Reducing Gd Dose for Moving Table MRA using Cine-PC to Map Bolus Transit

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Motivation:

Moving table, contrast enhanced, peripheral MRA has allowed assessment of peripheral vascular disease and whole body MRA with high accuracy, but prescribing the parameters for each station to optimize resolution, anatomic coverage and synchronization with the flow of Gd bolus down the leg can be challenging. Test boluses, and time-resolved imaging have been useful for determining how much imaging time can be spent on each station of anatomy while maintaining synchronization with flow of the Gd bolus. However, multiple Gd injections prior to bolus chase MRA increases the total Gd dose and increases the risk of venous contamination in distal stations. We explored using flow velocity measurements from cine-phase contrast images, at 6 anatomic levels with and without venous compression for optimizing bolus timing to maintain high SNR while minimizing Gd dose.

Method:

15 subjects (Age = 37 to 66, mean = 54, M/F = 6:9) were imaged at 1.5T (GE HDx 14.0) using a body phased array coil positioned initially on the abdomen and then on the calf. Underlying medical conditions included diabetes (n=3), hypertension (n=5), aortic aneurysm (n=1), myocardial infarction (n=1), calf trauma (n=2). First, 6 single slice axial 2D cine-phase contrast sequences at aortic arch, aorta below renal arteries, common femoral arteries (CFA), popliteal arteries, mid-calf and ankle were obtained using an eight channel body array coil and peripheral gating. Cine-phase contrast imaging parameters: TR/TE/flip angle = 10.8/4.9/30, FOV = 32 x 21.6cm, Matrix = 512 x 512, Slice thickness = 5mm, Bandwidth = 31.25kHz, NEX = 1; 4-8 views per segment reconstructed into 50 temporal phases. Venc = 120cm/s in the aorta and femoral arteries and 60cm/s in popliteal and calf arteries using phase unwrap as necessary. This sequence was repeated at each level with and without venous compression using bilateral thigh cuffs inflated to 60 mm Hg. Velocity measurements extrapolated from cine-PC images were used to divide the length of the corresponding arteries, measured on localizer images, to estimate bolus transit through the artery. Then time-resolved MRA with 1 to 1.5 second temporal resolution was performed at the abdomen-pelvis and calf stations using 5ml Gd with and without venous compression. Time resolved imaging parameters: TR/TE/flip angle = 4.8/1.7/30, Slice thickness = 5mm in abdomen and 3mm in calf with 20 partitions, zero interpolation and parallel imaging, Matrix = 256 x 192, Bandwidth = 62.5kHz.

Results:

These data from 15 volunteers show that the rate at which a Gd bolus flows down the aorta and peripheral arteries on time-resolved MRA can be accurately predicted from cine-phase contrast flow measurements by dividing artery length by the corresponding flow velocity. Mean contrast travel times from ascending aorta to CFA and from CFA to popliteal artery predicted from cine-PC were 6.2s and 12.3s compared to 5.9s and 11.6s measured by time-resolved MRA; Mean difference between the two methods were 0.6±0.5s and 1.0±0.7s. Mean contrast arrival times were 5.0±1.4 at right heart, 5.6±1.7 at pulmonary artery, 10.9±2.4s at pulmonary vein, 11.9±2.5s at ascending aorta. Venous compression delayed popliteal, mid-calf and ankle arrival times by 6.3s, 10.1s, 12.1s and lengthened bolus durations at those locations by 13.2s, 11.2s, 9.7s.

Prospective Clinical Study:

Time-resolved MRA was performed on 6 subjects (Age = 39 to 60, mean = 53, M/F = 2:4) with venous compression using only cine-pc calculations to estimate bolus timing. Time resolved imaging parameters: TR/TE/flip angle = 4.8/1.7/30, Slice thickness = 5mm in abdomen and 3mm in calf with 20 partitions, zero interpolation and parallel imaging, Matrix = 256 x 192, Bandwidth = 62.5kHz. In all subjects, the bolus timing was perfect with high quality obtained using only 15ml Gd or less. In two of these subjects, the bolus transit measured on cine-PC was so fast that only a two station MRA was possible (see figure 1, first and last image).

Discussion:

Although bolus chase MRA has revolutionized peripheral and whole body MRA, timing each station perfectly to synchronize with the arterial phase of a single bolus remains challenging, especially if only a standard dose of 0.1mMol/kg is used. These data indicate that cine-phase contrast flow measurements can accurately predict the rate of bolus transit and thereby allow optimization of imaging time for each station of the multi-station examination. Furthermore, measurements obtained during venous compression demonstrate the degree to which a bolus slows down in each individual patient. These data may also be useful for optimizing time-of-flight gating to systole or non-contrast MRA based upon subtraction of systolic from diastolic spin echo images as well as for determining if non-contrast MRA is likely to be diagnostic. Furthermore, changes in cine-PC flow curve waveforms may identify regions where atherosclerotic disease is likely to be significant. Now that parallel imaging allows shortening scan times to under 10 seconds per station, perfect sharing of an entire Gd bolus between multiple stations is possible with these contrast travel time measurements. Arrival time at the first station is not measured in advance but can be detected in real-time with fluoro-triggering. Our experience in patients shows that high quality bolus chase MRA with 0.1mMol/kg is now routine.

Figure 1. Prospective study using only cine-PC calculations

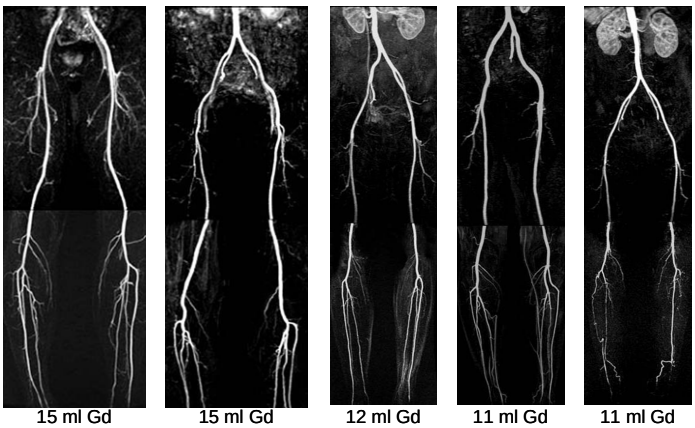

Table 1. Mean contrast arrival times and venous compression effects

	w/o Compression		
Reaches:	Arrival	Departure	Duration
Right Heart	5.0±1.4	10.2±2.3	5.2±1.9
Pulmonary Artery	5.6±1.7	11.5±2.7	5.9±1.7
Pulmonary Vein	10.9±2.4	15.5±3.8	4.6±2.0
Ascending Aorta	11.9±2.5	21.0±4.1	9.1±2.4
Aorta at Diaphragm	13.8±3.3	23.5±4.5	9.8±2.1
Aortic Bifurcation	16.1±5.1	25.8±6.9	9.7±2.8
CFA	18.3±5.9	30.7±6.9	12.4±5.0
Popliteal Artery	23.5±7.2	39.6±7.6	16.6±5.2
Mid-Calf	30.4±8.4	42.4±8.7*	12.8±4.5*
Ankle	38.0±11.8	46.9±15.1*	10.1±4.1*

	w/ Compression				
	Arrival	Departure	Duration	Time Gained w/Compression	Arrival Delay
Popliteal Artery	28.8±8.0	54.8±9.2	29.2±8.5	13.2±8.0	6.3±3.2
Mid-Calf	39.0±10.3	58.9±11.3*	22.2±7.9*	11.2±8.6	10.1±5.0
Ankle	49.6±15.8	64.9±19.2*	16.6±8.4*	9.7±8.8	12.1±6.1
			Average:	**11.4**	**9.5**