Feasibility of 4D Flow MRI of the Brain with y-z Radial Sampling and k-t SENSE: Comparison with 4D Flow MRI using SENSE

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INTRODUCTION

Time-resolved three-dimensional phase-contrast MRI (4D Flow MRI) is useful for quantitative and qualitative analyses of cerebral arterial blood flow [1]. The drawback of 4D Flow MRI is its lengthy scan time (e.g. >20 min). We proposed to apply two types of speed-up approach to the 4D Flow MRI of the cerebral arteries to reduce the scan time significantly. The one approach was y-z radial sampling that used a low-high profile ordering and acquired the spacing between all acquired profiles in the k-space along any straight line equidistantly. This k-space trajectory led to an elliptic k-space shutter in both k_y and k_z encoding directions [2]. The other approach was k-t SENSE that required low resolution training data and undersampled data to reconstruct k-space data [3]. The aim of this study was to assess the advantages and validate the feasibility of 4D MRI using y-z radial sampling and k-t SENSE by comparing with 4D Flow MRI using SENSE.

METHODS

Sixteen volunteers underwent three types of cerebral 4D Flow MRI: standard scan (using SENSE factor=2, TFE factor=2) and scans using two accelerated techniques: y-z radial sampling (data reduction=78.5% with SENSE factor=2, TFE factor=4-5) and k-t SENSE (reduction factor=5) to reduce the scan time. The imaging parameters of 4D Flow MRI were as follows; TR/TE=8.4-10.0/5.4 ms, FA=13 degrees, FOV=210X210X33.6 mm^3, voxel size =0.82x0.82x1.4mm^3, VENC=70 cm/sec, heart phase= 15. 4D Flow MRI was generated from the three-dimensional phase-contrast MRI data by using the GTFlow software (Gyrotools). *Image analysis: 1) Quantitative analysis of the blood velocity and flow*: Peak systolic velocity (PSV) and blood flow volume were measured in the 9 artery segments (i.e., bilateral internal carotid, anterior, middle, and posterior cerebral arteries, and basilar artery) in each subject, and correlation and agreement between the standard scan and each accelerated scan were evaluated for each artery segment. *2) Quantitative analysis of flow visualization*: The visualization of the 3D pathlines in the 4D Flow MRI was analyzed by quantifying the number of pathlines reaching at the target plane 7cm below the emitter plane, the origin of pathlines (Fig. 1 A). This quantitative analysis was done in the bilateral middle cerebral and basilar arteries in each subject, and the differences in the number of pathlines were evaluated between the standard scan and the two types of accelerated scans. *3) Qualitative analysis of flow visualization*: The sharpness of arterial edge and overall image quality were scored visually using a 5-points system (4: excellent – 0: poor). The differences in these flow visualization scores were compared between the standard scan and the two types of accelerated scans.

RESULT

The y-z radial sampling and k-t SENSE reduced the scan time of 4D Flow MRI by about 40% compared to that of the standard scan. *1) Quantitative analysis of the blood velocity and flow*: There were good correlations between the standard scan and two acceleration scans for the PSV and for the flow volume in all artery segments (y-z radial sampling: 0.700 - 0.916; k-t SENSE: 0.783 - 0.937). K-t SENSE scan significantly underestimated the PSV at all 9 segments ($p<0.05$). Fig. 2 shows an increase in mean difference and hence an underestimation of PSV at the basilar artery in k-t SENSE scan compared to the standard scan. 2) *Quantitative analysis of flow visualization:* The number of pathlines at the target plane slightly decreased in the y-z radial sampling scan, when comparing with the standard scan, whereas the number of the k-t SENSE scan was comparable to the standard scan (Fig. 1B). 3) *Qualitative analysis of flow visualization:* The scores of sharpness of the arterial edge and overall image quality in y-z radial sampling scan were significantly lower than those of standard scan. In the y-z radial sampling scan, the pathlines leaked out from the vascular edge because of stochastic noise and blurring. The scores of sharpness of the arterial edge and overall image quality did not differ between k-t SENSE scan and the standard scan (Fig. 3).

CONCLUSION

Both y-z radial sampling and k-t SENSE significantly reduced the scan time of 4D Flow MRI of the brain. The 4D Flow MRI using the y-z radial sampling was feasible for blood flow quantification. Using the k-t SENSE visualized the pathlines with good image quality. The two types of acceleration techniques, y-z radial sampling and k-t SENSE, will be appropriately combined with 4D Flow MRI based on the specific clinical aim: flow quantification in multiple cerebral arteries or comprehensive evaluation of the arterial flow pattern.

References

1. Bammer R. MRM, 2007; 57:127. 2. Giorgi B. AJR, 2002; 179:901. 3. Tsao J. MRM, 2003; 50:1031-1042.

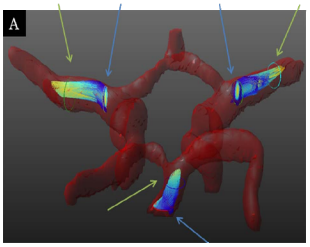

Fig. 1

A. Pathline-visualization at the BA and bilateral MCA. Blue arrows indicate emitter planes for the pathlines. Green arrows indicate the target plane.
B. The proportion of the number of pathlines reaching the target planes.

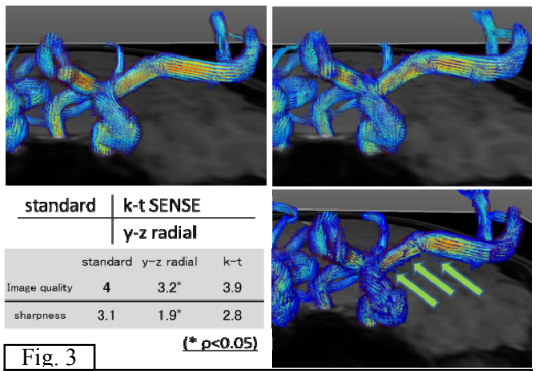

Fig. 3

1, The pathlines of k-t SENSE scan are comparable to those of standard scan.
2, Some of the pathlines leak out of the vessel in y-z radial scan, because of imaging blurring.

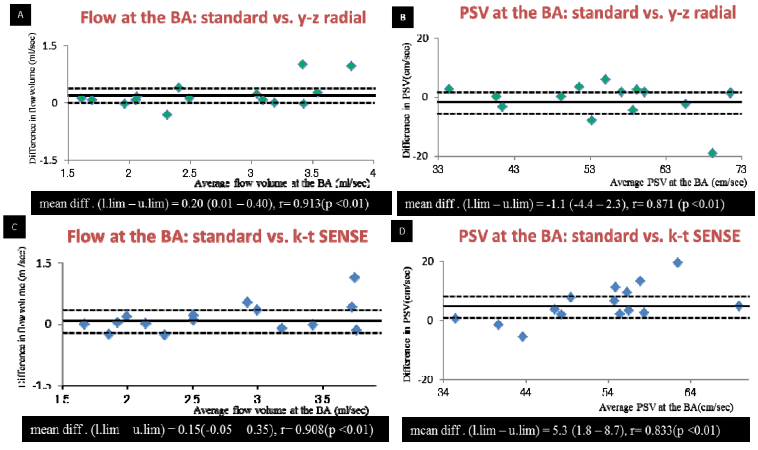

Fig. 2

Between the standard scan and y-z radial sampling, the agreement of flow (A) and PSV (B) is good at the BA.
Between the standard scan and k-t SENSE, the agreement of flow (C) is good, but the increase of mean difference and underestimation of PSV (D) are found at the BA of k-t SENSE comparing with the standard scan.