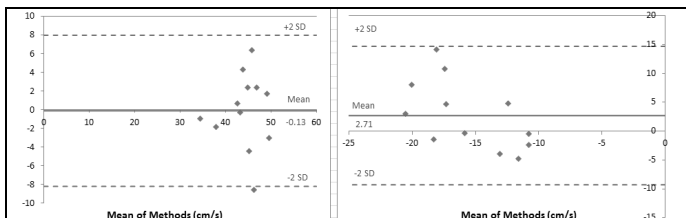# Reprojected Line Scan Phase Contrast MRA of Peripheral Arterial Disease

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Introduction

Hemodynamically significant peripheral arterial disease (PAD) can cause debilitating symptoms of claudication, or induce tissue ischemia that results in gangrene and limb loss. Several modalities are available to image the anatomic features of vascular disease. As used, DSA, CTA, and MRA generate anatomical "luminograms" but provide little information about the hemodynamic significance of a stenosis. Phase contrast (PC) techniques can provide this information, but relatively long scan times preclude applying the technique across the entire peripheral vascular territory. Real-time line scan PC offers sufficient rapidity, but has not been validated in this setting. We therefore optimized a reprojected line scan PC (rLSPC) technique and tested whether the method could be used to evaluate flow patterns throughout the peripheral vascular system within practical scan times.

Figure 1. Bland Altman plots showing differences in velocity for 2D PC vs. rLSPC at 30 degree flip angle in healthy subjects with triphasic flow. Left: Forward flow. Right: Reversed flow. There is good correlation between the two methods.
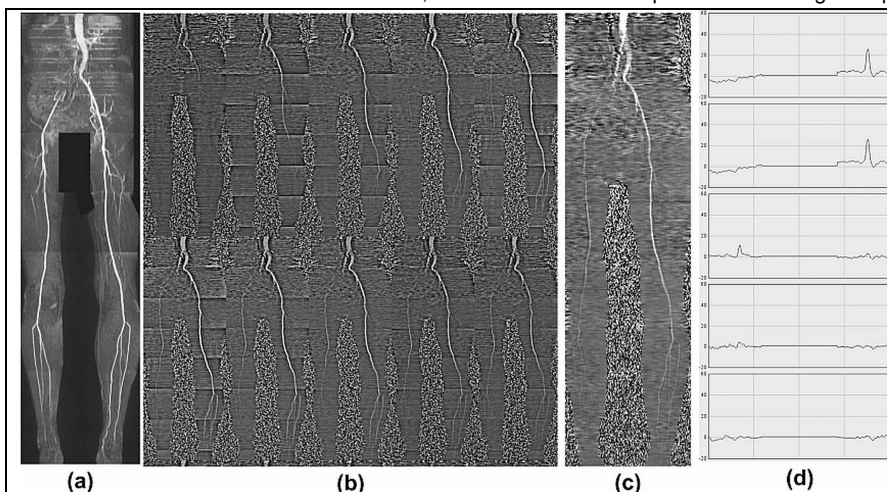
Subjects and Methods

The study was approved by the IRB and written informed consent was obtained from all subjects. Technique optimization and feasibility testing were performed in 19 healthy subjects and 6 patients (3 male, ages 59 to 80) with documented PAD. Magnetic resonance imaging was done on a 1.5 Tesla (MAGNETOM Avanto, Siemens Healthcare, Erlangen, Germany) scanner with 32 receiver channels and phased array coils. First, QISS non-enhanced MRA [1] was acquired from the level of the foot to above the renal arteries. Next, rLSPC was acquired as a series of time-resolved (cine) transverse one-dimensional phase contrast acquisitions, with each cine series spanning a single R-R interval. Within each R-R interval, a series of paired lines of data were acquired, alternately using flow compensation and flow encoding to a selected velocity-encoding sensitivity (VES). Temporal resolution for each pair of data lines ranged from 13 to 20ms. Based on studies of healthy subjects, the VES was empirically adjusted according to station location. Two data acquisition approaches were tested to minimize background phase shifts: a RACE-like technique with 90 degree flip angle [2]; and a subtractive technique using the difference of unsaturated and flow-suppressed data [3], with flip angles of 25, 30, 45, 60, and 90 degrees. Data were read out using a spoiled gradient-echo pulse sequence with 3mm slice, 1mm in-plane resolution, bandwidth 695 Hz/pixel. From 30 to 60 slices were acquired at magnet isocenter with 20% overlap between slices. A total of nine to 15 contiguous table positions were used to span the peripheral arteries from calf through supra-renal abdominal aorta. Phase images were reconstructed and subsequently reprojected into a coronal view for display of peripheral vessels. Coronal reprojections were created for all acquired temporal frames to visualize the flow over one R-R interval. Time-to-peak images were created by storing the time at which the peak phase shift was observed at each location in the coronal reprojection. Mean velocity and peak velocity images were obtained by averaging and maximum intensity projecting phase images across all temporal frames respectively.

Results

Strong agreement between rLSPC and 2D PC was obtained for mean arterial velocity (intraclass correlation coefficient = .830; P < 0.01) and for the time to peak blood flow (intraclass correlation coefficient = .801; P < 0.01). The RACE approach showed the best vessel conspicuity and scan time was half that of the subtractive method. However, the subtractive technique with a 30 degree flip angle better depicted triphasic flow and showed the best correlation with 2D PC **(Fig. 1)**. In healthy subjects, smooth, bilaterally symmetrical progression of flow was visualized from the supra-renal aorta to the ankles. Abnormal flow patterns including delayed pulse wave and collateral flow were depicted. For instance, in a patient with severe PAD and resultant ulceration of the right foot, rLSPC (but not MRA) demonstrated the hemodynamic consequences of a vessel occlusion, including unilaterally decreased mean flow velocity and slower pulse wave (**Fig. 2**).

Conclusions

Reprojected line scan phase contrast angiography provides a time-resolved measurement of flow velocity at any point along the course of the peripheral vascular tree. From this data, it is straightforward to generate maps of peak and mean velocity as well as time-to-peak measurements. Moreover, the data can be viewed using a cine display for qualitative evaluation of flow patterns. Given the extremely short time for data acquisition and brief interval between successive rephase/dephase flow encodings, there is negligible sensitivity to patient motion. Despite its benefits, rLSPC also has several potential drawbacks. Because the acquisition is projective, it is most suited to the evaluation of regions where the arteries are relatively sparse, so as to minimize vessel overlap. Arterial overlap will result in a summation of the respective phase shifts that may cause an erroneous measurement of flow velocity. Quantitative accuracy appears reasonable at and below the mid-thigh level. However, further work is required to improve the quantitative accuracy of the technique for more proximal regions, where the increased antero-posterior thickness of the body worsens accumulated phase errors from background tissue and eddy currents. Nonetheless, the technique appears capable of providing at least a qualitative display of normal and abnormal flow patterns throughout the peripheral vascular territory within practically useful scan times.

Figure 2. Patient with occlusion of right common iliac artery. (a) MRA. (b) Montage (10 out of 34 frames, 20 ms/frame) of sequentially acquired rLSPC images. There is delayed appearance of flow signal in the right pelvis and leg due to the presence of the obstruction, since flow through the collateral vessels is slower than in the contralateral healthy vessels. (c) Mean velocity image. (d) Velocity profiles taken at the level of the mid-thigh at various time points within the cardiac cycle.

References: [1] Edelman et al. MRM 2010; 63: 951-8. [2] Moller HE et al. JMRI 1996; 6:503-512. [3] Langham MC et al. MRM 2010; in press.