A noval method of correcting off-center errors for radial acquisition with arbitrary angle.

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Purpose Radial MR imaging using golden-angle acquisition scheme attracts huge attentions due to its robustness against motion and undersampling, as well as its flexibility to retrospectively balance the spatio-temporal resolution. However, one intrinsic problem of golden-angle radial acquisition is that its pulse sequence usually features abrupt gradient change amid repetitions, which makes it more vulnerable to hardware imperfection such as gradient delays comparing to conventional radial angle acquisition. Such gradient delays resulting in off-center error degrades the final image quality. Previously, a few self-calibration methods have been proposed to correct off-center shifts [1, 2]. Those methods require 0º-180º and 90º-270º degree projection pairs to estimate kx and ky shift, and only correct shifts along the radial direction. In reality, these pairs are not always possible for golden angle radial acquisition, and the shift perpendicular to radial direction should not be neglected. This abstract proposed a novel method which is applicable to golden angle scheme and can be easily extended to any arbitrary radial angle acquisition.

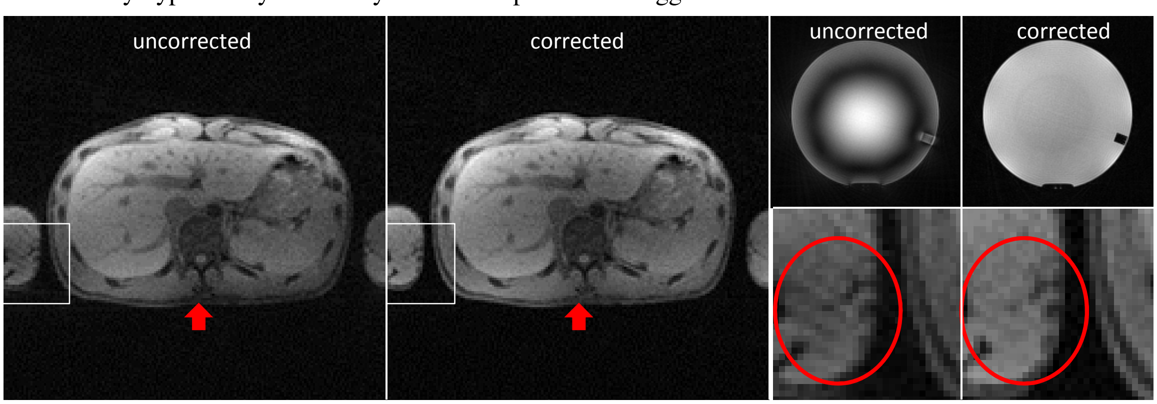
Methods Instead of searching for the 0º-180º and 90º-270º projection pairs as described previously, the proposed method requires an arbitrarily-defined number of pseudo anti-parallel projection pairs that have angle difference of 180º±1º to form a group of equations for solving off-center shifts in kx and ky direction. Linear regression methods such as least square method can be applied to these equations to calculate shift along *tx* and *ty*. The shift along radial direction can be calculated by applying the *tx* and *ty* values for each projection with an angle of φ:

$$\mathrm{k}_r(\varphi) = \frac{(\cos(2\varphi)+1)}{2}tx + \frac{(1-\cos(2\varphi))}{2}ty$$

Furthermore, the shift perpendicular to radial direction $\mathrm{k}_\perp$ can also be calculated in a similar approach with *tx* and *ty* for better accuracy.

$$\mathrm{k}_\perp(\varphi) = \frac{\sin(2\varphi)}{2}(tx - ty)$$

The correction is then followed by gridding reconstruction. For evaluation, this method was implemented for a 3D radial stack-of-stars sequence. A set of 3D T1W TFE images were obtained in both water phantom (3T Achieva, Philips Healthcare) and abdomen of a healthy subject under free breathing (1.5T Multiva, Philips Healthcare) using a 16-channel head coil and a Head Spine and Torso (HST) coil, respectively. For the phantom images, we intentionally bypassed system delay calibration phases to exaggerate the artifacts.



Result and Discussion The figure above shows a comparison of the reconstructed images before and after the radial off-center correction. Gridding with the corrected trajectory resulted in less streaking artifacts (circles) and better image homogeneity (points). Compared to the previous methods, the proposed method does not require the 0º-180º and 90º-270º pairs. Once more than one pair of pseudo anti-parallel projections are acquired, the proposed scheme can be applied to correct shifts both along and perpendicular to the radial direction. For example, 24 such pairs with 180º±0.5º angular difference can be found when 168 spokes are collected in a golden angle order.

Conclusion An off-center correction method for arbitrary radial angle acquisition, including golden angle scheme, is proposed. Both preliminary phantom and human data have proved its effectiveness and robustness in correcting errors caused by gradient delays and in improving image quality without extra scans or calibration procedures.

Reference: [1] Wieben O., et al. ISMRM 2003, p.298. [2] Block K.T., et. al. ISMRM 2011, p.2816;