# Peripheral Contrast-Enhanced MR Angiography Using a SNR and Timing Optimized Protocol: Evaluation of Patient Lower Extremity Hemodynamics in 48 Patients

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## Introduction

Peripheral contrast-enhanced MR angiography (pMRA) has benefited from new coil technology and accelerated imaging techniques such as view sharing and parallel imaging. These advances allow for more rapid image acquisition, thus decreasing the chances of lower extremity venous enhancement and making time-resolved acquisition feasible. Nonetheless, single injection moving table pMRA often suffers from timing problems such that venous enhancement degrades lower station interpretability or the bolus is overtaken. We discuss here our experience with a previously described optimized pMRA technique incorporating patient-specific timing parameters[1]. This technique starts with an aortic timing bolus followed by a time-resolved lower station MRA in order to first determine arterial transit speed and lower extremity venous arrival time. This permits optimal timing parameters to be chosen *a priori* for the subsequent high resolution, SNR-optimized 3 station exam designed to make best use of the available "venous free" time yet still begin lower station acquisition prior to venous enhancement. Because of the nature of this exam protocol, extensive data regarding contrast bolus kinetics are available and are presented and correlated with clinical parameters in attempt to better understand the variability in patient hemodynamics.

## Methods

Study Design. This was a retrospective study performed in compliance with the guidelines of the local IRB. Three-station moving-table pMRA was performed on 48 consecutive patients being evaluated for suspected or proven peripheral vascular occlusive disease (PVOD). Relevant clinical data including presence/absence of diabetes mellitus, peripheral ulcers, and claudication were noted.

MR Imaging. All studies were acquired on a 1.5T system (GyroscanNT, Philips Medical Systems, Best, the Netherlands) using a prototype 18 channel peripheral vascular coil. Using the technique referenced[1], an aortic timing bolus and time-resolved lower station MRA (5 sec temporal resolution) were first performed, followed by time and SNR-optimized 3 station moving table pMRA. Parallel imaging was used in all 3 stations, with true acquired resolution of $1.2\times2.1\times2.6$ / $1.2\times2.1\times2.0$ / $1.0\times1.0\times1.0$ mm$^3$ for the upper/middle/lower stations respectively, upper and middle acquisition times ranging from 5 to 20 sec and lower station acquisition times ranging from 45 to 60 sec. Each patient was administered a total extracellular gadolinium contrast agent dose of ~0.25 mmol/kg (n=43) or ~0.15 mmol/kg (n=5). An example image is shown in Figure 1.

Image Evaluation. For each extremity, aorta-foot transit time (afft), aorta-to-lower-extremity venous arrival time (vat), and lower extremity arterial-venous transit time (avtt) were measured using the aortic timing bolus and time-resolved lower extremity dataset. Each lower station from the moving table pMRA was graded for image quality (IQ) and venous enhancement on a 4 point scale; IQ, 3 = excellent, 2 = good (suffering slightly from lower vessel to background contrast or timing issues but still diagnostic), 1 = fair (significant artifacts or vessel-to-background contrast reduction and marginally diagnostic), and 0 = non-diagnostic; VE, 0 = none, 1 = some superficial venous enhancement not compromising image interpretation, 2 = deep venous enhancement not compromising interpretation, and 3 = venous enhancement rendering interpretation extremely difficult or impossible.

Statistical Analysis. Analysis of timing parameters was performed using a non-paired t-test. The qualitative scores (IQ and VE) were analyzed for significance using the Mann-Whitney U test for non-parametric data. Both considered a p value < 0.05 significant.



**Figure 1**. Typical 3D moving table SNR and timing optimized pMRA.

## Findings

This study examined multiple imaging and clinical variables in 48 patients undergoing 3-station moving table pMRA. Twelve patients (25%) were being evaluated for peripheral ulcers, the remaining 36 (75%) for claudication. Twenty of the 48 patients (42%) had diabetes mellitus (DM). The patients were sub-grouped into three different categories based on their clinical histories: DM with claudication, non-DM with claudication, and those with peripheral ulcers. The average aorta-foot transit time (afft), aorta-to-lower-extremity venous arrival time (vat), and lower extremity arterial-venous transit times (avtt) are shown in Table 1. Note the large amount of variability (standard deviation > 16-22 sec) in venous arrival and transit times within each category. Student t-test analysis demonstrated no significant difference (p>0.05) in any transit/arrival times between any of the categories. There was no grade 3 venous enhancement (VE). Nine of the 48 patients (19%) had Grade 2 VE; divided as 33% of those with peripheral ulcers vs. 14% of those with claudication.

|  | **aftt** | **vat** | **avtt** |
|---|---|---|---|
| **+ DM + Claudication** | 19 (7.5) | 37.2 (20.4) | 21.4 (19.5) |
| **- DM + Claudication** | 16.6 (7.9) | 33.9 (16.1) | 18.6 (16) |
| **All Claudication** | 17.4 (7.8) | 34.8 (18.0) | 18.7 (18.3) |
| **All Ulcer** | 18.2 (9.1) | 36.0 (22.3) | 18.3 (20.0) |

**Table 1**. Transit times in sec (std dev) for aorta-foot transit time (afft), aorta-to-lower-extremity venous arrival time (vat), and lower extremity arterial-venous transit time (avtt) for each subpopulation. DM = diabetes mellitus. No significant differences in any of the measurements.

There was a significant difference in venous enhancement grade (p=0.044) between patients with claudication (0.75) and those with peripheral ulcers (1.17). Overall, 56% of images evaluated were excellent quality (grade 3), and 42% good quality (grade 2). Distribution of lower station start times as determined by choosing the optimal timing parameter is shown in Figure 2, demonstrating a 15 sec variability in optimal bolus chase time down the extremities.

## Discussion

This study demonstrates the variability and difficulty in predicting arterial and venous contrast arrival without *a priori* knowledge of patient-specific timing parameters, as no correlations between patient history and arrival/venous times were evident. The average time of arterial and venous contrast arrival was not significantly different between patients with and without diabetes, or with claudication vs. peripheral ulcers. These findings are somewhat surprising given the general impression that arterial and venous contrast arrival times are faster in patients with diabetes and/or peripheral ulcers. However, consistent with other studies, this study found that patients with peripheral ulcers have significantly higher grade venous enhancement than those with claudication. Nonetheless, given the spectrum of patient clinical histories and differences in contrast arrival/propagation time, the pMRA protocol used for this study performed exceptionally well with very little venous enhancement overall, and no studies non-diagnostic secondary to venous enhancement. In addition, the image quality was very good with greater than 98% of images rated good or excellent.

## References

1.) Potthast S. et al. Peripheral moving table CE-MRA using a prototype 18-channel peripheral vascular coil and scanning parameters optimized to the patients individual hemodynamics. In press, *J Magn Reson Imaging*.
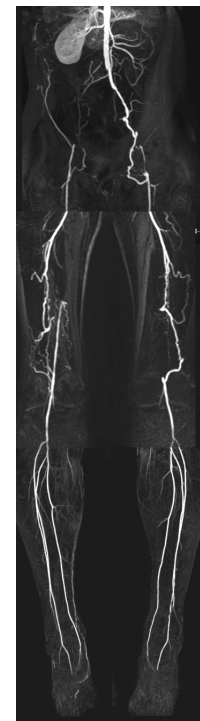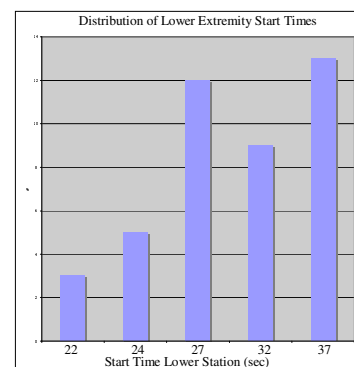
**Figure 2**. Histogram of # of cases vs. start time of lower station (as referenced from start time upper station).