Evaluation of Non Contrast Enhanced MRA in patients with PVD

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Target audience: Physicists and clinicians interested in arterial imaging.

Purpose: Several new non-contrast enhanced MR angiography (NCE-MRA) methods have recently been developed for imaging the arterial system without the time and resolution limitations of acquisition during first pass of a gadolinium-based contrast agent, or safety concerns related to Nephrogenic Systemic Fibrosis. Two such methods are based on a subtraction technique using either an acceleration-dependent or velocity-dependent method. The aim of this study was to assess the diagnostic performance of these methods, in patients with peripheral vascular disease, by comparison with our standard clinical images obtained using a contrast enhanced method: 'time resolved imaging of contrast kinetics' (TRICKS).

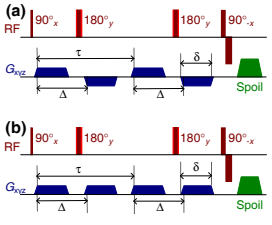

Fig. 1: flow-preparation modules for (a) velocity sensitisation and (b) acceleration sensitisation. The motion sensitisation gradients (MSG) are shown in blue.

Methods: 24 patients (17 male, 7 female) with a mean age of 64.9 years (range 54.7-80) with symptoms of peripheral vascular disease years were studied. Ethical committee approval and informed consent were obtained from all patients. All data was acquired using a 1.5 T MR system (Signa HDx, GE Healthcare, Waukesha, WI). Non-contrast-enhanced MRA was acquired using two subtraction-based methods, whose flow-preparation modules are shown in Fig. 1—the acceleration-dependent method ADVANCE-MRA[1] (Fig. 1b) and the velocity-dependent method VANESSA[2], modified to use an iMSDE flow-preparation module[3] (Fig. 1a). For each method fat-sat pulses were applied before both the flow-preparation and readout modules and the following acquisition parameters were used: TE 1.6 ms, TR 3.5 ms, flip angle 65°, acquisition matrix 256×256×28, FoV 33.3 cm, slice thickness 2.4 mm, ASSET factor 2, oblique coronal orientation. For flow-suppression, the ADVANCE-MRA used the motion-sensitisation gradients (MSG) with duration 8 ms (TE_{eff} 50 ms) and amplitudes 0.0, 0.5, 1.0, 2.0 and 5.0 mT/m for arterial depiction. The flow-sensitisation was placed in systole (peak arterial flow as determined by prior cine phase-contrast measurements) and was followed by a 200ms delay placing the readout in diastole. By contrast, the VANESSA acquisition used MSG duration 3.4 ms (TE_{eff} 35 ms) and amplitudes 0.0, 0.5, 1.0, 2.0 and 15.0 mT/m, with the final 15.0 mT/m images giving artery+vein images. The flow-sensitisation (iMSDE) module was placed in diastole for the bright-blood (0 mT/m) image and in systole for the remaining images, with no delay between flow-sensitisation and readout. The NCE-MRA acquisitions were followed by our standard clinical protocol using TRICKS, with the following scan parameters: TE/TR 2.8/8.3 ms; flip angle 45°; FoV 44×30 cm^2; acquired matrix 512×156×28; slice thickness 2.4 mm. The total scan time for a mask phase and 10 dynamic phases was 170 seconds. A dose of 10 ml Gadobutrol (Gadovist, Schering AG) was given, followed by a 20 ml saline flush, at a rate of 0.5 ml/second. The images were cropped, giving the same S/I FoV for all techniques, and assessed independently by two experienced vascular radiologists. Both MIPs and individual slices were available for assessment. The below knee arterial station was divided into 9 segments. The proximal and distal below-knee popliteal (Pop), tibio-peroneal trunk (TPT), proximal and distal anterior tibial (AT), proximal and distal peroneal and proximal and distal posterior tibial (PT) arteries were assessed in terms of vessel visibility (visible, partially visible and not visible), diagnostic confidence (on a 4 point Likert scale) and venous contamination (none, some but not affecting diagnosis and significant affecting diagnosis) for each of the 3 techniques. Diagnostic confidence was then differentiated into reasonably or very confident, v poorly confident or non-diagnostic for analysis purposes. From the disease evaluation, the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for detection of significant stenosis (>50%) were evaluated, considering TRICKS as the 'gold standard'. All statistical analysis was done using Microsoft Excel.

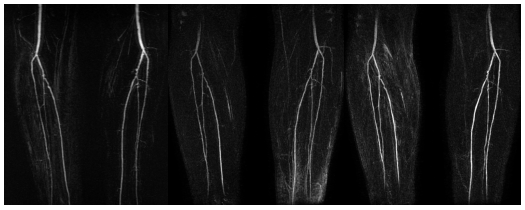

Fig. 2 Examples of (L-R) TRICKS, ADVANCE-MRA & VANESSA images.

Results: A total of 432 segments were assessed by each reviewer for each of the methods (total 2,592 segments). Combining the results from the reviewers, 820/13/31 segments (TRICKS), 608/149/107 segments (ADVANCE-MRA) and 707/105/52 segments (VANESSA) were graded as visible/partially visible/not visible. Overall diagnostic confidence was rated as reasonably or very confident in 98.5% of segments reviewed using TRICKS, 79.9% using ADVANCE-MRA and 92.1% using VANESSA. Table 1 shows the diagnostic confidence of each method by segment. The sensitivity, specificity, PPV and NPV of the two methods using TRICKS as the gold standard and considering stenosis >50% as significant disease on a per segment, per limb and per patient basis is shown in Table 2.

The degree of venous contamination was scored as none/some/significant in 96/3.5/0.5 % of evaluated segments using TRICKS as compared to 85.8/11.9/2.3 % using ADVANCE-MRA and 72.2/23.3/4.5 using VANESSA.

Method	Prox Pop	Distal Pop	TPT	Prox AT	Distal AT	Prox Peroneal	Distal Peroneal	Prox PT	Distal PT
TRICKS	99	99	99	99	99	98	98	98	98
ADVANCE-MRA	47.9	63.5	81.3	86.5	86.5	87.5	87.5	87.5	86.5
VANESSA	83.3	93.8	94.8	94.8	91.7	93.8	88.5	91.7	90.6

Table 1 – Percentage of segments with diagnostic confidence rated as reasonably or very confident for each method by anatomical location

Discussion: This work demonstrates that both an acceleration based subtraction technique (ADVANCE-MRA) and a velocity dependent method (VANESSA) can feasibly be used in the assessment of patients with peripheral vascular disease. Overall visualisation of the vessels is reasonable for both techniques when comparing to TRICKS, although the experienced reporters felt more confident using the VANESSA sequence for diagnostic use. Overall sensitivity for the detection of disease per patient is high. Previously reported issues with vessel visualisation near the edges of the field of view are less evident with the improved VANESSA method than with ADVANCE-MRA although, as expected ADVANCE-MRA is more resistant to venous contamination than VANESSA.. It may be the case that in the future, NCE-MRA is used as a screening tool to select patients for contrast enhanced and other more invasive diagnostic investigations.

Method	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
ADVANCE-MRA segment	63.4	92.5	50.4	95.4
VANESSA segment	65.3	92.7	52.5	95.6
ADVANCE-MRA limb	73	66.1	57.4	79.6
VANESSA limb	87.2	61.4	60.7	87.5
ADVANCE-MRA patient	92	60.9	71.9	87.5
VANESSA patient	96	43.5	64.9	90.9

Table 2 – Calculated sensitivity and specificity of the two methods for significant disease.

Conclusion: This data demonstrates the feasability of a NCE-MRA technique. With further refinement it may be useful in the investigation of the typically elderly arteriopaths with poor renal reserve seen in most vascular clinics.

References:

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