Intracranial Vessel Wall Imaging at 7 Tesla

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Purpose: To image intracranial vessel wall at 7T, at the level of the circle of Willis.

Introduction: Post-mortem studies show a high prevalence of atherosclerotic changes of intracranial arteries [1]. Despite these post-mortem studies, the most important cause of ischemic cerebral infarcts is thought to be embolic, and little is known about the role of intracranial vessel wall atheroma (atherosclerosis) in the occurrence of cerebral infarcts. An important reason for this might be the absence of imaging methods to depict the intracranial vessel wall. We hypothesize that 7 Tesla MRI would allow for the SNR and resolution that is needed for non-invasive imaging of the intracranial vessel wall at the level of the circle of Willis. Vessel wall imaging at 7T is challenging. The vessels of the circle of Willis do not have a single orientation, which prohibits the use of thick slices perpendicular to the vessel orientation, as is normally done in imaging of the carotid artery wall [2]. Besides, the intracranial vessels are smaller, and need a higher resolution than used for carotid vessel wall imaging [3]. Furthermore, as normally only a volume transmit coil for the head is available, non-selective inversion to null the blood signal cannot be used. Due to the limited extension of the standard volume coil, non-inverted blood would reach the imaged volume during the inversion delay needed to null the blood signal, which would lead to intense blood signal in the vessels. We developed a volumetric (3D) turbo spin echo (TSE) sequence for intracranial vessel wall imaging at 7 Tesla, which yields dark blood due to flow between excitation and refocusing in the TSE train.

Methods: Three healthy volunteers (three males, aged 28, 77 and 35 years) were imaged at a 7.0T scanner (Philips Healthcare) with a 16 channel receive coil and volume transmit/receive coil for transmission (Nova Medical Systems). A volumetric (3D) inversion recovery TSE sequence was used, in which the inversion was used to null CSF for contrast with the vessel wall. To improve the signal-to-noise ratio (SNR) of the vessel wall, T_2 preparation was applied prior to the inversion pulse, leading to saturation of tissues with short T_2 compared to the CSF T_2. This yields saturation recovery instead of inversion recovery for these tissues, and hence to more signal at the moment of acquisition. A dedicated refocusing sweep was used to obtain a constant signal response during the readout train, leading to a sharp pointspread function [4]. The following parameters were used: FOV 220 x 180 x 13 mm in transverse orientation, acquired resolution 0.8 x 0.8 x 0.8 mm^3, TSE factor = 60 (including 4 startup cycles), TR/TI/TE 6050/1770/23 ms, T_2 preparation time 250 ms, and SENSE factor 2.0 in LR direction. The scan duration was approximately 12 minutes. A time-of-flight angiography sequence was added to the protocol to identify the observed vessels on the black blood images.

Results and Discussion: Vessel wall could be clearly visualized in all three volunteers. Due to the isotropic resolution of 0.5 μl, the quality of the vessel wall depiction was independent of the vessel orientation, as shown by the sagittal reconstruction in Fig 1C. As we scanned only a limited number of healthy volunteers, the performance of this sequence in the presence of plaque or thrombus is yet unknown, and should be investigated in the future.
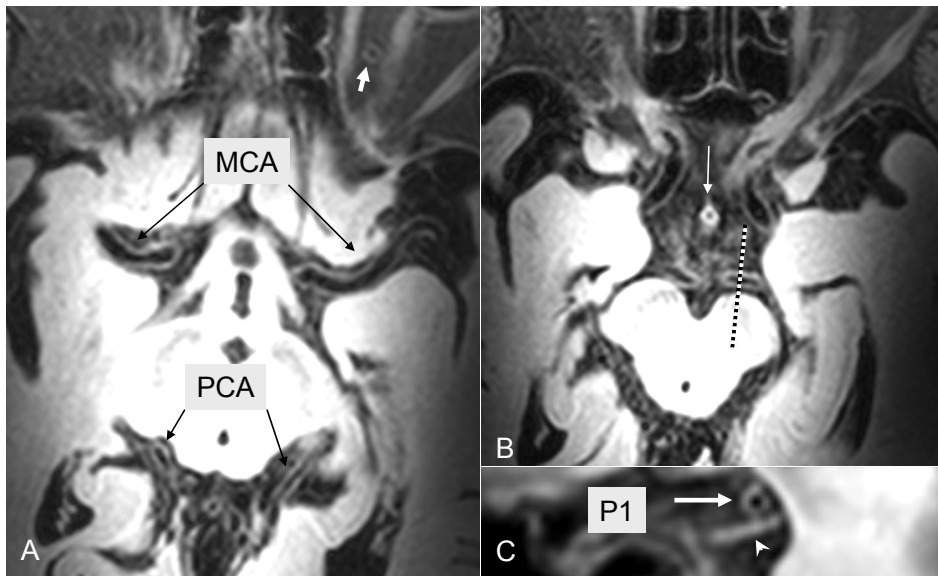

Figure 1. Intracranial vessel wall at the level of the circle of Willis of a 77 year old healthy male volunteer. A. Transverse image showing the MCA and distal PCA vessel walls. Also the vessel wall of the ophtalmica can be seen (short white arrow). B. Transverse image at the level of the carotid siphon and the first segment (P1) of the PCA. The long arrow in B indicates the infundibulum. C. Sagittal reconstruction as indicated by the dotted line in B, showing the vessel wall of the P1 segment of the PCA (long thick arrow). The arrow-head in C indicates the nervus oculomotorius (cranial nerve III). MCA: middle cerebral artery, PCA: posterior cerebral artery.

Conclusion: Non-invasive vessel wall imaging at 7T is feasible, and will allow to study the presence of vessel wall abnormalities in stroke patients.

References: *1) Vink A et al. J Anat 2002, 200(Pt 1):97-103. 2) Saam T et al. Radiology 2006, 240(2):464-472. 3) Moody AR et al. Circulation 2003, 107(24):3047-3052. 4) Busse RF et al. Magn Reson.Med. 2006, 55(5):1030-1037.*