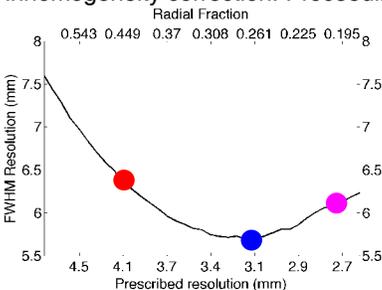


Figure 1: True vs prescribed resolution for flexTPI when the average T2 = 7 ms and  $G_{MAX} = 5$  mT/m.

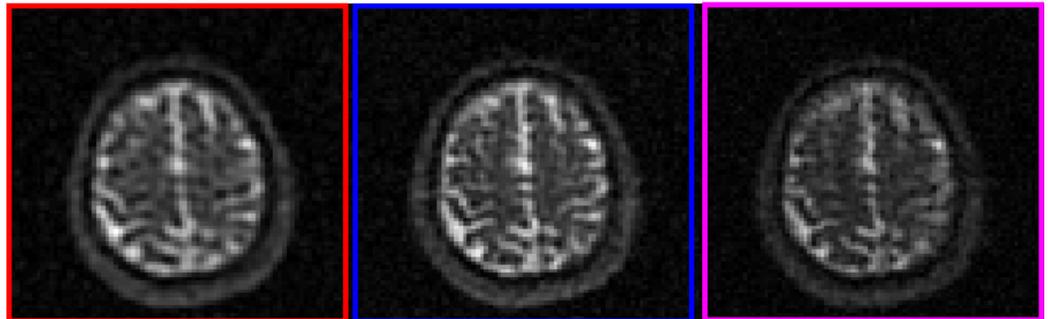


Figure 2: Representative axial slices from 3D acquisitions A (left), B (center) and C (right) illustrating the resolution