Rotation Correction with Self-Navigated MRI

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INTRODUCTION
Segmented sequences, such as turbo-spin-echo (TSE) sequences, measure multiple lines of k-space with a single excitation. Since k-space is acquired over time in a segmented fashion, object rotation must be considered in the image reconstruction. Previous methods to detect rotation of segmented data typically require prior patient preparation such as the application of spatial-frequency tuned markers(1), the acquisition of additional navigator data such as orbital/spherical navigators(2,3) or non-Cartesian sampling methods such as PROPELLER(4). The proposed technique compares adjacent sets of measurement lines in Cartesian k-space to detect and quantify object rotation. Because the proposed technique makes use of correlations between adjacent data sets, we greatly reduce the total amount of additional data required to quantify object rotations.

THEORY
Consider an object described by a function \( m(x,y) \) and Fourier transform \( M(k_x,k_y) \). The discrete k-space data sampled by the \( L^\text{th} \) echotrain of a TSE sequence can be written:

\[
M_L(n,m) = \sum_{j=0}^{N-1} \sum_{i=0}^{M-1} M(n-\Delta L \cdot j, m-\Delta k \cdot i) W(n-j, m-i)
\]

To find the amount of object rotation between two adjacent echotrains, \( M_L(n,m) \) and \( M_{L+1}(n,m) \), we first counter rotate \( M_{L+1}(n,m) \) by a test angle \( \phi \) and then re-grid the data to form \( M_{L+1}(n,m) \). The data from the two echotrains are then compared with a weighted difference formula:

\[
\Delta M_L(\phi) = \frac{1}{N_w} \sum_{n,m} \left| W(n,m) \right| \left( |M_L(n,m)| - |M_{L+1}(n,m)| \right)
\]

where \( C(m) \) is a convolution function to take advantage of correlations between adjacent data sets, \( W(n,m) \) is a weighting function to select the k-space points that contain information from both echotrains, \( N_w \) is the total number of points selected by \( W(n,m) \) and \( \epsilon \) is a small constant to prevent a divide by zero. If the rotated object is not angularly symmetric, then the weighted difference function in Eqn. 2 will exhibit a minimum value when the test angle \( \phi \) equals the object rotation.

RESULTS
Figure 1 shows the comparison of adjacent echotrains from an object rotated by 4.6 degrees. The weighted difference in Fig. 1c shows a definite minimum located at 4.6 degrees. The experiment is repeated comparing the second and third echotrains followed by the third and fourth echotrains with similar results. Applying the proposed self-navigating rotation correction to an entire data set is shown in Fig 2 and 3. The difference image comparing the corrected image to the original shows that most of the remaining artifact has a similar intensity to that of the surrounding noise.

CONCLUSION
This work provides a demonstration that in-plane rotational motion that occurs during the acquisition of MRI data can be quantified using a self-navigation technique. This method can be applied to any segmented sequence that samples k-space in sets of equally spaced lines. It does not require any patient preparation or the acquisition of separate navigator data. The method only requires a slight increase in the field of view along the phase encoding direction, but the amount of increase required is small enough that resolution or total scan time are not significantly affected.

REFERENCES