NON-CONTRAST ENHANCED 4D ARTERY-SELECTIVE MR ANGIOGRAPHY USING SPATIALLY SELECTIVE SATURATION

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Introduction

Selective visualization of the intracranial arteries is crucial in various cerebrovascular diseases. In recent years, different methods of selective, non-contrast enhanced (NCE) magnetic resonance angiography (MRA) were proposed. These are sequences based on arterial spin labelling (ASL) or on selective saturation [1,2]. Various approaches mainly on the basis of ASL have been presented allowing a comprehensive evaluation of cerebrovascular morphology and hemodynamic properties. The aim of this study is to present a method of time-resolved artery-selective NCE-MRA based on selective saturation and the inflow effect of unsaturated blood. Dynamic images are obtained by a stepwise increase of the inflow duration, while two-dimensional cylinder pulses are consecutively applied to saturate the arteries, which should not contribute to the final image.

Materials and Methods

The imaging sequence consisted of four initial 90° WET saturation pulses to null the signal of the brain tissue as well as the arterial and venous blood inside the FoV. During the whole inflow time, 2 two-dimensional 90° cylindric excitations, positioned over major brain feeding arteries are successively applied proximal of the imaging volume to saturate the inflowing blood (Fig. 1b). Thus, only blood of the non-saturated vessels will appear on the final images. The cylindrical RF pulses employ a diameter of 30mm with a total duration of 10ms. A non-selective 180° inversion pulse is performed after selective saturation to invert the magnetization of the static tissue and the blood, which has arrived inside the field-of-view already (Fig. 1a). After inversion, the selective pulses are again applied to saturate the later arriving blood. Before acquisition, a SPIR pulse is applied to saturate the cranial bone marrow. The acquisition consisted of a segmented 3D T1-TFE scan with a TFE factor of 46, resulting in images with 200ms temporal resolution. Images were acquired on six healthy volunteers using a 3T Philips Achieva MRI scanner. In all volunteers, imaging of both carotid arteries as well as the posterior circulation was performed. Other relevant parameters are: SENSE factor 3, FoV of 210x210mm, 0.9 mm^3 isotropic voxel size, 110 slices, 15° Flip Angle, TR/TE: 4.6/2.2 ms, resulting in a total scan duration of 5:10. The first inflow time was set to 400ms after the initial saturation to provide enough time for the upstream of unsaturated blood into the artery of interest.

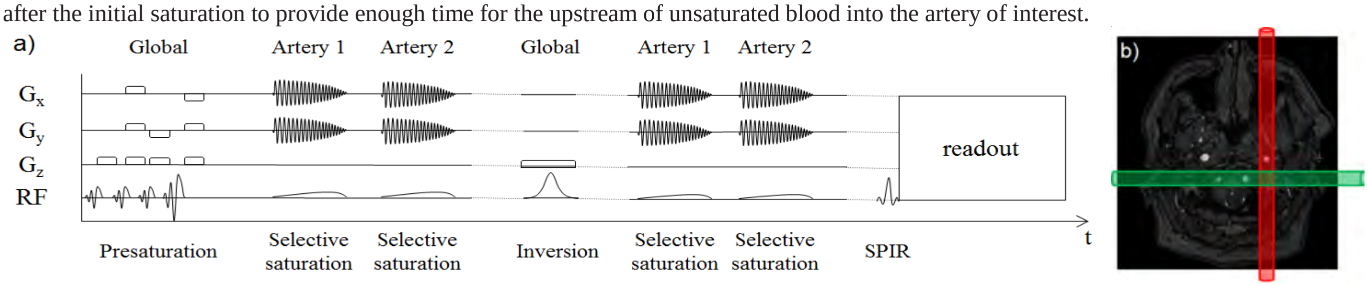

Fig. 1a: Schematic of the sequence for the first inflow time. After the initial presaturation, the cylindrical RF pulses are applied. The inversion pulse to ultimately null out the static signal at the beginning of image acquisition is applied non-selectively. The inflow times vary dynamically by increasing the time delay between presaturation and readout during image acquisition to obtain time-resolved images. The timing of the inversion pulse is adapted to the increasing inflow durations. b: Example for the planning to image the right carotid artery. Saturation bands are positioned over the left internal carotid artery (red) and both the vertebral arteries (green).

Results and Discussion

Image acquisition was successfully performed in all volunteers. The images show dynamic filling of the individual major intracranial arterial branches (Fig. 1a). Combining the three individual acquisitions gives a holistic picture of the whole cerebral vasculature (Fig.1b). Visual comparison with the TOF angiography with 0.45x0.79x0.7mm voxel size with a scan duration of 5 minutes shows the same extent of the inflowing blood as in the last dynamic scan, when all arteries are filled. Homogeneous background suppression in images acquired later than 1050ms was impeded compared with images acquired at shorter inflow times, as the wide range of tissue T1 relaxivities leads to imperfect nulling of the transversal magnetization when using only a single inversion pulse. The use of a double inversion recovery scheme could overcome this problem by reducing the differences between the different relaxation constants at the time of readout. However, in that case, perturbations of the obtainable signal may occur and remain to be evaluated [3]. The presented method might be a valuable tool for the assessment of intracranial crossflow in patients with carotid stenosis or to evaluate the feeders of arterio-venous malformations.

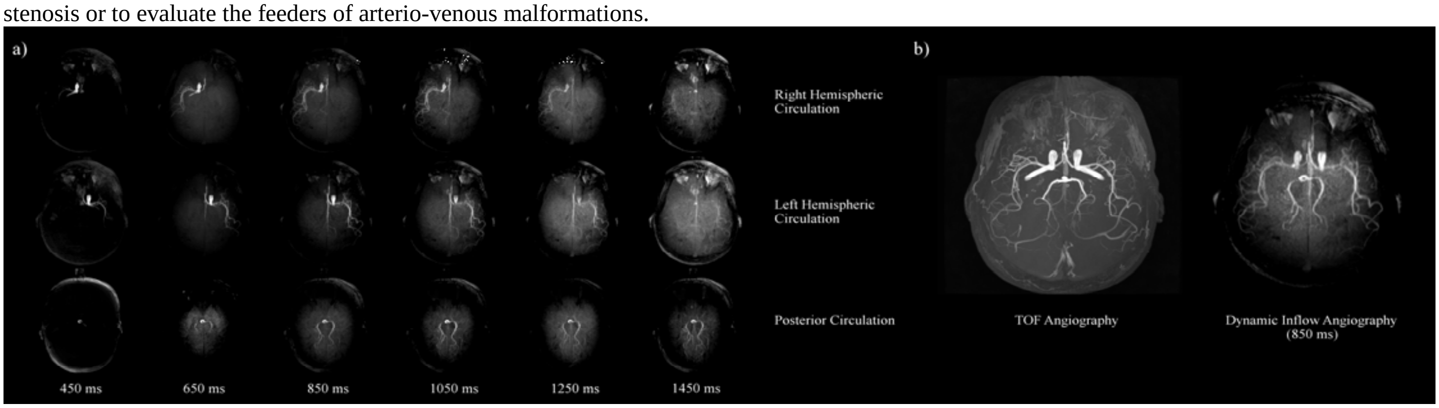

Fig. 2a: Representative transversal maximum intensity projections of one healthy volunteer. The individual flow territories of a single major intracranial artery can be visualized individually without unwanted appearance of the saturated arteries. The posterior circulation shows later filling than the carotid arteries. As a result of insufficient background suppression in the later dynamic scans, the noise level adds up in the fused images (b).

[1] Helle et al Proc. ISMRM 2011: 650 [2] Ito et al J Stroke Cerebrovasc Dis. 2014;23: 1019-23 [3] Maleki et al MAGMA 2012;25: 127-33