Calculating Peripheral MRA Bolus Timing using Cine-Phase Contrast Flow Measurements

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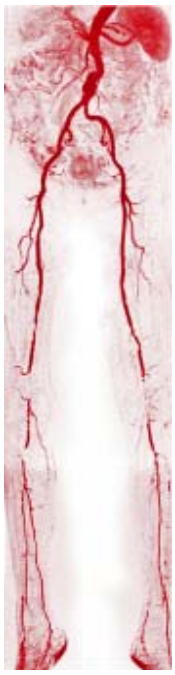
Motivation:

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, Gd injection prior to bolus chase MRA increases the total Gd dose and increases the risk of venous contamination in distal stations. We explored the potential for using flow data derived from cine-phase contrast images to calculate bolus velocity at 7 anatomic levels with and without venous compression.

Method:

Five volunteers and 4 patients (mean Age = 46, Age Range = 25-65, M/F=4:5) 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. Seven single slice axial 2D cine-phase contrast sequences at abdominal aorta above renal arteries, aorta below renal arteries, common iliac arteries, common femoral arteries (CFA), popliteal artery, midcalf and ankle were obtained using an eight channel body array coil and peripheral gating. Imaging parameters: TR/TE/flip angle = 10.8/4.9/30, FOV = 32 x 21.6cm, matrix = 512x512, Slice thickness= 5mm, Bandwidth = 31.25kHz, NEX = 1; 8 views per segment. Venc = 120cm/s in the aorta, iliac and femoral arteries and 60cm/s in popliteal and calf arteries using phase unwrap as necessary. This sequence was repeated at each artery with and without venous compression using bilateral thigh cuffs inflated to 60 mm Hg. Then time-resolved MRA with 1.8 to 2 second temporal resolution was performed at the abdomen-pelvis and calf stations using 6 ml Gd with and without venous compression. Imaging parameters: TR/TE/flip = 4.8/1.7/30, slice thickness = 5mm in abdomen and 3mm in calf with 20 partitions, zero interpoloation and parallel imaging, matrix = 256 x 192, bandwidth = 62.5kHz.

artery	Mean velocity
Aorta above renals	14.9 cm/s
Aorta below renals	8.8 cm/s
Common iliacs	6.9 cm/s
CFA	4.9 cm/s
popliteal	2.4 cm/s
Anterior tibial	1.3 cm/s
Posterior tibial	1.3 cm/s
peroneal	1.2 cm/s
AT at ankle	1.4 cm/s
PT at ankle	1.3 cm/s



MRA with 11ml Gd timed by cine pc

Results:

These data from 4 patients and 5 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. Mean velocities are listed in Table 1. Mean time to reach from antecubital vein in the arm to pulmonary arteries=5.8s; to ascending aorta=10.3s and to upper abdominal aorta=13.1s. Times from abdominal aorta to ankles are listed in Table 1. Interestingly, venous compression did not substantially affect the cine phase contrast flow measurements yet it slowed down arterial flow on time-resolved MRA by 2-fold. This may reflect the order of acquisition as cine pc data were acquired first, possibly before the full effect of venous compression occurred. Dilatation of calf veins and cessation of venous flow with venous compression suggests that venous capacitance with dilution of Gd likely was important part of the hemodynamics of prevention of venous enhancement by venous compression

.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. In addition, NSF concerns have motivated the search for ways to reduce total Gd contrast agent dose. These data indicate that cine phase contrast flow measurements can accurately predict the rate of bolus transit and thereby allow optimization of the time of each station of the multistation 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.

Table 1. Bolus velocity calculated from time-resolved MRA & cine-pc

Table 1.		without venous compression		with venous compression	
Artery traversed	distance	Time-resolved	Cine PC	Time-resolved	Cine PC
AA → CFA	46.4cm	5.7s	5.8s	-	-
CFA → Popliteal	40cm	8.1s	7.9s	-	-
Popliteal → ankle	31.5cm	16.3s	16.9s	31.8s	13.6
AA → ankle	118cm	30.2s	30.6s		

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