Single Injection Peripheral MRA: SNR and the Two Station Timing Bolus

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Introduction

Single injection moving table peripheral contrast-enhanced MRA often produces spectacular results, but despite faster upper and middle station acquisition times, detrimental lower station venous enhancement can still occur. This has led many investigators to embrace the more robust double injection approach, acquiring the lower station with the first contrast injection, and the upper and middle with the second. While this approach works well for venous suppression, we demonstrate here that middle and lower station SNR is significantly degraded as compared to single injection technique. Furthermore, we describe a two station timing bolus method of *a priori* predicting venous enhancement and determining which patients need one vs. two injections, thereby allowing the use of the higher SNR single injection technique whenever possible.

Methods

High resolution peripheral moving table sagittal WakiTrak MRA (1) was performed on 39 consecutive subjects (70 lower extremities) following a two station timing bolus (standard parameters - Table 1). All imaging was performed using a Philips 1.5T Intera System. Prior to imaging, a two station timing bolus was performed using a 2cc bolus of gadolinium chelate followed by 25cc of NS, both at 2cc/sec. Immediately following contrast visualization in the abdominal aorta (standard real-time fluoroscopic imaging), the table was moved (4 sec) to the lower station, and dynamic 2D axial slices were obtained above the ankle for 100 sec (0.5 images/sec, SI saturation pulses, water selective excitation, TR/TE/flip angle/slice thickness = 20/5.4/30/20 mm). Timing data was immediately evaluated (IDL, Research Systems Inc., Boulder, CO) to determine a.) the vein-aorta transit time, b.) the aorta-leg transit time, c.) whether venous enhancement was seen, and d.) the arterio-venous delay time (if venous seen). Based on the supervising radiologist's immediate evaluation of venous enhancement and the likelihood of success using a standard single injection moving table study, the patient either underwent a standard 1 injection (n=32) or 2 injection (n=7) exam. The double injection study was performed as lower station (injection 1) followed by the upper/middle station (injection 2), and spatial resolution and scan time in the middle station was typically increased over the single injection study. All patients received 40 cc gadolinium chelate. Single injection patients received a biphasic bolus averaging 18 cc @ 1.8 cc/sec followed by 20 cc @ 1.2 cc/sec. Double-injection patients received a 15cc bolus for imaging the lower station at an average rate of 1.1cc/sec, followed by a biphasic second bolus averaging 12 cc @1.5cc/sec followed by 13 cc @1.2 cc/sec for imaging the upper and middle stations. All injections were flushed with 25 cc of NS at the final rate. All datasets were reviewed and graded for diagnostic quality (yes/no), venous enhancement (5 point scale; 0 - none, 4 - severe/non-diagnostic), and signal to noise (SNR) of each station was calculated as mean vessel divided by mean subtracted background (subset of all 7 double injection and 7 most recent single injection patients). SNR data was corrected for any pulse sequence alterations from the standard protocol.

Parameter	Upper	Middle	Lower
Coil	SENSE Coil	Q Body Coil	SENSE Coil
Profile order	rev CENTRA	Linear	CENTRA
Orientation	Coronal	Coronal	2 Sagittal Stacks
TR/TE/α	4.4/1.28/40	4.3/1.28/40	12/1.79/35
FOV	440 (RFOV 90%)	440 (65%)	440 (40%)
Matrix	384 x 208 x 25	253 x 212 x 22	448 x 448 x 80
SENSE Factor	2.5 L/R	NA	2.5 A/P
Scan Time	9.5 s	13 s	~ 75 s
Measured Voxel	1.15 x 2.12 x 2.80 mm^3	1.72 x 2.08 x 2.80	0.98 x 0.98 x 1.0
Recon Voxel	0.86 x 0.86 x 1.4 mm^3	0.86 x 0.86 x 1.4	0.86 x 0.87 x 0.5

Table 1

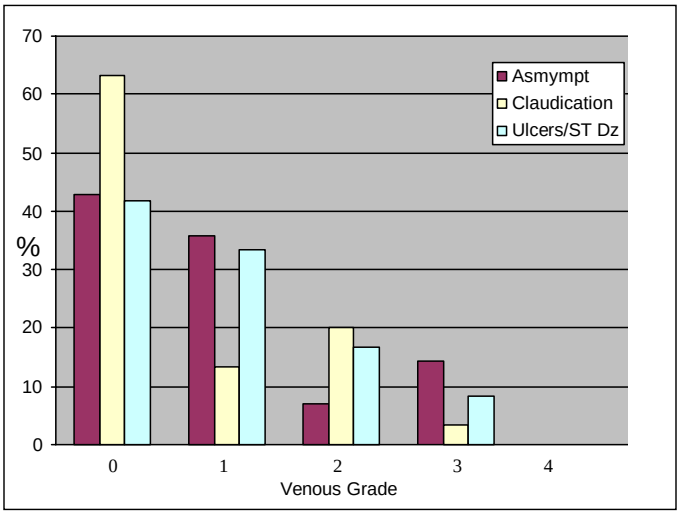

Figure 1. Venous enhancement by disease type (n=39)

Findings

Referrals were for claudication (62%), lower extremity ulcers (23%), graft surveillance (8%), rest pain (5%) and blue toes (2%). The 2 station timing bolus worked in all cases and demonstrated venous signal in 20 (29%) of extremities. All MRA exams were diagnostic (i.e. no venous grade 4). No venous enhancement was observed in 23 patients (59% - grade 0), with grade 1 in seven (18%), grade 2 in six (15%), and grade 3 in three (8%). Venous enhancement by disease type is seen in Figure 1. Using the two station timing bolus data, the time between the beginning of lower station acquisition and onset of venous enhancement (T_{avs}) was calculated, and a scatter plot of venous grade verses T_{avs} is shown in Figure 2. SNR for the single injection technique was greater than for double injection by 20%, 32%, and 38% in the upper, middle, and lower stations respectively (p = 0.22, p = 0.008, p = 0.035).

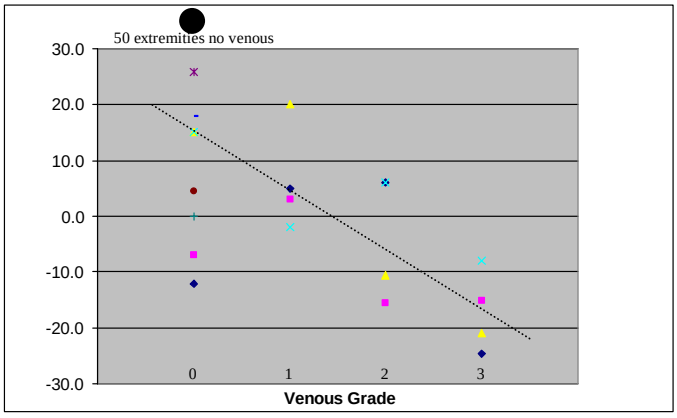

Figure 2 – Scatter plot of Tavs versus venous grade.

Discussion

The sagittal WakiTrak technique described here performed extremely well in both single and double injection variants, being 100% diagnostic in 39 patients having a mixture of claudication and soft tissue disease (zero grade 4, and only 8% grade 3 venous signal). The single injection technique proved superior in terms of SNR, being significantly greater in the middle and lower stations. This likely relates to the higher bolus rates possible for single injection, as the contrast is more effectively shared over all three stations. Out of 39 patients, we chose the double injection technique 7 times (18%). This was based on our imperfect and still evolving understanding of the relationship between T_{avs} and venous enhancement. As can be seen from Figure 2, for all 50 extremities (71% - big black dot) where no venous was detected with the two station timing bolus, no venous contamination was seen. Furthermore, based on a rough fit (dashed line) in Figure 2, a T_{avs} of approximately 0 sec seems to represent the transition point between a very acceptable minimal venous (grade 1) and the still very diagnostic grade 2 venous. Thus using the two station timing bolus in combination with a T_{avs} threshold of approximately zero appears to be a good way to *a priori* determine whether the higher SNR single injection technique will give good results, or the decreased SNR double injection technique must be used. Further data collection and computer modeling is underway.

Bibliography

1. Maki JH, Wilson GJ, Eubank WB, Hoogeveen RM. Proceedings Eleventh Scientific Meeting ISMRM, Toronto, Canada. 257.