Non-Contrast Enhanced Time-Resolved 4D MRA with Dynamic Golden Angle Radial Acquisition and K-Space Weighted Image Contrast (KWIC)

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Introduction: The evaluation of dynamic flow patterns within the cerebrovasculature is useful for a number of clinical indications, such as steno-occlusive disease, arteriovenous malformation, and cerebral aneurysm. Recently, non-contrast time-resolved 4D dynamic MRA (dMRA) was introduced by combining arterial spin tagging with a segmented multiphase TrueFISP readout – a technique termed TrueSTAR (1, 2). While initial implementation has demonstrated the capability of this technique to provide a temporal resolution of 50-100ms and a spatial resolution of a few mm^3, the scan time may still be too long in clinical settings to cover adequate number of time frames with high spatial resolution. Dynamic radial acquisition with golden angle view increment (3) is a recent development for 4-D dynamic MRI, which offers a high degree of efficiency and flexibility for retrospective image reconstruction. The present study explores the feasibility of both single- and multi-shot interleaved golden-angle radial acquisition strategies followed by temporal filtering (k-space weighted image contrast or KWIC (4)) to achieve 4D dMRA with high SNR, low streaking artifacts and high temporal fidelity.

Methods: The pulse sequence consisted of continuous 2D TrueFISP readout following slice-selective or non-selective inversion pulses, as in FAIR. For single-shot acquisition, dynamic radial sampling with view angle increment of θ_g=111.25° (golden angle) (3) was utilized. In addition, several multi-shot versions of the sequence were also evaluated, in which the starting view angle was (n-1)*θ_g for shot #n and for each shot the view angles were incremented by Ns*θ_g, where Ns is the total number of shots. This scheme permits an interleaved acquisition while still providing the flexibility of golden angle acquisition in which the number of views used during reconstruction is flexible. Imaging parameters were as follows: FOV=256mm, 500 views per shot, TR=4.58ms, TE=TR/2, flip angle=30°, bandwidth=630Hz/pixel, 10x4mm slices covering the Circle of Willis and main branches, scan time = Ns x 1 min. Each data set was reconstructed using 160 total views per time frame, with an effective temporal resolution of 92 ms (20-view window) via the KWIC filter (4). In KWIC the central region of k-space is encoded with fewer radial views (20 in this study), while progressively greater numbers of views are used towards the outer regions. Since image contrast is determined mainly by the signal at k-space center, the effective temporal resolution is determined by the temporal width of the central views. For the 8-shot acquisition, no KWIC filtering was necessary. For comparison, a 2D Cartesian version of the sequence was also evaluated with closely matched imaging parameters with a total scan time of 10 min. Twenty-two phases (10 shots) with temporal resolution of 110ms were acquired.

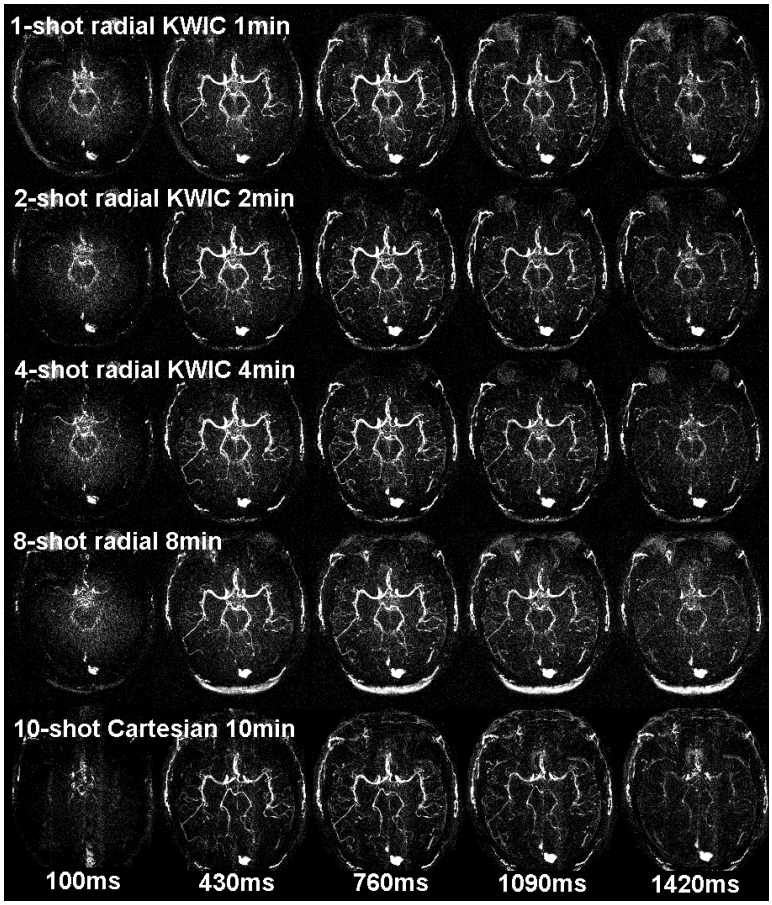

Fig. 1 Radial dMRA MIP images at 5 phases reconstructed using different numbers of shots, compared to the Cartesian acquisition.

Results and Discussion: Figure 1 shows dMRA images acquired at 5 phases using radial and Cartesian acquisitions with different numbers of shots. The overall image qualities for all scans are similar. Dynamic filling of small branches of MCA and PCA is clearly visualized for all acquisitions. Aside from slightly different levels of noise and image sharpness between radial and Cartesian images, the image qualities are largely consistent between the two sampling schemes. The SNRs (defined as peak MCA signal/background mean) for the radial scans ranged from 8.5 to 9.5, while the value was 10.3 for Cartesian. Figure 2 depicts the signal time course in the MCA, demonstrating excellent agreement among the techniques.

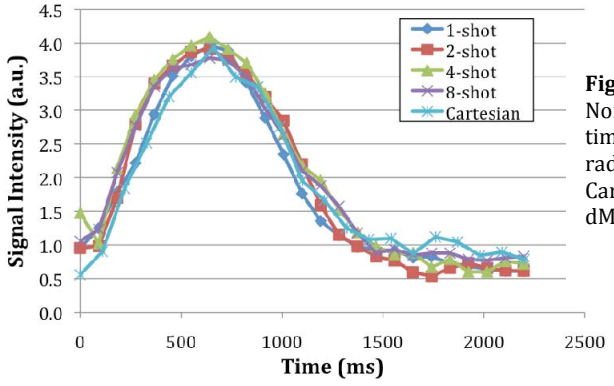

Fig. 2 Normalized MCA time courses of radial and Cartesian based dMRA.

Conclusion: Our preliminary work demonstrates the feasibility of single-shot and interleaved multi-shot dynamic golden angle radial acquisition scheme for non-contrast enhanced dMRA. For single-shot, the scan time is only one tenth of the standard Cartesian based dMRA, without observable temporal smoothing. As a next step, the utility of dMRA with dynamic golden angle radial acquisitions needs to be evaluated in clinical studies.

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References (1) Yan et al Radiology 2010, 256:270-9; (2) Bi et al MRM 2010, 63:835-41; (3) Winkelmann et al IEEE TMI 2007, 26: 68-75; (4) Song et al MRM 2004, 52:815-824.