Contrast Enhanced MR Angiography at 7 Tesla: Challenging the Limits of Spatial Resolution

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Aims:

1. To determine whether contrast-enhanced MR angiography (CE-MRA) is feasible at 7Tesla (7T).
2. If feasible, to explore potential increases in spatial resolution achievable using 7 T for CE-MRA.

Background:

Improving spatial resolution remains one of the key goals in contrast enhanced MR angiography (CE-MRA). Various strategies are being explored, aimed at enhancing spatial resolution on current clinical scanners. Ultra-high field strength scanning offers a possible new approach, and CE-MRA in human subjects at 7T has not previously been studied. Whilst the intrinsic increase in signal achievable at 7T should allow smaller voxel sizes and therefore higher resolution, there are several potential technical limitations. B1 and Bo field inhomogeneities seen at 7T are not a particular problem in CE-MRA, although gross variations in RF power will cause variations in background suppression. The general increase in relaxation times would be expected to improve background suppression. However, conversely restrictions imposed by SAR constraints become more significant at higher field strengths, and this in turn will limit both the achievable flip angles and minimum achievable TR and hence background suppression. A further potential disadvantage is the reduced relaxivity generally shown by gadolinium based contrast agents as the field strength increases [1] which may reduce their efficacy at 7 Tesla.

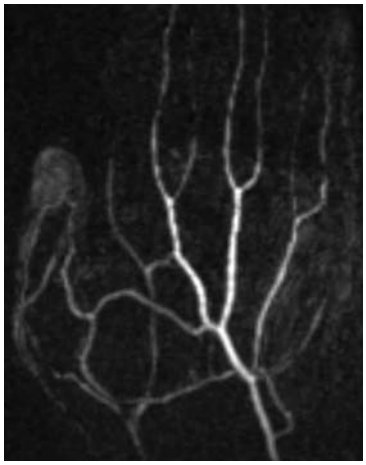

Fig 1: MPR image of dynamic CE-MRA at 7T using 0.7mm isometric voxels.

Aim 1

Methods: Scanning was performed using a Philips (Best, NL) 7 Telsa Achieva. (Gradient 40 mT/m; 200Tm-1s-1; RF Tx 4kW) using a transmit receive quadrature birdcage volume coil. Ethical approval was obtained from the local committee. Imaging of the hand vessels was chosen as a good anatomical location in which to examine high resolution imaging of small vessels and due to the constraints of coil size. Dynamic (4DTrak) MR angiographic images were obtained using the following parameters: TR=4.2 ms, TE=1.5 ms, FA=12^0, 40% keyhole acquisition, 15s temporal resolution, 0.7 mm^3 voxel size, matrix 256x256x55. The TR/ FA combination was limited by SAR constraints. Intravenous Gd-DTPA, (Magnevist®, Schering) 0.1 mmol/kg was injected via the antecubital fossa by hand injection at a rate of 1ml/sec without the use of automated timing paradigms.

Results: High-quality images were obtained (fig 1) demonstrating the feasibility of CE-MRA at 7T.

Aim 2

Methods: Scanning was performed as above for Aim 1. However, the blood-pool agent Gadofosveset, (Vasovist™, Schering) 0.3 mmol/kg was used to allow scanning in the steady-state, which enabled multiple sequential acquisitions at increasing spatial resolutions. Steady state scanning also removed the variable of differing k-space sampling strategies. Spatial resolutions using isometric voxel sizes from 0.5 mm^3 to 0.2 mm^3 were obtained by reducing the FOV. (TR 5.2- 10.7 ms, TE 1.9-3.7 ms, acq time 1.9-3.9 mins).

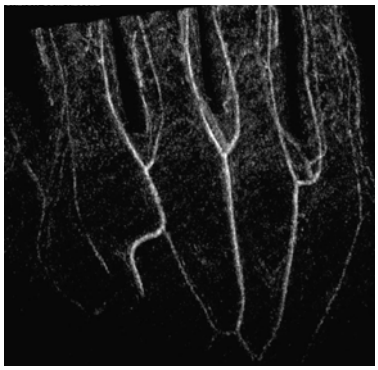

Fig 2: MPR image in the steady state at 7T using 0.23mm isometric voxels. On this slice the palmar digital arteries are clearly delineated.

Results: We assessed images for overall quality and for the ability to separately delineate the small vessel dorsal and plantar digital arterial supplies. Imaging using 0.23 mm isometric voxels appeared to be the limit at which high quality images were obtained using our current parameters (Fig 2). As a comparator, imaging was then performed at 3T maintaining comparable parameters, including coil and sequence selection, thereby ensuring the only significant variable was the field strength. At 3 T and 0.3 mm^3 no significant signal remained (Fig3a). To ensure this was not a result of contrast washout, the subject was immediately returned to the 7T scanner and rescanned using 0.3mm isometric voxels without further contrast administration, high quality images were again achieved. (Fig3b).

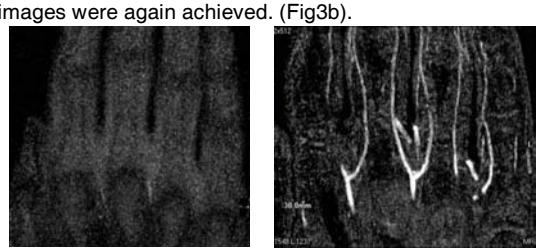

Fig 3a Fig 3b

Fig 3: Delayed imaging at 3T (left) followed by 7T (right) using 0.3mm isometric voxels

Conclusions: We have produced the first CE-MRA images in human subjects at 7T and have demonstrated that despite possible technical problems, high quality imaging is feasible. Our initial results have shown that the ultra-high field strength has the potential to offer significant improvements in spatial resolution. Future work should consider the optimum contrast agent for use at high field although work from our group has shown that, as might be predicted from published data at lower fields[1], the relaxivity of gadofovest falls with field strength, but still exceeds that of Gd-DTPA at 7T. It will also be necessary to optimize the flip angle and TR and TE at 7T. Ultimately we wish to attain the highest achievable spatial resolution during dynamic scanning, which creates additional challenges due to the shorter scan times required but also offers opportunities to adjust k-space sampling strategies

References: [1]Rohrer et al.Invest.Radiol2005;40(11)715-724

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Synopsis

Contrast Enhanced MR angiography at 7 Tesla: Challenging the limits of spatial resolution

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We have produced the first CE-MRA images in human subjects at 7T and have demonstrated that despite possible technical problems, high quality imaging is feasible. We used a blood pool agent to enable multiple sequential acquisitions at increasing spatial resolutions, and have demonstrated high quality images of digital vessels of the hand to a resolution of 0.23mm isometric voxels. Our initial results have shown that the ultra-high field strength has the potential to offer significant improvements in spatial resolution.