A Universal Timing Strategy for Moving Table Peripheral MRA

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Introduction

Single injection moving table peripheral contrast enhanced MR angiography (pMRA) is increasingly utilized for the evaluation of peripheral atherosclerotic occlusive disease (PAOD). While the majority of exams are successful, a sizable fraction are not; almost always due to lower station venous contamination. This is largely due to the tremendous inter-patient variability in arterial and venous flow dynamics. While numerous strategies exist in attempt to minimize venous enhancement, no single effective and coherent method applicable to all MR platforms has to date emerged. By utilizing our extensive database of contrast-enhancement timing parameters, we attempted to devise and test a universally applicable and inherently simple-to-perform pMRA timing strategy.

Methods

Timing Algorithm. With IRB approval, a retrospective analysis of 71 pMRA studies (112 extremities) for which extensive two-station timing bolus technique data (two separate boluses to evaluate both aortic and lower extremity contrast arrival times) (1) was available were analyzed to determine the following hemodynamic contrast transit times: antecubital-to-aorta (AC-Ao), antecubital-to-foot (AC-F), antecubital-to-lower ext venous arrival (AC-venous), aorta-to-foot (Ao-F), and aorta-to-lower extremity venous arrival (Ao-venous). These values were then analyzed in attempt to determine whether basic timing parameters available a simple lower extremity time-resolved run (i.e. AC-F and/or AC-venous) could be used to *a priori* predict the optimum rate of table translation for the pMRA in order to a.) not outrun the bolus, and b.) avoid lower extremity venous enhancement.

Clinical Evaluation. The proposed timing algorithm (below) was incorporated into our standard clinical pMRA 1.5 T protocol (Philips Achieva, Philips Healthcare, Best, the Netherlands) and implemented as a high (5 s) temporal resolution time-resolved study of the lower extremities (3cc Gd-BOPTA, Bracco Diagnostics, Princeton NJ), followed by 3 station pMRA (additional 17 cc contrast) using table translation times per the timing algorithm. 35 consecutive patients (mean age 66 – claudication 60%; ulcers/rest pain/osteomyelitis 40%) were examined to determine a.) whether the bolus was outrun, and b.) the degree (if any) of venous enhancement. In those patients who exhibited venous enhancement, the arterial-venous window (AVW - defined as [AC-venous time] minus [AC-F time]) was evaluated to see if this *a priori* parameter could help predict impending venous enhancement.

Findings

As expected, there was a broad range of hemodynamic timing values among different patients (Table 1). We noted a very good correlation between AC-F and Ao-F times ($R^2 = 0.76$) (Figure 1). Based on this, we developed a 4-tier timing strategy as overlayed on the Figure 1 data. This uses only the AC-F time (x-axis Figure 1 – easily determined from time-resolved lower extremity) to establish the proper time to begin the lower station, t_{LS} (ie how quickly to progress through the upper and middle stations). For AC-F < 40 s, t_{LS} is 25 s. Based on our 2 station timing bolus data, this should never outrun the bolus (all Ao-F < 25 s – see Figure 1), with an estimated approximately 15% venous. Similarly for an AC-F of 40-50 s, we propose a t_{LS} of 30 s (estimated 6% venous), and for AC-F 50-60 s and > 60 s, a t_{LS} of 35 and 45 s respectively (no venous anticipated).

Applying this timing algorithm to 35 patients, all were technically successful and the bolus was never outrun. Venous contamination (none serious enough to render the study non-diagnostic) was seen in 7 (20%), largely confined to those with rapid (< 45 s) AC-F times. Two of these seven were claudicants. Figure 2 shows the AC-F times of the 7 venous patients (circles - timing algorithm overlaid).

We further investigated whether any other information could predict which of these "fast" flow patients would have venous enhancement. Examining AVW in the 20 fastest patients (group containing all venous), AVW averaged 32 s for patients without venous (range 15-45 s, not seen in 4), and 7.5 s for patients with venous (range 0-20 s).

Region	Mean (s)	Std Dev (s)	Range (s)
AC-Ao	21.4	4.5	13-37
AC-F	39.7	9.3	13-70
AO-F	18.3	8.2	5-46
AVW*	34.5	17	0-65^

Table 1 – Data from 2 station timing technique (n = 71).
* = venous seen in only 67% cases. ^ = no venous seen in 33%.

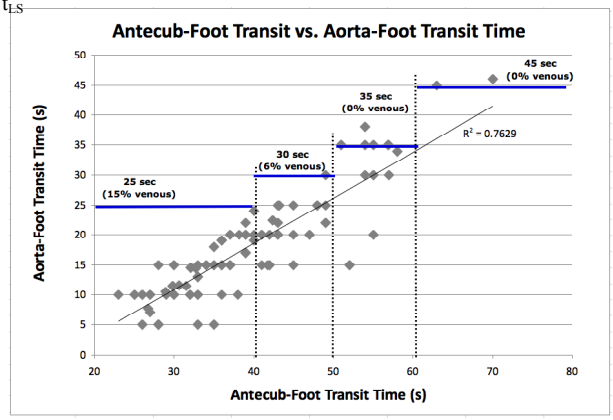

Figure 1 – Plot of AC-F time vs. Ao-F time. Proposed timing parameters are overlaid, as are predicted rates of venous.

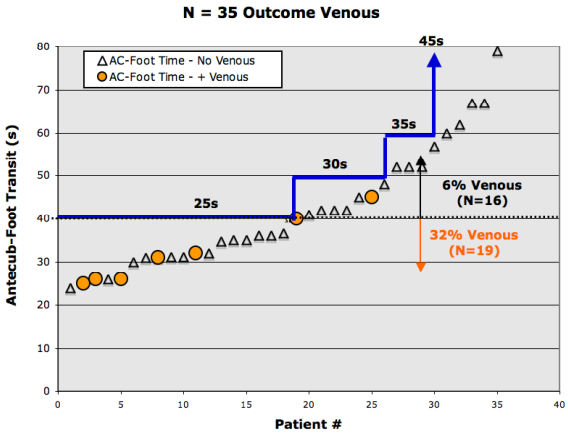

Figure 2 – Scatterplot of AC-F time for each patient, with labels showing venous or not. Timing strategy overlaid.

Discussion

This proposed pMRA timing algorithm is applicable to all MR platforms, requiring only the additional performance of a simple time resolved lower extremity study (diagnostically useful in of itself). The AC-F time is then measured and the speed at which the upper and middle station is scanned determined per the algorithm. Slower flow allows for longer upper and middle station times, which can translate into higher resolution and/or greater SNR. Our results as implemented in clinically complicated patients (40% ulcers/rest pain/osteomyelitis) were very good, with no cases of outrunning the bolus, and only 20% venous. Interestingly, venous contamination was not confined merely to the non-claudicators, and cannot be predicted by the AV-F time alone. Taking the algorithm a step further, the minority of patients with AC-F time < 40 s and AVW < 15-20 will almost certainly have venous contamination, and a hybrid 2 injection technique will likely be more successful.

References 1.) Maki et al. Maximizing SNR for Peripheral MRA Using a priori Knowledge of Bolus Kinetics and the Optimal Choice of Imaging Parameters. MRA Club Istanbul, 2007.