Comparison between Cartesian and Spiral MR flow imaging of stenotic flow.

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TARGET AUDIENCE: People with an interest in scan time reductions, spiral k-space trajectories and stenotic flow assessment.

PURPOSE: Spiral k-space trajectories have previously successfully been used to reduce the scan time of 4D flow MRI of aortic and intra-cardiac flow[1,2]. Spiral k-space trajectories are relatively insensitive to flow and motion artifacts. This makes spiral 4D flow MRI well suited for stenotic flow assessment. The purpose of the present study was to compare the performance of spiral and Cartesian MR flow imaging for the assessment of velocity and turbulent kinetic energy (TKE) in stenotic flow.

METHODS: A stack-of-spirals 3D phase-contrast (PC) MRI sequence was evaluated in-vitro against a conventional Cartesian sequence using stationary flow in a straight-pipe phantom with a 14.6 mm diameter and a 75% area-reduction stenosis (outlined in Figure 1). The fluid consisted of water, and two different flows with Reynolds numbers 1000 and 2000 were imaged for evaluation of TKE assessment. As the viscosity of water is much lower than the viscosity of blood, these Reynolds numbers resulted in relatively low velocities. Therefore, a separate acquisition with flow settings corresponding to a moderate aortic stenosis (peak velocities around 2.8 m/s) was performed to study displacement artifacts. The spatial resolution of all acquisitions was 1.5 mm isotropic. In the spiral acquisition, each slice consisted of 12-15 spiral readouts of 5.5-6.0 ms. The scan time of the spiral sequence was around 1/3 of the Cartesian.

Total TKE in the post-stenotic region was computed by integration of TKE between the center of the stenosis and six diameters downstream. Displacement artifacts were assessed by visual inspection of velocity and magnitude data.

RESULTS: The TKE from the spiral and Cartesian data showed good agreement. Figure 1 shows the TKE for Reynolds number 1000, for which the total TKE from the spiral and Cartesian data were 20.8 and 20.3 μJ, respectively. For Reynolds number 2000 the total TKE from the spiral and Cartesian data were 95.6 and 93.6 μJ, respectively.

Although displacement was observed in both the spiral and Cartesian data, it was generally less prominent in the spiral data as seen in Figure 2 and 3. The peak velocities from the spiral and Cartesian data also showed good agreement.

DISCUSSION: The TKE and velocities from the spiral and Cartesian acquisitions showed good agreement for all flows. As expected, displacement artifacts were less prominent in the spiral acquisitions.

CONCLUSION: Spiral 4D flow MRI appears favorable for the assessment of stenotic flow. The spiral sequence was three times faster, and less sensitive to displacement artifacts, when compared to a conventional Cartesian sequence.

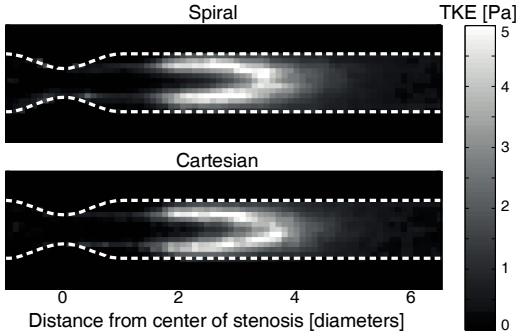

Figure 1. Cross sectional images of the turbulent kinetic energy (TKE) from the spiral and Cartesian acquisitions of the flow with Reynolds number 1000.

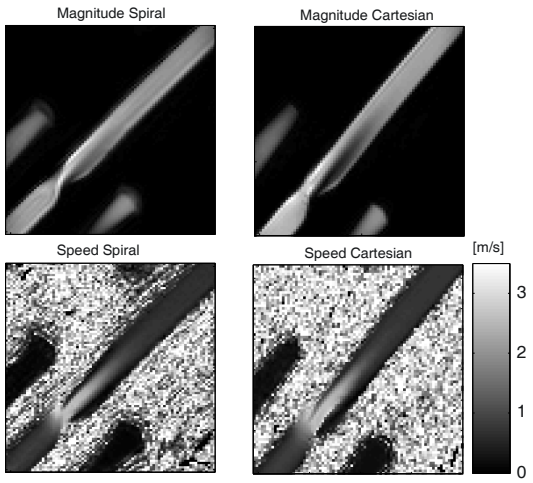

Figure 2. Cross sectional images of the magnitude and speed from the spiral (left) and Cartesian (right) acquisitions with an oblique orientation. Frequency and slice encoding was carried out along the vertical and horizontal axis, respectively. The stenosis and jet were displaced towards the upper left corner. Displacement was less prominent in the spiral data.

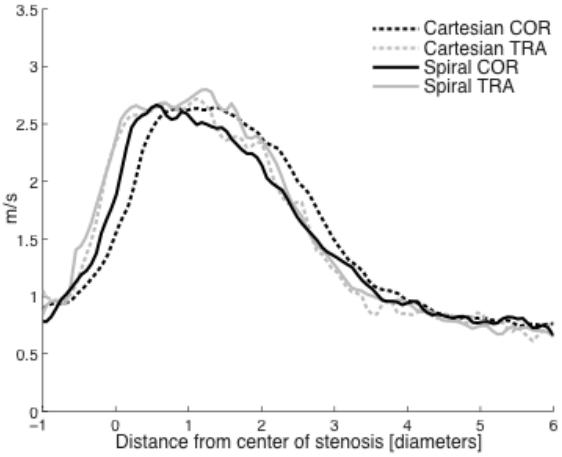

Figure 3. The velocity along the centerline of the phantom from the spiral and Cartesian acquisitions. Two different orientations were imaged, COR: coronal and TRA: transverse, with frequency and slice encoding in the principal flow direction, respectively. No significant displacement is expected for the transverse orientation. There was around 50% less displacement for the spiral data compared to Cartesian.

REFERENCES: 1. Sigfridsson A, et al. Four-dimensional flow MRI using spiral acquisition. Magn Reson Med. 2012; 68(4):1065-1073. 2. Petersson S, et al. Retrospectively gated intra-cardiac 4D flow CMR using spiral k-space trajectories. 16th Annual SCMR Scientific Sessions 2013.