Target volume coronary MRA revisited: Usefulness of non-rigid reregistration of multi-frame 3D MRA acquisitions at 3T

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Target audience: Cardiovascular radiologists, cardiologist, cardiovascular surgeon, and scientists interested in coronary artery imaging.

Purpose: Free-breathing whole-heart coronary MR angiography (MRA) is an established method that can visualize all coronary arteries within a single acquisition[1]. However, a long acquisition time and suboptimal arterial signal due to thick SLAB are major limitations of 3T gradient-echo whole-heart coronary MRA without contrast. Alternatively, target-volume coronary MRA can be used to visualize coronary arteries within a predefined target volume within a shorter acquisition time[2]. In addition, relatively small SLAB volume of this approach permits acquisitions of multi-frame 3D data without prolonging scan duration. Recently, non-rigid image registration has been emerged as a technique which can merge images and improve SNR and CNR[3]. The purpose of this study was to develop a new technique to obtain high quality free-breathing target-volume coronary MRA with shorter acquisition time by employing multi-frame 3D acquisitions and non-rigid image registration.

Methods: Nine healthy volunteers (32±7 years, 9 male) underwent target volume coronary MRA and whole heart coronary MRA during free breath by using a TFE sequence with T2 preparation and fat saturation at 3T (Ingenia). For target volume coronary MRA, three successive 3D datasets were acquired separately for RCA and LCA during diastole (SENSE factor = 3; acquisition duration per cardiac cycle =30ms for RCA, 50ms for LCA; navigator gating window = 4mm; resolution = 0.64x0.64x1.5mm; slab thickness = 4.5cm). Three-point planning system was used to define the imaging plane for target volume coronary MRA. Then, target volume MRA images were merged by using a non-rigid image registration technique optimized for coronary MRA. Briefly, a movement on each voxel in 2nd- and 3rd- frame images (f_2 and f_3) was determined using the intensity differences and the gradient information compared with the 1st frame images (f_1). Those movement fields were smoothed by a 3D Gaussian filter, were transformed iteratively, and were registered on to the 1st frame images so that those maximized a local voxel-based similarity metric. The merged images for frame 1+2 (f_{1+2}) and frame 1+2+3 (f_{1+2+3}) were generated. For whole-heart coronary MRA, single 3D dataset was obtained (SENSE factor =3; acquisition duration per cardiac cycle = 30ms; navigator gating window = 4mm; resolution = 0.64x0.64x0.8mm; slab thickness = 12cm). Effective scan times and vessel length of RCA, LMT+LAD and LCx were obtained for each coronary MRA technique. For target volume coronary MRA images, signal to noise ratio (SNR) and contrast to noise ratio (CNR) were measured for RCA, LAD and LCx. Then, three observers compared the visibility of coronary arteries among f_1, f_{1+2} and f_{1+2+3} with two-alternative forced-choice method[4]. The total of 27 pairs among f_1, f_{1+2} and f_{1+2+3} was compared twice by changing the right/left location. Visibility of the coronary arteries is superior when the average number selected as having better visibility is greater.

Results: Target-volume coronary MRA successfully evaluated all segments of the coronary arteries in 9 volunteers. No significant difference was observed in the vessel length of RCA (123±37mm and 123±39mm, p=0.86), LMT+LAD (119±24mm and 122±28mm, p=0.47) and LCx (62±17mm and 64±22mm, p=0.67) between target-volume and whole-heart coronary MRA images, respectively. Effective scan time for target-volume coronary MRA (396±83s) to cover all coronary arteries was significantly shorter than that of whole-heart coronary MRA (877±382s, p=0.0056). Among 3 different frames of target-volume coronary MRA images in a cardiac cycle, both SNR and CNR were the highest in the first frame (Table 1). When comparing the merged coronary MRA generated by non-rigid registration with the first-frame coronary MRA, SNR was continuously improved as the number of superposition increases, while CNR plateaued when the number of superposition exceeded two (Table 1; representative images, Figure 1). The average number selected as having better visibility was significantly greater for f_{1+2} (34.3±1.70) than for f_1 (1.67±1.70, P<0.001) and for f_{1+2+3} (30.67±2.50) than f_1 (5.33±2.5, P<0.001). However, no significant difference was noted in the average number selected as having better visibility between f_{1+2} (14.67±4.92) and f_{1+2+3} (20.33±4.92, P=0.072)

Discussion and Conclusions: Multi-frame 3D acquisitions and non-rigid image reregistration allow for acquisition of free-breathing target-volume 3T coronary MRA covering entire coronary arteries with the image quality that is superior to the single-frame acquisition, within a significantly shorter acquisition time compared to whole-heart coronary MRA.

References: **1.** Kato S, et al. J Am Coll Cardiol. 2010; 56:983-991., **2.** Kim WY, et al. N Engl J Med 2001; 345:1863-1869., **3.** Kroon DJ, et al. IEEE International Symposium on Biomedical Imaging 2009:963-966., **4.** Nakayama R, et al. Journal of Digital imaging. 2011;24:75-85.

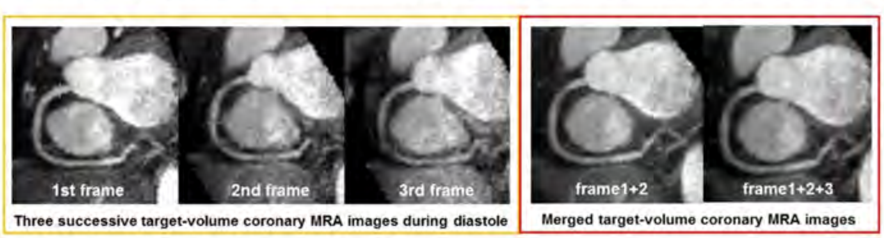

Figure 1. Target-volume coronary MRA for RCA. Three successive coronary MRA images during diastole (left) and merged coronary MRA images (right).

Table 1. SNR and CNR of coronary artery in target-volume coronary MRA

	1st frame	2nd frame	3rd frame	Merged image (frame 1+2)	Merged image (frame 1+2+3)	p
SNR rca	13.1±3.8	10.6±3.8*	8.7±2.7*	16.1±6.0*	16.8±5.1*	* p<0.05
SNR lad	14.5±2.8	13.4±1.8	10.9±2.9*	17.5±3.2*	19.3±3.0*	* p<0.05
SNR lcx	14.3±5.5	13.2±7.1	11.7±5.9*	17.6±7.5*	19.0±9.3	* p<0.05
CNR rca	6.8±2.5	3.9±2.2*	2.1±1.5*	7.4±4.0	7.1±3.7	* p<0.05
CNR lad	7.1±2.0	5.4±1.4*	2.7±0.6*	8.1±2.5*	7.6±2.1	* p<0.05
CNR lcx	7.9±2.5	6.4±5.4*	5.1±4.6*	8.9±5.6	9.3±7.3	* p<0.05

*: p value against 1st frame