Time-Resolved 4D MRA using TrueFISP based Spin Tagging and Dynamic Golden Angle Radial Acquisition

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Introduction: The evaluation of dynamic flow patterns within the cerebrovasculature is useful for a number of clinical indications, such as carotid stenosis, arteriovenous malformation, and cerebral aneurysm. Digital subtraction angiography and (dynamic) contrast enhanced MR angiography (MRA) are the clinical standard for these indications, yet these procedures bear considerable risks and require injection of contrast agents. Recently, unenhanced time-resolved 4D dynamic MRA (dMRA) has been introduced by combining arterial spin tagging with a segmented multiphase TrueFISP readout – a technique termed TrueSTAR (1, 2). Both millimeter (1-4mm^3) spatial resolution and millisecond (50-100ms) temporal resolution have been demonstrated using this technique. The present study explored the feasibility for applying dynamic radial sampling with golden angle view increment in TrueSTAR to reduce the total scan time by nearly 10 fold.

Methods: The pulse sequence consisted of continuous 2D TrueFISP readout following slice-selective or non-selective inversion pulses, as in FAIR. Dynamic radial sampling with a constant azimuthal increment of 111.25° (golden angle) (3) was implemented during TrueFISP readout (see Fig. 1). Imaging parameters were as follows: FOV=256mm, 500 views, TR=4.22ms, TE=TR/2, flip angle=30°, bandwidth=630Hz/pixel, 10x4mm slices covering the Circle of Willis and main branches, scan time = 1 min. Thus, for each slice, only a single slice-selective/non-selective excitation and data readout pair was acquired; no interleaving was performed. For comparison, the standard TrueSTAR sequence with Cartesian acquisition was applied at the same slice positions. Imaging parameters were: FOV=256mm, matrix=256x256, TR=4.42ms,TE=TR/2, flip angle=30°, bandwidth=630Hz/pixel, 22 phases between 118 and 2344ms with a step of 106 ms, scan time=8min. For this preliminary work, a dynamic image series was reconstructed using radial undersampling with 60 and 20 views/frame. A temporal shift of 10 views was used to step to the next time frame.

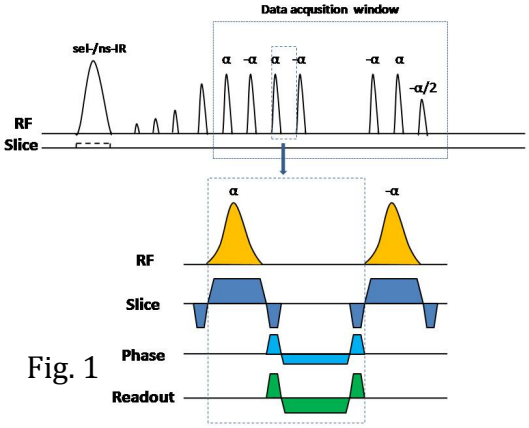

Fig. 1

Results and Discussion: Figure 2a & b show dMRA images acquired at 5 representative phases using radial acquisitions with 60 and 20 views/frame, respectively. The streaking artifact is clearly visible in 20 view/frame images, but is largely suppressed in 60 view/frame images which also demonstrate dynamic filling of small branches of MCA and PCA. The dynamic time courses of the 60-view radial dMRA are largely consistent with the dMRA images acquired with standard Cartesian acquisition (Fig. 2c), although a small degree of temporal smoothing is observed (Fig. 2c). The ghosting artifacts around the Circle of Willis in Fig. 2c (arrow) due to pulsation effects are suppressed in radial dMRA images which took 1/8 time (1min) to acquire.

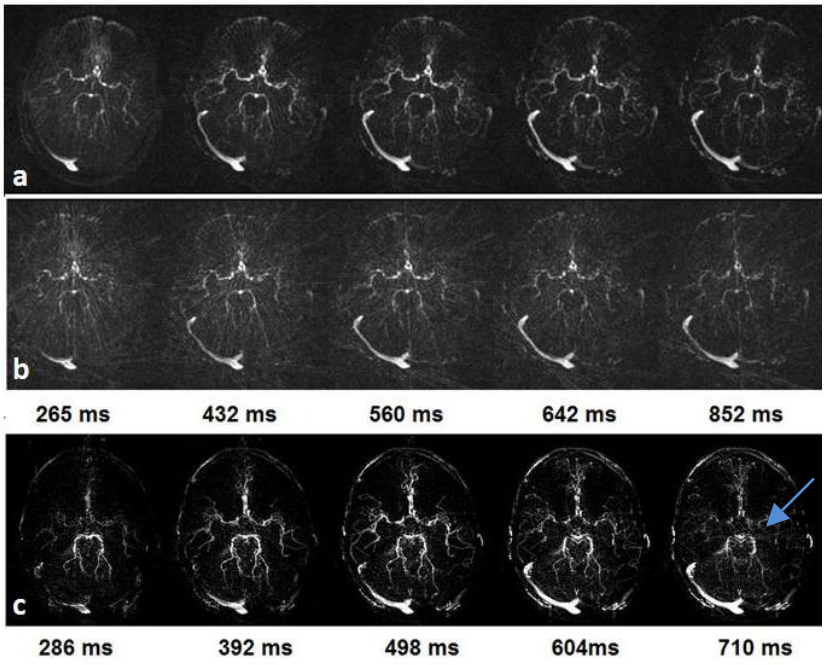

Fig2. Radial dMRA images at 5 phases reconstructed using (a) 60, (b) 20 view/frame, along with dMRA images with Cartesian sampling (c)

Conclusion: Our preliminary work demonstrates that dynamic golden angle radial acquisition scheme can drastically reduce the scan time (nearly 10 fold) for time-resolved dMRA with spin tagging. Such improvement in scan time may permit a more robust protocol, less affected by patient motion. In the future, this technique can be combined with compressed sensing or HYPR, KWIC to reduce streaking artifacts, improve temporal resolution and SNR.

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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.