Effects of Translation and Pulsation on 3D Contrast-Enhanced MRA of the Carotid Arteries

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Introduction: Stroke is the second leading cause of death and the most common cause of complex chronic disability worldwide (1). It has been shown that imaging cerebrovascular patients as soon as possible results in the best prognosis for the patient and is the most cost effective (2). 3D Contrast Enhanced Magnetic Resonance Angiography (3D CE-MRA) is now one of the most widely used radiological methods for evaluating an important indicator in cerebral ischemia: arterial stenosis. A potential problem with carotid 3D CE-MRA is that cardiac gating is typically not used, predisposing the acquisition to carotid motion during the scan time. Although it has been hypothesized that carotid artery motion has a significant effect on 3D CE-MRA image quality (3,4), the link has not been directly tested experimentally in patients. Thus our goal is to examine the degree of carotid artery motion and compare it to image sharpness in the corresponding 3D CE MRA exam in patients presenting with suspected carotid artery disease.

Methods: A cinematic (CINE) steady-state free precession (SSFP) protocol was used to obtain time resolved images of the internal or common carotid arteries at the carotid bifurcation, 11-14 mm above the bifurcation, and 11-14 mm below the bifurcation. CINE images were acquired in 7 patients immediately prior to receiving 3D CE-MRA of the carotids and in 5 healthy volunteers. A Matlab program was written to detect the carotid lumen and measure its movement throughout the cardiac cycle in the CINE images (see Fig. 1). Movement was characterized as pulsatile (change in cross-sectional area) and translational. Another Matlab program was used to quantitatively measure vessel wall sharpness in the 3D CE-MRA images (see Fig. 2), using image cross sections at the same location as the CINE exam. Sharpness in the 3D CE-MRA scan was defined as the average intensity gradient of the vessel wall. A qualitative measurement of image quality was also provided by an experienced neuroradiologist using a four-point scale.
Cinematic SSFP: 4 mm slice thickness, 3 slices, cardiac gated, reconstructed to 22 frames/heartbeat, TE/TR 2.5/45 ms, flip angle 70°, in-plane matrix 320x320, FOV 22x22 cm yielding 1.89 mm^3 true voxel volumes, typical scan time of 80 seconds with pulse oximeter triggering.
3D CE-MRA: 0.9 mm slice thickness, 72 coronal slices, TE/TR 1.59/4.3 ms, flip angle 25°, in-plane matrix 384x512, FOV 22x30cm yielding 0.31 mm^3 true voxel volumes, elliptical centric acquisition order, typical scan time of 40 seconds with no cardiac gating.

Results: On average, across the cardiac cycle, peak-to-peak pulsation was 128±8% and peak-to-peak translation was 1.67±0.68mm in patients. This compares closely with previously measured peak-to-peak translation: 1.44±0.43mm (3). The Table illustrates the pulsation and translation for each patient as measured from the CINE images, as well as the sharpness score measured from the CE-MRA exam. Figure 3 illustrates the effect of slice location on cross-sectional area variation.

Conclusions: Carotid artery movement due to pulsatile blood flow varies sizably between individuals and between locations within an individual. Our data from 14 arteries does not show a direct correlation between carotid artery movement and 3D CEMRA image quality. Image quality may be limited more by other factors such as the timing of movement within the 3D k-space acquisition, contrast variation, low resolution and noise than by vessel movement. In conclusion, vessel movement arising from variations across the cardiac cycle may not be an important factor until 3D CE-MRA image resolution has been further improved.

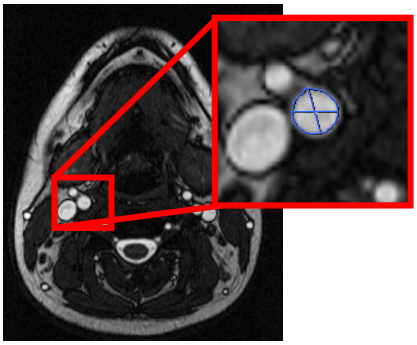

Fig. 1: An axial CINE slice used for motion measurement. The vessel detection software calculates both the cross-sectional area and the isocenter of each vessel.

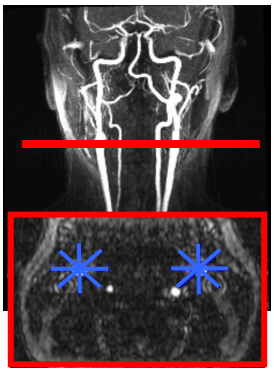

Fig. 2: Vessel sharpness is measured from an axial slice of the coronal 3D CE-MRA data set that matches CINE locations. Blue lines represent the measured intensity gradients.

Patient (age)	Location	Pulsation (CINE)		Translation(mm) (CINE)		Sharpness (3D CE-MRA)	
		Right	Left	Right	Left	Right	Left
P1 (74)	Above Bif.	120%	110%	1.12	0.42	71.5	69.0
	At Bif.	128%	110%	1.30	1.10	60.5	57.5
	Below Bif.	139%	115%	1.39	1.48	51.8	47.8
P2 (21)	Above Bif.	120%	138%	1.50	1.55	94.0	79.3
	At Bif.	129%	155%	0.66	1.80	86.8	86.8
	Below Bif.	147%	168%	0.66	1.07	85.0	89.5
P4 (56)	Above Bif.	131%	119%	1.58	1.22	91.5	66.8
	At Bif.	117%	123%	1.10	0.94	66.0	61.8
	Below Bif.	121%	118%	1.01	0.41	54.8	50.0
P5 (87)	Above Bif.	112%	115%	1.06	0.72	47.0	54.0
	At Bif.	110%	114%	0.83	1.29	50.5	66.5
	Below Bif.	128%	115%	1.13	0.49	50.0	58.0
P6 (47)	Above Bif.	118%	110%	1.41	2.24	72.3	66.5
	At Bif.	112%	153%	3.96	5.32	77.8	60.8
	Below Bif.	120%	116%	1.64	2.34	66.3	61.5
P7 (49)	Above Bif.	N/A	140%	N/A	2.65	N/A	52.3
	At Bif.	130%	115%	1.64	0.52	49.5	49.3
	Below Bif.	116%	117%	0.59	1.48	46.8	44.0
P8 (42)	Above Bif.	134%	117%	0.53	0.38	82.3	76.0
	At Bif.	137%	114%	1.20	1.07	77.3	79.8
	Below Bif.	145%	124%	1.29	0.64	79.0	64.0

Table 1: Cumulative data from 7 patients illustrating pulsation and translation from the CINE exam and the 3D CEMRA sharpness measure. There is no significant correlation between vessel movement (pulsation or translation) and vessel sharpness in the 3D CE-MRA images.

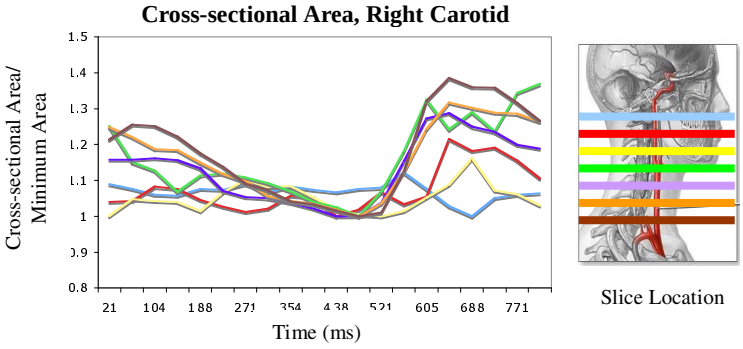

Fig. 3: Change in cross-sectional area across the cardiac cycle. In this subject vessel movement measurements were taken at several locations (see diagram at right) to demonstrate intra-patient variability. Note reduced pulsation as one moves superiorly.

References:

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