3D GRASE ASL is highly sensitive to detect hyperperfusion states in patients with acute stroke

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Introduction:

Cerebral hypoperfusion in stroke patients typically occurs after acute embolic occlusion of an intracranial vessel, or may be chronic in long-standing and progressive atherosclerotic obstruction of brain-supplying arteries. Several imaging methods are available for the semiquantitative or quantitative analysis of reduced cerebral blood flow (CBF) and/or cerebral blood volume (CBV), e.g. SPECT, PET, Xenon-CT, and dynamic susceptibility contrast perfusion MRI (DSC-MRI).
Hyperperfusion states usually reflect increase of CBV and/or CBF after recanalization and vasoparesis or in pathological states of high energy demand. In stroke, assessment of hyperperfusion may have therapeutic implications for stroke patients since thrombolysis may be needless or even harmful if vessel recanalization had already occurred.
Arterial spin labeling (ASL) techniques provide non-invasive information on cerebral perfusion. By varying the time between labeling the blood and actual readout of this information (inflow time TI) the presence of labeled blood can be captured in arteries (short TI) or microvasculature (long TI). Using a novel single-shot 3D readout technique, the acquisition of micro-vascular perfusion is possible even at multiple TI in less than 7 min. For assessment of macrovascular flow, a dynamic ASL angiography (DynAngio) was used by means of a Look-Locker approach to sample more than one TI after labeling.
In the present study, we sought to analyze if ASL can be used to evaluate hyperperfusion states in acute stroke patients. Therefore, hemodynamic information of both parts of the vascular tree arising from DynAngio and ASL perfusion maps was analyzed. ASL perfusion maps were compared to dynamic susceptibility contrast perfusion MRI (DSC-MRI) displayed on time-to-peak maps (TTP).

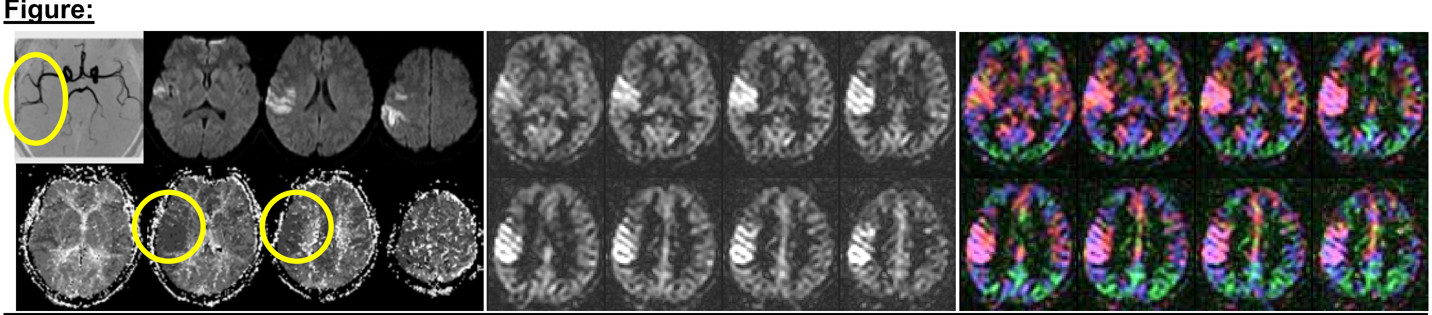
Patients and Methods:

A clinical 1.5T scanner (Magnetom Sonata, Siemens, Erlangen, Germany) was used for imaging. A standard MRI protocol included TOF-MRA, diffusion-weighted imaging (DWI) and DSC-MRI, analyzed on TTP maps. ASL perfusion maps were obtained using a single-shot 3D-GRASE read-out module. Microvascular perfusion (CBF) and bolus arrival time (BAT) were extracted from time series using nonlinear least-square optimization. For time series, multiple TI ranging from 400 ms to 3200 ms were measured in 8 time steps (TR 3000 ms), the acquisition time was 6:38 min. In addition, the DynAngio providing time-resolved images of blood inflow into the arterial tree was measured in all patients using 40 different phases of inflow at a temporal resolution of 36 ms (TR 12 s/TE 3.7 ms, spatial resolution 0.9x0.9 mm2, slab thickness 60 mm), the acquisition time was 2:20 min.
A total of 36 patients (14 w., 22 m., mean age 59 y.) with acute hemispheric stroke were examined within 48 hours after symptom onset. On DWI, acute MCA territory stroke was present in 31 patients, 5 patients had PCA territory stroke. 28 of 36 patients (78%) showed signs of hypoperfusion with delayed contrast bolus arrival on TTP maps and persistent arterial obstruction (8 complete, 19 partial) on TOF-MRA. In 7 patients (19%), signs of local hyperperfusion were present with an earlier arrival of contrast bolus on TTP and signs of vessel recanalization on TOF-MRA. In one patient with minor stroke, there was no evidence of vessel pathology or a perfusion deficit.

Results:

DynAngio and 3D GRASE ASL perfusion maps were obtained in good quality in 34/36 patients. Movement artifacts led to limited image quality in two patients. Areas showing signs of local cerebral hypoperfusion with a delay of contrast bolus arrival on TTP and persistent arterial obstruction were identified on ASL perfusion maps with a reduced CBF in 26/28 patients (93%). Moreover, the extent of perfusion deficit was estimated to be smaller on ASL perfusion maps compared to the area visible on TTP in 8 patients. On the other hand, hyperperfusion states demonstrating areas with recanalization with earlier contrast arrival on TTP were detected in 7 patients that showed a strong increase on ASL perfusion maps of CBF as shown below.
The figure illustrates an example of a 19 year old female patient with DWI showing acute stroke in the right middle cerebral artery territory and stronger flow signal of the affected MCA on TOF-MRA, indicating vessel recanalization (a). Correspondingly, TTP maps show an area of lower signal which reflects earlier contrast arrival in the ischemic tissue (b, yellow circle). This hyperperfusion phenomenon is demonstrated on the 3D GRASE ASL perfusion sequence as area of strong CBF increase (c: grey scale perfusion maps; d: color-coded overlay of CBF and BAT).

Figure:



Conclusion:

ASL MRI is highly sensitive to detect areas of hyperperfusion with increased CBF in patients with recanalization after acute hemispheric stroke. According to our data, there is a very good agreement of ASL perfusion maps with DWI and TTP findings both for hypoperfusion and hyperperfusion. The use of ASL is advantageous since it is noninvasive and repeatable, and since it provides valid information at reasonable acquisition times. In particular, the combination of ASL perfusion and DynAngio is promising since it allows assessment of hemodynamic impairment in both macro- and microvascular compartments.