Combined parallel imaging and compressed sensing for rapid Inflow-enhanced Inversion Recovery (IFIR) imaging of carotid arteries

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Target audience: Radiologists and scientists who are interested in vascular imaging

Background: Inflow-enhanced inversion recovery with 3D fast spin echo readout (IFIR-FSE) is a promising technique to visualize the carotid arteries without using contrast agents[1]. It has the advantage of improved visualization of the entirety of the vessel course from arch to skull base, in comparison to time-of-flight (TOF) imaging which is often limited at the aortic arch. Contrast-enhanced MRA (CE-MRA) has high contrast to noise ratio, faster acquisition and allows complete visualization of the neck vasculature, but does require contrast. Theoretically, if images with sufficient quality can be obtained with IFIR-FSE, it may be possible to omit CE-MRA and prevent potential adverse effects of contrast administration and reduce health care costs. However, relatively long scan times even with parallel imaging (PI) techniques hinder the routine use of IFIR-FSE. Recently, further acceleration using compressed sensing (CS) has been applied with IFIR-FSE[2], which can reduce the scan time without significant image degradation.

Purpose: To elucidate the appropriate acceleration factors for rapid acquisition of IFIR-FSE using both PI and CS in healthy volunteers and to perform preliminary clinical evaluation of the optimized sequence in patients with carotid disease.

Methods:

<u>*<Volunteer study>*</u> Supra-aortic arteries including the aortic arch were scanned with 8 different protocols of 3D-IFIR-FSE with varying acceleration factors in 6 volunteers; PI factor (phase×slice direction) =2×1, 3×1, 2×2, or 3×2; CS factor= 1 (off) or 2. Other MR parameters were as follows: 3T MR system (Discovery750/HDxt GE Healthcare); FOV, 32cm; slice thickness, 1.4mm; number of slices, 72; Matrix 224×256; bandwidth, 125kHz; TR, ~4s; TE, 33ms; inversion time, 2000ms; peripheral cardiac gating. A scan with PI of 2×1 and CS factor 1 was used as control protocol and to calculate actual acceleration by relative scan times. On-line CS reconstruction was used and completed in 3 minutes for one series. CS was combined with autocalibrating PI by randomly undersampling at uniformly undersampled PI locations and then including PI autocalibration data. Reconstruction applied Sparse MRI[3] to each channel to first restore PI uniformly undersampled locations followed by normal PI reconstruction with channel sum of squares. Acceleration was thus split between CS and PI. Supra-aortic arteries are depicted by using inflow effect during inversion time with 2000 ms while background tissues are suppressed by multiple inversion pulses. To reveal the relative image qualities of the 8 different acceleration protocols, Scheffe's paired comparison was used. A radiologist rated the image quality of 8 protocols by direct comparison using a 7-point scale, which ranged from -3 (the left side image is definitely better) to +3 (the right side image is definitely better). This method enabled to provide relative visual score (VS) of the image quality for 8 protocols, statistically compare them, and provide p value between any pairs of the 8 protocols (Fig 1).

<u>*<Feasibility study in patients>*</u> IFIR-FSE of PI=2×1 with/without CS (per above protocol) were tested in 2 patients who were scheduled for neck MRA scan. All patients also underwent TOF MRA and CE-MRA.

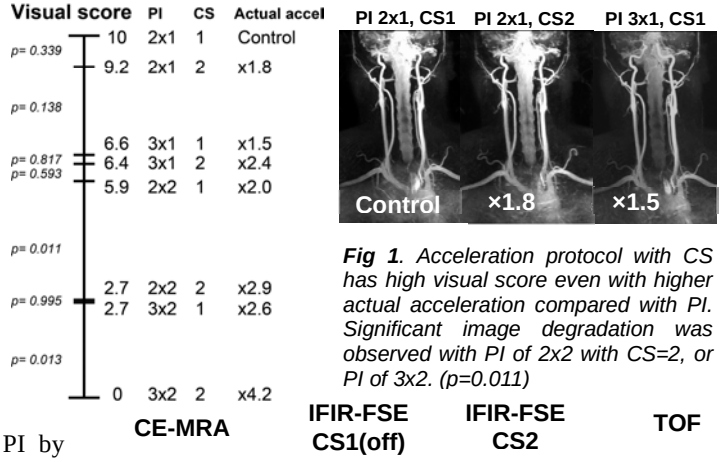

Fig 1*. Acceleration protocol with CS has high visual score even with higher actual acceleration compared with PI. Significant image degradation was observed with PI of 2x2 with CS=2, or PI of 3x2. (p=0.011)*

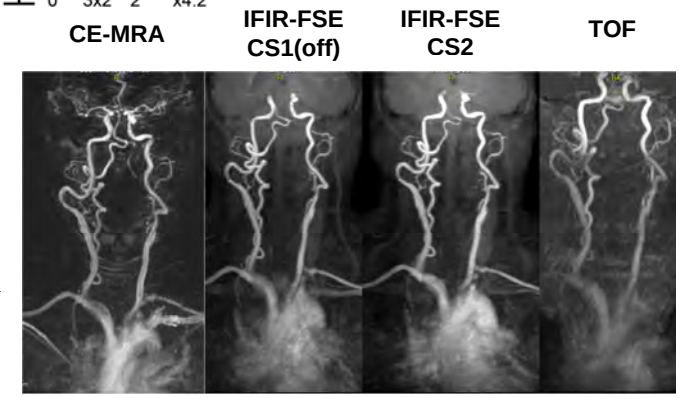

Fig 2 *Clinical patient images (L to R: CE-MRA, IFIR 2x1without CS, IFIR 2x1 with CS, TOF). This particular patient does not have a significant vascular stenosis in the neck; however, the acceleration protocol with CS continues to demonstrate excellent*

Results: Generally, CS worked better than PI to accelerate the image acquisition. Visual scores of protocol with PI of 2×1 and CS factor of 2 were VS=9.2, followed by control protocol (VS=10). No significant difference in VS was observed between the two next protocols up to actual accelerations of ×2.4. However, significant image degradation was observed by using more acceleration such as combined use of PI of 2×2 and CS of 2, or PI of 3×2. IFIR-FSE enabled to visualize the carotid arteries better than TOF, even with CS factor 2 (Fig.2).

Conclusion: IFIR-FSE in combination with parallel imaging and compressed sensing yields excellent image quality of the entirety of the carotid vessels in a clinically feasible time. This may serve as a good alternative for CE-MRA in patients with a contraindication to contrast administration.

References; 1) Takei N, et al. 2012; 35: 957-62, 2) King K. ISMRM 2010; 4881, Stockholm. Sweden, 3)Lustig M et al., MRM 2007;58:1182.

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