Initial evaluation of a new NCE Angiography method in patients and comparison with TRICKS

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Introduction

Non-contrast enhanced MR angiography (NCE-MRA) methods allow imaging of arteries without administration of gadolinium-based contrast agents; this avoids the time and resolution limitations and associated with acquisition during the first pass, and safety concerns due to Nephrogenic Systemic Fibrosis. A recently demonstrated NCE-MRA technique [1] uses a controllable flow suppression module to obtain bright- and dark-blood images, which are subtracted to give an image showing only flowing blood. The degree of flow sensitivity can be varied by adjusting area under the motion-sensitising gradients. This approach is known as 'Vascular Anatomy by Non-Enhanced Static Subtraction Angiography' (VANESSA), and has been used to achieve excellent visualisation of the peripheral arteries in healthy volunteers. The aim of this study was to evaluate the initial diagnostic performance of the method in the peripheral leg arteries of patients by comparing with our standard clinical images obtained using time resolved imaging of contrast kinetics' (TRICKS) [2].

Materials/Methods

8 patients were examined using a 1.5 T Signa HDx scanner (GE Healthcare, Waukesha, WI). All patients were suspected arteriopaths and had been referred for peripheral MR angiography. Ethical committee approval was obtained for this study and all patients gave informed consent. A preliminary phase-contrast acquisition was used to determine the approximate time of peak flow in the popliteal artery, relative to the peripheral pulse trigger. This peak time was used as the trigger delay for the subsequent NCE-MRA sequence, which consisted of a 90° fat suppression pulse, followed by a modified MSDE preparation [3,4] and a 3D balanced SSFP readout.

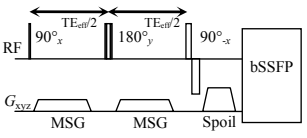

Fig. 1: modified MSDE module.

The modified MSDE preparation module is shown schematically in Fig. 1, and consists of $90°_{x}$, $180°_{y}$ and $90°_{-x}$ pulses with an effective echo time (TE_{eff}) of 25 ms. The $180°_{y}$ refocusing pulse and the $90°_{-x}$ tipup pulse are composite pulses designed to reduce the influence of B_0 and B_1 inhomogeneities [5]. The motion sensitisation gradients (MSG) have duration 8 ms; they are adjusted to control the degree of flow suppression. For this study, a series of 9 different flow sensitivities (MSG moments 0.05, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0 and 20.0×10^{-6} s^2T/m) was acquired in a single acquisition. These were interleaved with 3 bright-blood acquisitions acquired with no MSG. Subtraction of bright- and dark-blood images gave a series of vascular images with increasing flow sensitivity, showing the gradual appearance of first arteries and then veins.

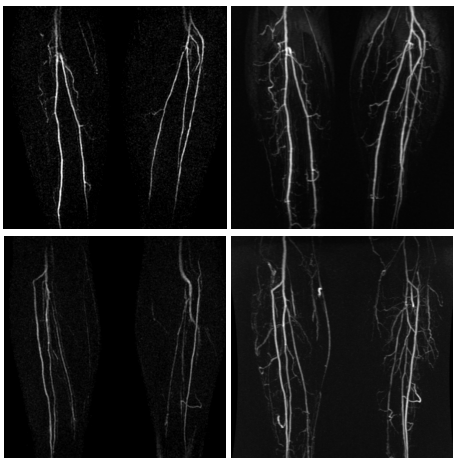

Fig. 2: Example comparisons in two patients of NCE (left) and TRICKS (right) MIPs.

Scan parameters were as follows: TE/TR 1.8/3.8 ms; 1.0 Nex; flip angle 65°; matrix 256×230×16; FoV 33.3×30 cm^2; sagittal orientation; parallel imaging (ASSET, factor 2); acquired resolution 1.3×1.3×4.2 mm^3. The scan time is 16 heartbeats per phase, or 192 heartbeats in total.

This was followed by our standard clinical protocol using TRICKS, with the following scan parameters: TE/TR 2.8/8.3 ms; flip angle 45°; matrix 512×156×28; FoV 44×30 cm^2; acquired resolution 0.9×2.0×2.4 mm^3. A mask phase, followed by 10 dynamic phases, were acquired with a scan time of 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.

Maximum intensity projections (MIPs) of the images for each technique were assessed by three experienced radiologists in consensus. Five arterial segments were assessed for each leg: below-knee popliteal (Pop), anterior tibial (AT), TP-trunk (TPT), peroneal (Per) and posterior tibial (PT). Firstly the visualisation of the segment was assessed, as fully, partially or not visualised. Segments that were not fully visualised were further categorised as being due to either disease or technique issues. Arterial disease was then evaluated: segments were rated as either normal, stenotic or occluded. Finally, the presence of artefacts affecting each segment was assessed on a 4-point scale (0–3).

Visualisation	Full	Disease		Technique	
		Partial	None	Partial	None
TRICKS	67	5	1	2	5
NCE	58	5	2	6	9

Table 1: Degree of visualization for the 80 vessel segments as assessed. Each entry shows the number of vessels assessed as being in the corresponding category.

	Normal	Stenosis (>50%)	Occluded
TRICKS	56	12	7
NCE	45	15	6

Table 2: Arterial disease evaluation

	None (0)	Mild (1)	Moderate (2)	Severe (3)
TRICKS	60	10	3	7
NCE	65	15	0	0

Table 3: Image artefact evaluation.

Results

Comparisons of example images for the two methods are shown in Fig. 2. Comparable vessel anatomy is observed, but the images are not identical since the NCE images are more sensitive to degree of flow in the vessel being imaged, and since veins appear at different points in the two series. In some cases, several images from the series are needed to distinguish artery from vein.

80 vessel segments were evaluated for the 10 patients. Table 1 shows the numbers of segments which were assessed as fully visualised, as partially or not visualised due to disease, and as partially or not visualised due to the imaging technique. For the NCE sequence, 9 segments were not visualised due to technique – these included 6 popliteal arteries (see discussion) and 3 other segments that were stenotic according to the TRICKS assessment. In the TRICKS sequence, 5 segments were not visualised due to technique because of severe motion artefact.

Segments which were rated as not visualised due to technique (or partially visualised but not sufficiently for a diagnosis to be made) were excluded from the subsequent analysis. This left 75 segments for the TRICKS and 66 segments for NCE. Table 2 shows the number of vessels rated as normal, stenotic and occluded for each method.

Of 62 segments not excluded for either method, 14 were scored as diseased for both techniques. In 13/14 of these cases, there was agreement about the extent of disease (7 stenotic, 6 occluded) and disagreement for only 1/14 cases. A further 10 segments were rated as diseased (all stenotic) for one method and normal for the other (3 for TRICKS only, 7 for NCE only).

Artefacts levels for two sequences are shown in Table 3. No vessel segments were affected by moderate or severe artefacts for the NCE sequence, while 10 were affected for TRICKS.

Discussion & Conclusions

This study represents the first investigations in patients using VANESSA. The artefact levels observed using this sequence were lower than using TRICKS, and there was a moderate agreement between the pathology as rated by the two methods, although the number of disagreements suggests that further development is needed before VANESSA could be recommended for routine clinical use.

While most vessel segments were fully visualised using VANESSA, in many cases the popliteal arteries were either not seen, or only partially seen. Two instances were due to variant anatomy, with an unusually high popliteal bifurcation, and could have been resolved by more careful positioning of the imaging volume. The popliteal artery is always at the superior margin of the FoV, where signal loss occurs due to inflow of blood through a region of magnetic field inhomogeneity: this leads to signal loss in the underlying bSSFP sequence used for the image readout. The readout was timed to coincide predominantly with the slow flow during early diastole for healthy volunteers, but the effect of distorted flow profiles in patients were not sufficiently taken into account. Better images might be obtained in future by delaying the readout further into diastole, and/or by using a different readout sequence such as GRE or FSE instead of bSSFP.

In this study only MIP images were assessed, potentially allowing some vessels to be obscured by overlying structures, and some pathology to be misdiagnosed. A more detailed evaluation using the multiple sets of source images is in progress.

References [1] Priest AN et al. proc ISMRM 2008;16:727. [2] Turski PA et al. Top Magn Reson Imaging 2001;12:175–181.
[3] Koktzoglou I et al. JCMR 2007;9:33–42. [4] Wang J et al. MRM 2007;58:973-81. [5] Brittain JH et al. MRM 1995;33:689–696.

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