Reproducibility and Consistency of the Fast 3D-MERGE Imaging Using CS Reconstruction

Hao Li[1], Li Dong[2], Bo Li[3], Bin Chen[3], and JUE ZHANG[1,3]

[1]*Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, Beijing, China,* [2]*Radiology, Beijing Anzhen Hospital, Beijing, Beijing, China,* [3]*College of Enigneering, Peking University, Beijing, Beijing, China*

Purpose:

High-resolution 3D-MERGE technique based black-blood imaging has been reported to quantitatively measure carotid atherosclerotic plaque morphology and tissue composition, and receive more and more clincial concerns. However, it brings about relative long time consuming, which can increase the probability of motion artifacts due to swallowing, respiration or neck movements. In our previous research, compressed sensing (CS) is used to improve temporal resolution by reconstructing images from a dramatically small number of data without introducing severe image artifacts [1]. The purpose of this study is to determine the reproducibility of the fast 3D-MERGE imaging using CS reconstruction and the consistency of this method when using different CS acceleration factors.

Materials and Methods:

Six healthy human subjects (4 men and 2 woman, 22-50 years) participated in this reproducibility study. MR images of the carotid arteries were acquired on a clinical 3T scanner (Signa TM; GE Medical Systems, Milwaukee, WI) with an eight-channel phased-array bilateral carotid coil. In this study, the conventional 3D MERGE with full sampling and CS based 3D MERGE sequences using acceleration factors from 2 to 5 were implemented to conduct the black-blood imaging. The matrix size was 256 × 256, and number of slices is 32. Scan time for the full, 50, 33, 25 and 20% of the k-space sampling took 65, 33, 26, 22 and 17s, respectively.

For each subject, bilateral arteries were reviewed. For each artery, each axial image was evaluated and graded for image quality using criteria described previously [2]. After image review and registration, totally 744 images were selected for this study. One radiologist blinded to timepoints, sampling mode and clinical information measured the arterial lumen area (LA), wall area (WA), and total vessel wall area (TVWA).

Intraclass correlation coefficient (ICC) and interscan coefficient variation (CV = 100%*interscan SD/overall mean) were used to express reproducibility. An ICC value of 1 indicates perfect agreement, 0.75–1 indicates excellent agreement, and 0.5–0.75 indicates fair agreement, less than 0.5 indicates poor agreement. Two-sample unpaired t-tests were performed for interscan measurements, and for the grand mean of LA, WA and TVWA between the undersampled and the fully sampled images. P-value less than 0.05 was considered significant. Beside, Bland–Altman plots were used to investigate the relationship between the interscan variation and the magnitude of the measurements.

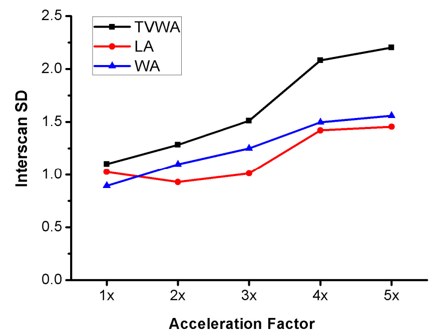

Figure 1. The mean of interscan SDs of TVWA, LA and WA of each sequences using different CS acceleration factors.

Results:

Fig. 1 shows interscan SDs of TVWA, LA and WA of sequences using different CS acceleration factors. The SDs increases when using larger acceleration factors, which means smaller sampling would affect the reproducibility, but only to a limited degree (SD<0.25). Table 1 shows the ICC and CV of different sampling. All the sampled and undersampled datasets achieve ICCs larger than 0.75, which indicates excellent agreement. It is especially remarkable that 2x and 3x acceleration factors achieve high ICCs (>0.92) and CVs (<5%) similar with full sampling. No significant differences are found between repeated scans in each sequences. Except for the WA of the sequence using 4x acceleration, there were no significant differences in the mean of LA, WA and TVWA between the fully sampled and undersampled datasets of 2x-5x. Bland–Altman plots for interscan measurements (Fig. 3) demonstrate random error scattering patterns with no significant bias and no significant correlation between bias and mean for different acceleration factors.

Conclusions:

The CS-3D MERGE technique, which offers significant improvement of scan efficiency, achieves similar reproducibility with full sampled sequence, and good consistency between different CS acceleration factors.

	LA						WA						TVWA					
	Scan(mm^2)	Rescan(mm^2)	ICC	CV[a]	P^b	P^c	Scan(mm^2)	Rescan(mm^2)	ICC	CV[a]	P^b	P^c	Scan(mm^2)	Rescan(mm^2)	ICC	CV[a]	P^b	P^c
1x	48.8±45.8	48.7±45.0	0.99	2.2%	0.72		26.5±17.2	27.2±19.6	0.95	3.3%	0.81		75.3±62.8	75.9±66.0	0.99	1.5%	0.75	
2x	49.5±33.7	49.3±34.6	0.99	1.9%	0.99	0.84	27.3±17.8	27.2±18.4	0.92	4.1%	0.67	0.78	76.9±52.9	76.6±47.9	0.99	1.7%	0.88	0.82
3x	50.1±44.2	50.7±44.2	0.99	2.1%	0.79	0.94	27.6±20.7	28.5±20.2	0.92	4.7%	0.31	0.74	78.6±65.3	79.3±64.4	0.99	1.9%	0.58	0.88
4x	50.2±47.1	48.0±47.2	0.98	3.1%	0.26	0.52	29.8±15.9	30.8±19.5	0.83	5.1%	0.20	0.03	80.0±63.0	78.9±66.8	0.98	2.8%	0.88	0.85
5x	49.0±40.2	47.9±47.6	0.97	3.0%	0.96	0.38	29.4±22.6	31.3±21.3	0.99	5.3%	0.24	0.05	78.4±62.8	79.2±68.9	0.97	2.9%	0.66	0.98

Table 1. Comparison of Reproducibility of Entire Artery Measurements

[a]The CV represent the variation of matched locations between repeated scans. [b]*P* for interscan measurements. [c]*P* for comparison of grand mean (scan and rescan) between 1x and other acceleration factors.

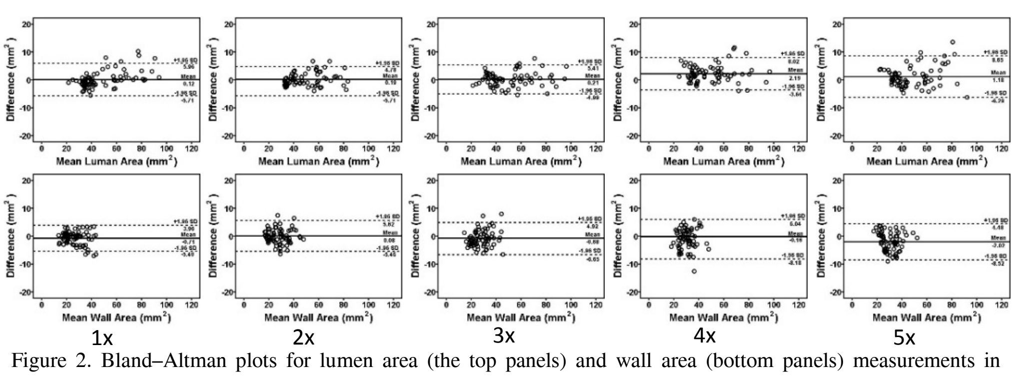

Figure 2. Bland–Altman plots for lumen area (the top panels) and wall area (bottom panels) measurements in different CS acceleration factors

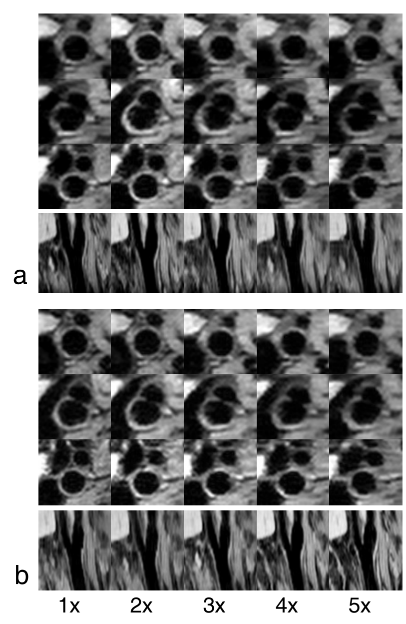

Figure 3. Representative images from 2 scans of one subject. a: the first scan. b: rescan.
Top: Three axial slices showing the vessel wall. Bottom: Oblique reformats of images showing comparable vessel wall delineation of the right carotid artery.

References:

[1] Li, Bo, et al." Magnetic Resonance in Medicine, Magnetic Resonance in Medicine, 2012.

[2] Underhill H, Yarnykh V, Hatsukami T, et al. Radiology 2008;248:550–560.