Accelerated Supra-aortic Artery Imaging without Contrast Agent using Combined Compressed Sensing and Parallel Imaging

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Target audience

Scientists and physicians interested in cardiovascular MR and wishing to know the application of compressed sensing to non-contrast MRA.

Introduction: Non-contrast enhanced MR Angiography (NCE-MRA) has improved recently and is now a viable clinical application.[1] No adverse effects associated with NSF is one of features for NCE-MRA and enables repeated scanning over long period of time such as screening and follow-up after surgery. Accelerated scan time is a key to expand the use of NCE-MRA into clinical. Compressed sensing (CS)[2] utilizes sparsity in compressive image and combined with parallel imaging (CS+PI) allows greater acceleration than only PI[3,4]. MRA has binary appearance that increases sparsity is promising for applying CS. In this work, we explore NCE-MRA with CS+PI technique for supra-aortic artery imaging[5]and demonstrate feasibility.

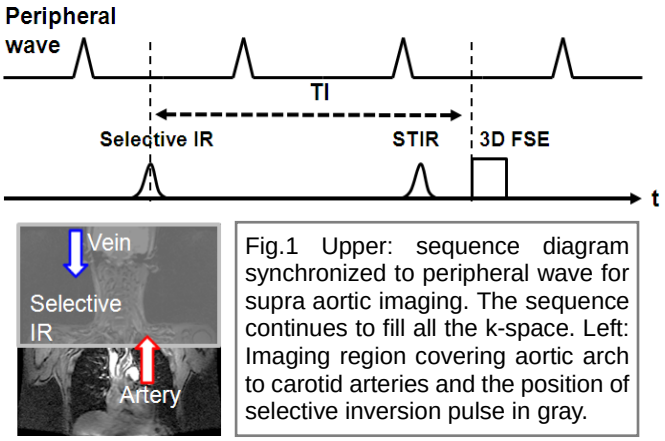

Fig.1 Upper: sequence diagram synchronized to peripheral wave for supra aortic imaging. The sequence continues to fill all the k-space. Left: Imaging region covering aortic arch to carotid arteries and the position of selective inversion pulse in gray.

Materials and Methods: ***Supra-aortic arteries*** including aortic arch through carotid arteries are depicted by using inflow effect during inversion time with 1600 msec while background tissues such as fat, veins, muscle and CSF are suppressed by multiple inversion pulses (*Fig.1*). Beginning with cardiac triggered spatial selective inversion pulse, a segmented 3D FSE sequence with flow compensated gradient along readout acquires MR data at diastole in length of 200 msec. ***CS+PI*** acquisition and reconstruction are implemented into the supra-aortic artery imaging. CS and data driven PI is combined in serial[6]. Sampling pattern in elliptical shape of ky-kz plane is uniformly undersampled with auto-calibration signal (ACS) points for PI and is further randomly undersampled with Gaussian pattern for CS. The acquired data sets are reconstructed using L1-norm minimization to first restore conventional parallel imaging for each coil k-space data set, followed by the normal parallel imaging reconstruction.

Experiments: A volunteer was scanned on a 1.5T GE Excite scanner with 8 channel head neck receiver array coil under IRB appproval. 2D acceleration factor was changed with 2x1, 4x1, 4x2 and 6x2 in PI alone. 2x1 was used for reference. The similar acceleration factor was used in CS+PI with fixed value of 2 for CS. Net acceleration is to be defined as #full sampling data / #undersampling data. The following scan parameters were used: Coronal scan plane, TR/TE = 4000/33.6 msec, Matrix = 256x256x60, FOV 32x32x8.4cm, slice thickness 1.4mm, ACS size 24x24, flip angle 90 deg and 180 deg for 1st excitation pulse and refocusing pulses in FSE respectively. Phased array coil intensity correction was applied on resultant images.

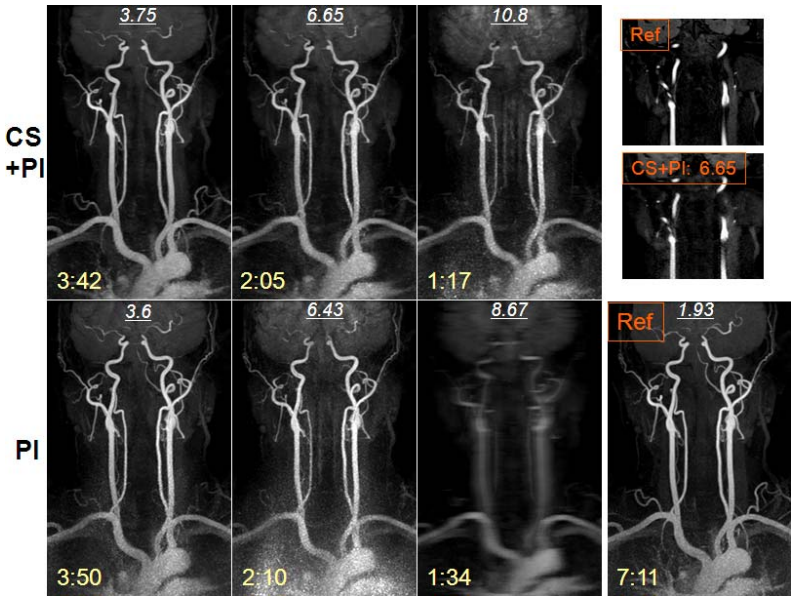

Fig.2 Comparison result of CS+PI and PI alone. Underlined net acceleration and scan time in yellow is shown on each coronal MIP. Reference image is scanned with 1.93 net acceleration. Reference and CS+PI are compared in slice on upper right.

Results: Fig.2 shows that the main vessels were identified on all the images for CS+PI. CS +PI accelerated scan up to net acceleration 10.8 and scan time was down to 1:17 retaining artery signal intensity. In addition, it shows the superior result with less noisy image, especially on aortic arch compared to PI alone. Slice by slice comparison gave similar depiction of artery between CS+PI and the reference but slight blurring was seen on CS+PI image.

Discussion: With increase of 2D acceleration factor, SNR of arterial signal dropped gradually in CS+PI. The image degradation is dominantly caused by the property of PI due to the use of high acceleration factor and the effect of g-factor because fixed CS factor is used. CS technique that inherently has denoising effect suppresses noise magnification when the high 2D acceleration is used. Better acceleration could be achieved by optimized CS+PI combination by forcing more sparsity and using less 2D acceleration. Moderate net acceleration at 3.75 and 6.65 using CS+PI depicts arteries reliably that is comparable to PI only at 3.6 net acceleration. But further work is needed to evaluate the application clinically.

Conclusion: We demonstrated the feasibility of supra-aortic artery imaging with CS+PI. CS+PI improves supra-aortic artery depiction and achieves higher acceleration compared to PI only.

References:

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