Highly Accelerated Intracranial 4D Flow MRI with CIRcular Cartesian UnderSampling (CIRCUS)

Jing Liu[1], Farshid Faraji[1], Sarah Kefayati[1], Henrik Haraldsson[1], and David Saloner[1,2]

[1]*Radiology and Biomedical Imaging, University of California San Francisco, San Francisco, CA, United States,* [2]*Radiology Service, VA Medical Center, San Francisco, CA, United States*

INTRODUCTION

4D flow MR imaging has high potential to provide a comprehensive evaluation of intracranial hemodynamics. Because high spatial resolution is required, scan times can be excessive even for limited coverage. In this study, we implemented a novel undersampling scheme, which integrates the features of randomization, variable-density, and flexible time-resolved interleaving, to achieve highly accelerated data acquisition. We compared 4D flow images reconstructed with our proposed acceleration method to those acquired with a conventional acceleration method, based on qualitative and quantitative measurements.

MATERIALS AND METHODS

4D flow data was acquired on a 3.0T Siemens Skyra scanner with a 20-ch head coil. Data from a volunteer was obtained in the axial plane, covering the Circle of Willis, with scan settings: VENC=1m/s, FOV=18x18cm^2, slice thickness=1.4 mm, matrix=128x128x24, FA=15^o, TR/TE=6.0/3.5ms, 15 time frames with 72.5ms temporal resolution. Both iPAT (R=2, effective R=1.7) and our proposed pseudo-random undersampling scheme, CIRcular UnderSampling (CIRCUS) (R=4) [1], were applied with a scan time of 12.7 and 5.3 mins respectively. In addition, with CIRCUS acquisition, data could be retrospectively trimmed to mimic acquisitions with shorter scan times. In this study, we also reconstructed images from a partial data with CIRCUS to mimic a scan of 3 mins. CIRCUS was also applied to two patients with intracranial aneurysms with acquisition in the oblique sagittal plane to provide extended coverage of the feeding arteries, with scan settings: VENC=1m/s, FOV=24x18cm^2, slice thickness=1.3 mm, matrix=192x144x26, FA=6^o, TR/TE=6.4/3.7ms, 16 time frames with 52.7ms temporal resolution, and scan time (R=5.3) of 5.4 and 5.1 mins respectively (depending on heart rate). Data acquired with CIRCUS was reconstructed using a multicoil compressed sensing reconstruction exploiting joint sparsity along the temporal dimension with a total variation constraint [2,3]. We compared qualitative image quality as well as quantitative measurements (per-pixel flow velocities and flow-waveforms within selected vessels).

RESULTS AND DISCUSSION

Fig.1 shows the image quality comparison between the conventional acceleration method iPAT and the proposed CIRCUS method. Despite the significant reduction in scan time, CIRCUS maintains good image quality even at R=7. The statistical analysis of the velocities in Circle of Willis show good agreement between iPAT and CIRCUS. Fig.3 shows the flow-waveforms of middle cerebral artery obtained with different methods. The normalized root-mean-square-errors (NRMSE) of the flow-waveforms between the methods are smaller than 5%. Fig.4 shows swirling flow in the proximal portion of the fusiform internal carotid artery aneurysm, data acquired with CIRCUS (R=5.3).

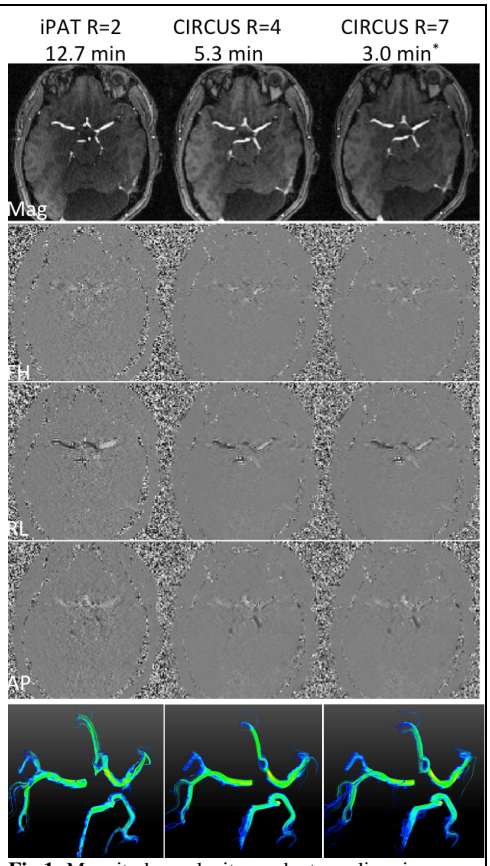

Fig.1 Magnitude, velocity and streamline images achieved with iPAT and CIRCUS.

CONCLUSIONS

We have successfully acquired highly accelerated intracranial 4D velocity data. Our preliminary results demonstrate excellent image quality and accurate velocity measurements. Data from more subjects will be acquired and analyzed for further validation.

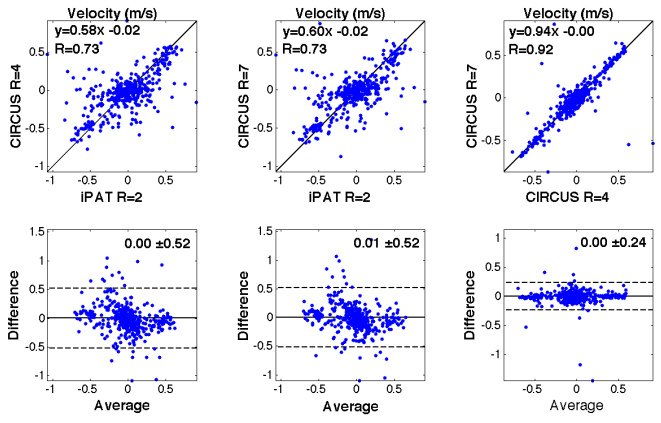

Fig.2 Linear regression and Bland-Altman plots of per-pixel flow velocities in RL direction) of Circle of Willis between the acceleration methods.

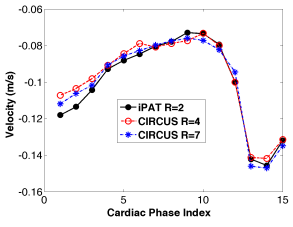

Fig.3 Flow waveforms in middle cerebral artery in RL direction, with different acceleration methods.

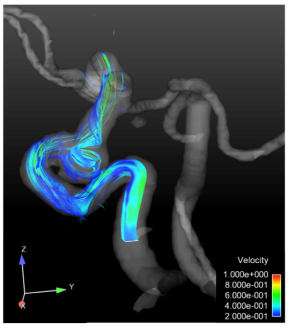

Fig.4 Streamlines from a patient with a fusiform ICA aneurysm. obtained with CIRCUS (R=5.3).

REFERENCES

1. Liu J, et al. QIMS, 4(1):57-67, 2014. **2**. Otazo R et al. MRM 64(3):767-76, 2010. **3**. Feng L et al, MRM 70(1):64-74, 2013.