An improved algorithm for trajectory correction in radial MRI

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Target audience Users of radial MRI techniques.

Purpose Radial acquisition has inherent advantages over Cartesian k-space sampling, such as lower sensitivity to motion and flow artifacts and efficient coverage of k-space. In addition, repeated sampling of the k-space centre yields a signal that can be used as a navigator for retrospective gating of k-lines into frames covering the cardiac or respiratory cycles. However, radial acquisitions can suffer from trajectory errors leading to reduced image quality. Furthermore, trajectory errors lead to an extra modulation of the navigator signal for retrospective gating. Here we present a new method of retrospective trajectory correction that uses all spokes of a radial acquisition and compare it to an existing method that uses a two-spoke pre-scan calibration [1], demonstrating it in the mouse heart.

Methods We imaged ten C57 mice at 4.7T with a Bruker BioSpec 47/40 system. We acquired retrospectively-gated cine MRI with 1mm slices across the heart with Cartesian and radial sampling. Radial acquisitions covered 360° with 1440 spokes (256 points per spoke, echo position 5%) with 5.6/1.0 ms TR/TE, FOV 3.5x3.5 cm. Cartesian images were also acquired with the same field of view. We considered trajectory correction using the phase of two perpendicular k-space lines (acquired along the x- and y-directions, following Block *et al* [1]) compared to using all antiparallel spokes covering 360°. In each case we considered the additional impact of correcting for B0 effects, following Moussavi *et al*[2].
Retrospectively gated images were reconstructed using a non-uniform fast Fourier transform[3]. Small trajectory errors lead to reduced signal in the subject ("shading") and artifactual signal outside the subject ("halos", see Figure 1B). We quantified this with two measures. The first summed the signal inside the body (where lower values indicate more severe artifacts) and the second summed signal outside the body (where increasing values reflect more severe artifacts). These artifacts do not change with the phase of the heart cycle so we averaged the cine frames to calculate a value for each image with high signal to noise ratio. The object mask used was derived from the Cartesian images automatically using a threshold. As a further measure of trajectory correction, we summed the first two harmonics of the sweep frequency under each scheme tested compared to uncorrected data.

Results With no correction applied, we saw artifacts in all images. Artifacts consisted of shading (Figure 1B, arrow) and/or halos (Figure 1B, arrowhead). The figure shows the corrected images using the phase information with two perpendicular directions (Figure 1C) and with every direction (Figure 1D). The additional effect of B0 correction is shown in Figure 1E, little further improvement was seen in our images. Quantification of the improvement is shown in Figure 2. An increase in signal inside the object is seen with all correction methods and this improves when more spokes are used, and furthermore with the B0 correction even though the improvement in the image appearance was minor. Furthermore, reductions of the signal outside of the subject were seen with all schemes and these were significantly lower when more spokes were used. The improvement on the navigator signal was congruent with the other measures.

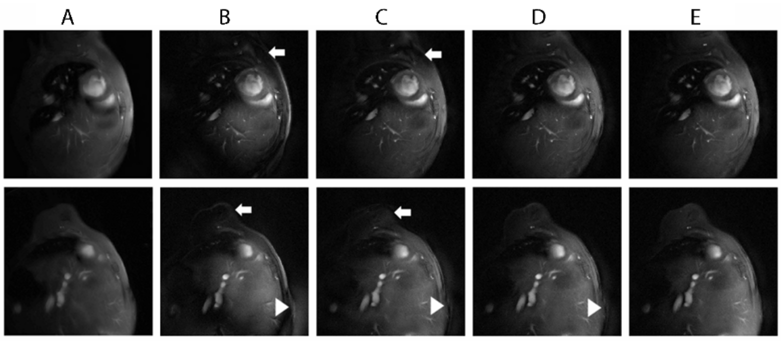

Figure 1 Effects of trajectory correction using the phase of the projections on a short-axis slice before applying gating. Arrows point to shading artifacts, arrowhead to halos. A) Cartesian image. B) Radial image before any correction is applied. Shading is visible in several parts of the body. C) Correction of linear eddy current terms is applied using the Cartesian axes. Artifacts are still visible especially at the edge between body and air. D) Correction of linear terms using the whole sweep. The image is artifact-free. E) B_0 correction is applied, edges are sharper.

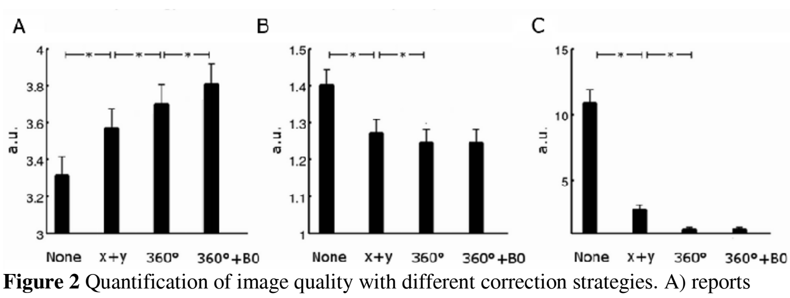

Figure 2 Quantification of image quality with different correction strategies. A) reports the mean intensity inside the body (shading), B) reports the mean intensity outside the body (halos), while C) reports the modulation on the navigator signal. Graphs show mean ±SEM. *$p<0.01$ paired t-test

Conclusions We have shown that retrospective correction of radial MRI data can be obtained using our method, outperforming current strategies. The method utilises data from the whole sweep and does not require additional calibration or preparation. This correction improves image and navigator signal quality in radially acquired cine MRI.

References

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