Ultra-Short TR Contrast-Enhanced MR Angiography with Spiral Centric Phase Reordering

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Introduction

For the contrast enhanced MR angiography (CE MRA) [1] with a 3D Spoiled GRE sequence, the speed is a primary design requirement [2]. One way to improve the speed is to maximize the sequence efficiency (i.e. the ratio between DAQ event and TR) by skipping the phase encoding (PE) rewinders. This, however, introduces the phase coherence artifacts in backgrounds, in particular within the body regions where soft tissues are more prominent.

The current study proposes a novel spiral centric phase reordering algorithm that significantly reduces the phase coherence artifacts and allows ultra-short TR CE MRA while skipping PE rewinders.

Methods

Our standard CE MRA sequence utilizes the centric phase reordering [3]. The centric reordering sorts the ky-kz points with the preference order of 1) radius from [ky,kz]=0 (*kr*) and 2) azimuth angle with respect to ky axis (Φ). With this, the ky-kz points are chosen from inside out in linear fashion. However, the centric reordering requires frequent jumps between 4 quadrants since radii take priority over azimuth angles. These jumps result in the large amount of the total reordering distance, S_{tot} (i.e. the sum of the trajectory distance, in mm^{-1}). Large S_{tot} enhances the phase coherence artifacts.

To reduce the S_{tot}, we propose *the spiral centric reordering algorithm* (Figure 1). Based on radius, ky-kz data points are segmented into the concentric ring regions of equidistant width, and then they are assigned with corresponding region integer number (*N*) in ascending order from center to outer (e.g. center=0, 1st increment =1, etc). The sorting is then performed with the preference order of 1) *N*, 2) Φ, and 3) *kr*. With this algorithm, the ky-kz data are acquired in spiral fashion (one ring region at time, for in-out diretion). *kr* is used as a tie breaker when Rn and Φ are identical. This eliminates virtually all the quadrant jumps except corners.

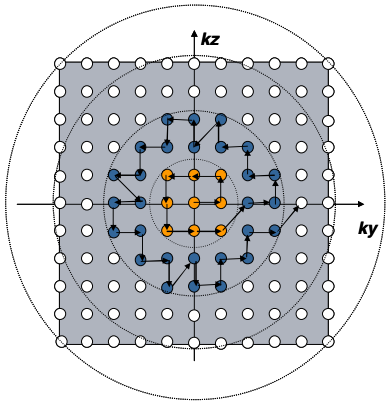

Figure 1: Schematic diagram of the Spiral Centric Reordering. Arrows show the trajectory starting at the center (the first 2 region progressions are shown). Different colors represent the centric regions (orange: N=0, blue: N=1).

Results, Discussion and Conclusion

Figure 2 shows the results of the high-resolution body CE MRA without PE rewinders in 1.5T Siemens Avanto MRI scanner (TR/TE 2.28/0.95ms, total scantime 19 sec, FOV 500mm, voxel size 1.3 x 1 x 1.4mm^3, 288 x 512 x 128 matrix, iPAT 3, 16% read out echo asymmetry, 6/8 partial Fouriers, 25 degrees FlipAngle, and BW 610Hz/pixel). In this high-resolution single-breath hold scan, PE rewinders save 4 seconds of the total scan time (23 sec compared to 19 sec, 17% total scantime reduction). The original centric reordering, which has more than 10 times the total reordering distance, results in visible coherence artifacts (vertical line structured noises shown in Figure 2(a) and 2(c)). The proposed spiral centric reordering successfully mitigates the phase coherence artifacts (Figure 2(b) and 2(d)). The complete CE MRA subtracted MIP (Figure 2(e)) shows no coherence artifacts. With this reordering algorithm, the ultra-short TR high-resolution CE MRA is attainable.

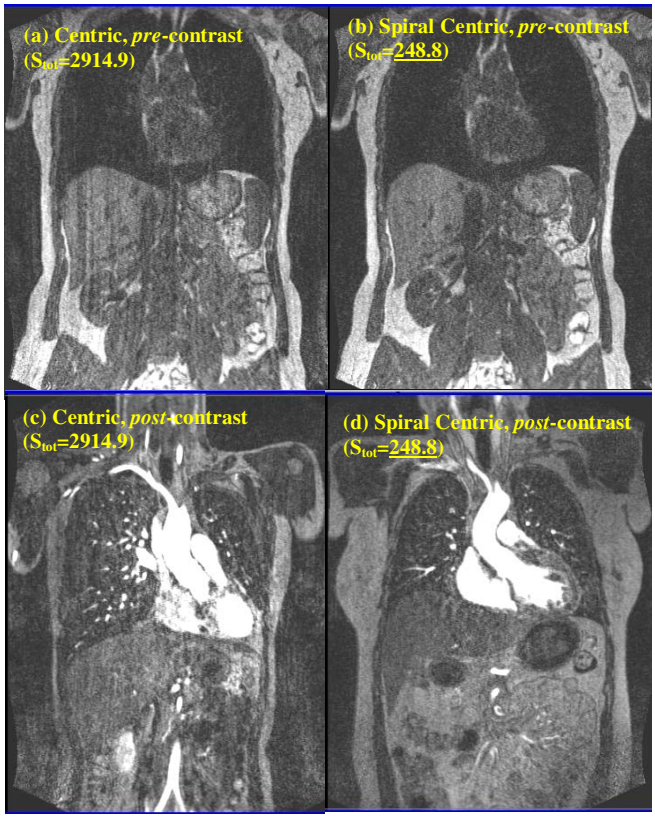

Figure 2: Representative result images of high-resolution body CE MRA without PE Rewinders. (a)(b) The body pre-contrast mask of **the same patient** with Centric Reordering and Spiral Centric Reordering are shown. The total reordering distance S_{tot} is more than 10-fold shorter in Spiral Centric, and the phase coherence artifacts (i.e. vertical lines along the Read Out direction) are successfully mitigated. (c)(d) The body post-contrast images of **the different patients**, with the Centric and the Spiral Centric Reordering. (e) Coronal subtraction MIP (the difference between pre and post contrast CEMRA images) with the Spiral Centric shows no visible residuals from coherence artifacts.

References

[1] Prince, et al.1999. [2] Bernstein et al.2004. [3] Wilman, et al., Rad.1997.