Dynamic non-contrast enhanced Angiography based on Superselective Arterial Spin Labeling and Compressed Sensing

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INTRODUCTION:
The visualization of cerebral arteries is important in the diagnosis of many cerebrovascular diseases such as arterio-venous malformation and steno-occlusive disease. Highly resolved spatial and temporal images as well as vessel-selective information are most often required for a complete evaluation of the cerebrovasculature and for the choice of the optimal treatment strategy. Nowadays, these requirements can only be fulfilled by intra-arterial digital subtraction angiography (DSA). However, this procedure necessitates ionizing radiation and exogenous contrast agents and is invasive which bears the risk of severe complications such as vessel dissection. On the other hand, conventional MR angiography (MRA) techniques (e.g. time-of-flight (TOF)) lack at least one of the demanded properties (temporal/spatial resolution, vessel selectivity). In the past, a variety of MRA approaches based on arterial spin labeling (ASL) have been proposed that can potentially overcome the limitations of existing methods, but suffer from long measurement times, especially when aiming to fulfill all of the above mentioned requirements [1-3]. Recently, it was shown that compressed sensing can be used to decrease the number of profiles needed for data acquisition to achieve a shorter overall scan time by performing incoherent sampling and exploiting image sparsity [4,5]. In this study, Superselective ASL [6] and undersampled 3D balanced steady-state free precision (bSSFP) image acquisition is employed in order to provide dynamic and vessel-selective angiography images of the cerebral arteries with sufficient spatial resolution and a reasonable measurement time.

MATERIALS AND METHODS:
In 5 healthy subjects, the major brain feeding arteries (internal carotid arteries (ICAs), vertebral arteries (VAs)) were labeled globally (all arteries at the same time) and individually. In addition, superselective labeling was performed on the anterior cerebral arteries (ACAs). The results were compared with conventional TOF angiography and undersampled data acquisition with only 30% of k-space filled and subsequent compressed sensing reconstruction.

All measurements were performed on a Philips 1.5T Achieva scanner using the body coil for transmission and an 8-element phased-array head coil for signal reception. Labeling parameters were as follows: labeling duration 450 ms (200 ms for the ACAs), labeling delay 50 ms, and only one pair of label and control images were acquired. Image acquisition employed a segmented 3D Cartesian bSSFP sequence with spiral golden ratio shot order [7]. The image volume was positioned at the level of Circle of Willis with the following parameters: FOV 200x200x48 mm³, voxel size 2x2x2 mm³, TFE factor 16, flip angle 90°, TR/TE 3.6/1.3. The trajectory is suitable for compressed sensing reconstruction, because it provides variable density incoherent sampling. Ten time-frames were acquired after labeling the blood resulting in a temporal resolution of about 127 ms and an overall scan time of approximately 5:40 min for full k-space sampling (Fig.1). Angiography images were obtained by complex subtraction of label and control images and subsequent maximum intensity projection (MIP).

RESULTS:
Time-resolved angiograms demonstrate the filling of the cerebral arteries at the level of the Circle of Willis (Fig.2). Even distal branches of the middle cerebral arteries (MCAs) and the posterior cerebral arteries (PCAs) can be depicted in later time-frames. Undersampled data acquisition results in comparable image quality as with full data sampling. The same results can be achieved with selective labeling of the major brain feeding vessels (Fig.3) and with superselective labeling of the ACAs (Fig.4). However, since the blood of the ACAs dilutes into the microvasculature and tissue shortly after being labeled, no signal can be detected in later time-frames.

CONCLUSION:
Superselective ASL in combination with compressed sensing can provide vessel-selective, temporally and spatially highly resolved angiograms in a complete non-invasive way, hence, overcomes limitations of existing MRA methods and potentially provide the same information as with DSA. Compressed sensing allows increasing the temporal and/spatial image resolution without increasing the measurement time which might be critical in clinical applications.

REFERENCES: