Non-Contrast Thoracic MRA within Single Breath-Hold Using Highly-Accelerated Parallel Imaging

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Introduction: Contrast-enhanced 3D magnetic resonance angiography (CE-MRA) is routinely used to diagnose aortic disease.[1-4] ECG-triggered CE-MRA of the thoracic aorta is challenging, due to competing demands of high spatial resolution and high temporal resolution within a breath-hold (BH). In addition, patients with impaired renal function are poor candidates for CE-MRA, because they may be at risk of Nephrogenic Systemic Fibrosis associated with gado-linium-based contrast agents. Non-contrast ECG-triggered MRA (NC-MRA) is an alternative method for patients with poor intravenous access or contraindications to gadolinium administration, and it also has the benefit of not needing data subtraction. ECG-triggered NC-MRA based on T2-prepared and fat suppressed balanced steady state free preces-sion (b-SSFP) imaging with navigator gating has been shown to produce good image quality, but the examination time can take approximately 10 minutes.[5-6] We propose to perform single breath-hold ECG-triggered NC-MRA of the tho-racic aorta using highly-accelerated parallel imaging and compare it against ECG-triggered CE-MRA.

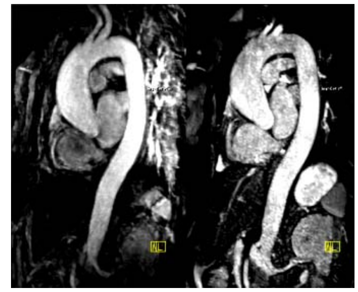

Fig.1: Multi Planar reconstruction of Left: CE-MRA and Right: NC-MRA in a patient with aneurysm of the aorta root.

Methods: Following informed consent, 18 subjects (7 controls, 12 patients; 14 male, age 23 to 79 years, mean age 39 ±13 years) were imaged at 1.5T (Siemens, Avanto) with BH NC-MRA followed by CE-MRA. Imaging parameters for BH NC-MRA using b-SSFP were: TR/TE 2.3/1.6ms, FA70°, FOV 400x400x64mm, voxel size 1.6x1.6x1.6 mm^3, 2D GRAPPA acceleration of 3x2, segments 48, 6/8 partial Fourier in both phase encode and partition directions, partition oversampling 20%. Both coil sensitivity (early systole) and MRA (mid diastole) data were acquired in the same BH to reduce scan time and improve registration between coil sensitivity data and imaging data[7]. Pre- and post-contrast CE-MRA used similar parameters with matched spatial resolution, TR/TE 3.6/1.1ms, FA 17°,BW 330Hz/pixel,1D GRAP-PA acceleration factor 2. Gd-DTPA 0.15 mmol/kg at 2cc/sec was administered with arterial timing based on a timing bolus. Source and subtracted images (for CE-MRA) were reviewed in blinded fashion by a cardiologist and a radiolo-gist. Image quality (1=non-diagnostic, 2=satisfactory, 3=good, 4=excellent), artifacts (0=non-diagnostic, 1=severely limiting, 2=mildly limiting, 3=not limiting, 4=no artifact) and pathology were recorded for 8 arterial segments (sinuses of Valsalva, sinotubular junction, ascending/arch/descending/diaphragmatic aorta, coronary artery origins/ great ves-sels). Orthogonal diameters for CE-MRA and NC-MRA examinations were measured by segment at 6 standard sites. Wilcoxon matched-pairs signed rank test and student's t-test was used to compare categorical and continuous variables.

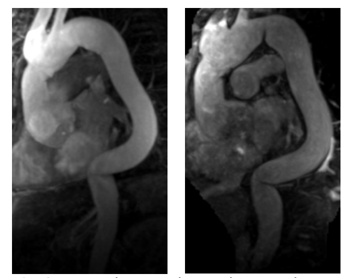

Fig.2: Maximum intensity project of Left: CE-MRA and Right: NC-MRA from a patient with tortuous thoracic aorta.

Results: Of 18 subjects studied, overall mean total scan time for the two methods was 37.3±7.0s (CE-MRA) and 18.5±5.9s (NC-MRA) for each individual scan. Table 1 shows no significant difference in image quality and artifact scores ($p>0.05$) for all evaluated segments except the great vessel origins, where signal loss due to susceptibility with SSFP readout was noted, and coronary artery origins where increased motion artifact was noted for CE-MRA com-pared to NC-MRA. Figure 1 shows CE-MRA and NC-MRA images from a patient (59yo, female) with an aneurysm of the ascending aorta. Figure 2 shows CE-MRA and NC-MRA images from a different patient with tortuous thoracic aorta. The relative merits of each technique are: CE-MRA provides superior vascular delineation because of higher contrast-to-noise ratio; whereas the single BH ECG-triggered NC-MRA provides sharper delineation of the aortic root, including assessment of coronary artery origins, due its superior temporal resolution. Mean aortic dimensions are summarized in Table 2. The two sets of measurements were not significantly different ($p > 0.05$) and were in good agreement (Fig. 3; mean difference = –0.073 ± 0.144 cm; upper and lower 95% limits of agreement = 0.210 and -0.357, respectively).

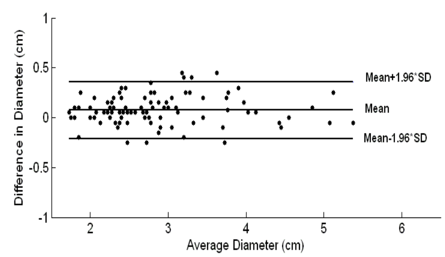

Fig. 3: Bland-Altman plot shows no minimal significant difference in measurements made with 3D NC-MRA and CE-MRA data sets.

Conclusions: This study demonstrates the feasibility of highly accelerated single BH NC-MRA with isotropic spatial resolution and diagnostic image quality. This technique provides good image quality and adequate contrast-to-noise ratio for confident assessment of cardiothoracic aortic diseases. It is faster than CE-MRA, does not require subtraction and can be repeated rapidly without contrast injec-tion.

References:[1]. Gebker, R et al. JCI. 2007;[2]. Groves, EM et al. Am J Roentgenol. 2007;[3]. Prince, MR et al. Am J Roentgenol. 1996;[4]. Krinsky, GA et al. Am J Roentgenol. 1999;[5]. Kanal E, et al Radiology. 2008; [6]. Srichai, MB et al.Tex Heart Inst J. 2010.[7]. Xu, J. et al., ISMRM, 2010,P670.

Table 1: Comparison of overall IQ and artifact scores, and mean orthogonal diameters between CE-MRA and NC-MRA.

Aorta Segment	IQ (Mean ± SD)			Artifact(Mean ± SD)			Diameter (cm)(Mean ± SD)		
	CE-MRA	NC-MRA	p-value	CE-MRA	NC-MRA	p-value	CE-MRA	NC-MRA	p-value
SOV	2.86 ± 0.56	3.11 ± 0.65	0.30	2.75 ± 0.55	2.72 ± 0.86	0.84	3.64 ± 0.69	3.54 ± 0.76	0.036
STJ	2.94 ± 0.64	3.31 ± 0.62	0.72	2.83 ± 0.51	3.14 ± 0.59	0.11	3.22 ± 0.78	3.09 ± 0.76	0.011
AA	3.25 ± 0.67	3.17 ± 0.77	0.77	2.94 ± 0.51	2.92 ± 0.84	0.93	3.28 ± 0.79	3.20 ± 0.80	0.013
ARCH	3.39 ± 0.53	3.42 ± 0.91	0.94	3.22 ± 0.46	3.17 ± 0.97	0.98	2.51 ± 0.45	2.48 ± 0.47	0.257
DA	3.69 ± 0.35	3.81 ± 0.35	0.489	3.56 ± 0.38	3.61 ± 0.44	0.83	2.45 ± 0.31	2.39 ± 0.34	0.044
DIAPH	3.78 ± 0.26	3.81 ± 0.35	1.0	3.56 ± 0.34	3.56 ± 0.38	1.0	2.08 ± 0.32	2.04 ± 0.32	0.250
GV	3.58 ± 0.49	2.39 ± 0.78	0.00012	3.50 ± 0.57	1.61 ± 0.81	0.00041	NA	NA	NA
CA	1.53 ± 0.50	2.31 ± 0.93	0.0133	1.0 ± 0.64	1.92 ± 1.17	0.0166	NA	NA	NA

Note- SOV= Sinus of Valsalva; STJ=Sinotubular Junction; AA= Ascending Aorta; ARCH= Aortic Arch; DA= Descending Aorta; DIAPH= Diaphragmatic Aorta; GV= Great Vessels; CA= Coronary Arteries.