Leg MR Angiography with Cuff-Compression: Quantitative Dynamic Analysis

M. K. Santos[1], P. Sharma[1], B. Kalb[1], J. Oshinski[1], and D. Martin[1]
[1]Radiology, Emory University, Atlanta, Georgia, United States

INTRODUCTION: Three-dimensional contrast-enhanced MR angiography (CE-MRA) has been shown to be comparable to DSA in the evaluation of lower extremity vessels, being mostly performed using a multi-station moving-table bolus chase technique. Although CE-MRA image quality is generally excellent for evaluation of the abdomen, pelvis and thigh, it is inadequate for assessment of the calf and foot in up to one third of the exams (Bilecen et al., J Magn Reson Imaging 2004), usually due to venous contamination. Several methods have been proposed for overcoming this problem, including application of venous compression using a blood pressure cuff. Benefits of the cuff compression method have been demonstrated in qualitative analysis in different studies (Herborn et al., Radiology 2004; Zhang et al., J Cardiovasc Magn Reson 2007). The observed decrease in the incidence of venous contamination has been ascribed to increased venous pressure and delayed venous filling. Limitations of prior studies include: 1) a lack of quantitative evaluation of the arterial inflow and venous outflow changes induced by the compression cuff; 2) a lack of quantification of the potential benefits that may be expected for prolongation of the arterial phase MRA; and 3) a lack of understanding regarding the hemodynamic changes. The purpose of this study is to evaluate quantitatively the effect of mid-femoral cuff compression on arterial inflow and venous outflow kinetics using high temporal resolution CE-MRA of the calves in order to address the 3 limitations previously described.

MATERIAL AND METHODS: ***Participants:*** This study was HIPPA compliant and IRB approved. MRA was performed in 4 volunteers (all males, ages 28-47 years, average 35) with no history of peripheral vascular disease. ***Pressure Cuff Application:*** For venous compression a 16 cm blood pressure cuff (W. A. Baum Co. Inc.) was placed at the mid-femoral level unilaterally and manually adjusted to a pressure of 60 mmHg 3 minutes before data acquisition. ***Imaging:*** Gadolinium-chelate (Multihance, Bracco Diagnostics) was administered intravenously at a dose of 0.05 mmol/kg, using a power injector at a flow rate of 2ml/s, followed by a 15 ml saline flush at the same rate. All images were performed on a clinical 1.5T MR system (Magnetom Avanto, Siemens Medical Solutions), using a dedicated peripheral vascular coil. A high temporal resolution 3D CE-MRA protocol was applied, using 500mm FOV, 52 slices of 1.7mm thickness, TR/TE/flip = 2.3/1.0ms/25, and 448 matrix (with y,z-undersampling, partial fourier acquisition and parallel acceleration) to achieve an acquisition time of 6,12 seconds for each 3D volume. Fifty dynamic scans were acquired sequentially for a total time of 300 seconds, initiated together with the contrast infusion. ***Image Analysis:*** Coronal maximum intensity projections (MIPs) were reconstructed for signal intensity measurements. Regions of interest (ROIs, surface of 1.25 mm2) were positioned in the center of the selected vessels, always at same level on both legs, approximately 4.0 cm above the interarticular line, using the source images as reference for adequate anatomical position. The contrast arrival time was recorded for arteries and veins, as well peak signal time in the arteries. The average difference in contrast arrival and peak were statistically compared to zero using a paired t-test with a significance level of p=0.05.

Table 1: Arrival and signal intensity peak time, in seconds, for all volunteers. PA: popliteal artery, w/:with cuff, w/o: without cuff, NI: not identified by 300 sec.

Subject	PA w/		PA w/o		Difference		Veins w/o	Veins w/
	Arrival	Peak	Arrival	Peak	Arrival	Peak	Arrival	Arrival
1	36.7	42.8	30.6	36.7	6.1	6.1	104	NI
2	36.7	42.8	30.6	36.7	6.1	6.1	97.7	NI
3	24.4	42.8	24.4	30.6	0	12.2	61.2	171.4
4	30.6	36.7	24.4	30.6	6.1	6.1	73.4	91.4

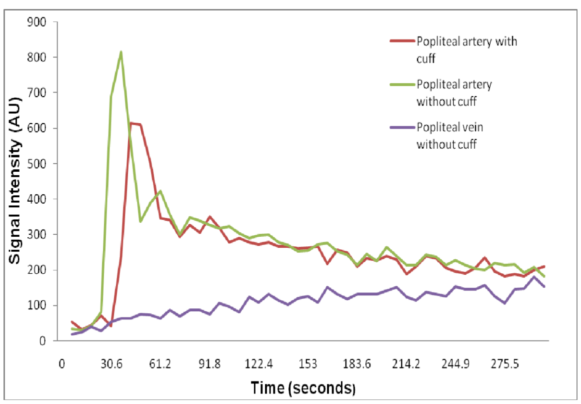

Fig.1

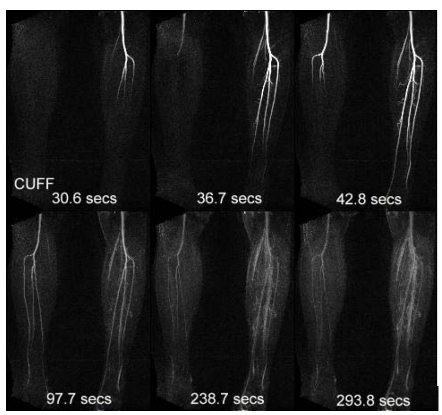

Fig.2

RESULTS: Table 1 describes the arrival time and signal intensity peak time for the popliteal arteries, popliteal or saphenous veins, measured at the same level, along with the time difference between legs, for all participants. On the cuff side, as neither the popliteal or saphenous vein was identified, an unspecified vein arrival time, localized in the superior calf, was used to complete data in the table. Fig. 1 shows a graph with signal intensity against time line curves for the selected vessels of one volunteer, and Figure 2 illustrates the MIP images at different times for this same subject. In 2 of 4 subjects, no increased signal (above background) was observed in the veins with the pressure cuff after 300 seconds (Fig. 1). Even in the volunteers where a calf vein became contrast-filled on the cuff side, the veins never became as intense as the adjacent arteries Additionally, it was found that the arterial in-flow time was significantly reduced on the pressure cuff side in comparison to the control side ($p<0.05$), which is also evident in both the signal intensity plot and MIP images.

DISCUSSION: Our study shows that there is a delayed arterial inflow, a finding not previously described in the existing literature. This finding may be explained on the basis of partial compression of the superficial femoral artery. Although described for a cylinder, Poiseuille's Law ($R=8\eta\Delta\chi/\pi r^4$) describes the exponential inverse relationship between flow resistance (R) and vessel diameter (r^4). Even a small reduction in arterial cross-sectional diameter may produce large changes in flow resistance. There is, in addition, a more marked delay in venous filling that may not be fully accounted for from delayed arterial inflow alone. Additional factors are likely related to increase in venous pressure and delayed capillary venous flow. Our findings quantitatively evaluate the delay in venous filling and indirectly show that this results from multi-factorial events that occur subsequent to supravenous-subarterial blood pressure cuff inflation. Beneficial clinical impact may be derived from this venous filling delay, with a pure arterial phase prolongation in the order of minutes. Beneficial imaging options then include using a longer image acquisition time to gain higher resolution, higher contrast, and potential reduction in the quantity of gadolinium contrast required.