Using Quantitative Arterial Spin Labeling at 3.0T for Therapy Monitoring of Cerebral Arteriovenous Malformations

L. Lüdemann[1], J. Heidenreich[2], E. T. Han[3], R. Felix[1], H. Bruhn[1]

[1]Department of Radiology, Nuclear Medicine and Radiooncology, Charité, Berlin, Germany, [2]Department of Radiology, Charité, CBF, Berlin, Germany, [3]Applied Science Lab West, GE Healthcare, Menlo Park, CA, United States

Introduction

Since the occlusion of cerebral arteriovenous malformations (AVM) is usually performed invasively in a number of subsequent steps, close monitoring of treatment success is warranted. MR perfusion imaging overcomes pertinent shortcomings of conventional imaging techniques because it shows functional features of the AVM itself. Usually, dynamic contrast-enhanced MR imaging (DCE-MRI) yields representive images of the perfusion distribution but does not allow for quantification and fails to represent adequately the extremely high perfusion values in the large vessels of the AVM (Fig B). Employing the FID of DCE-MRI dynamically changing image distortions during bolus passage were found, due to the large amount of contrast agent flowing through the AVM. Therefore, FID-DCE-MRI did not allow to calculate perfusion maps within the AVM. However, arterial spin labeling (ASL) permits both adequate representation of perfusion through the AVM and perfusion quantification. Moreover, repeated investigations without need for contrast agent applications are possible.

Methods

Twelve patients (5 men, 7 women, aged 22-36 years) with AVM were investigated with perfusion imaging using a continuous ASL technique[1]: (4 interleaves, 4096 points per interleaf, TR=5000 ms, TE of spiral readout= 9 ms, FOV=22 cm, slice thickness 7mm, 6 number of pairs, 2.5 s labeling duration, 3 slices) on a 3-T whole-body scanner (GE Healthcare, USA). Image acquisition was repeated twice with a delay time of 0.8 s and 1.2 s with a labeling distance of 50 mm. For reference to perfusion imaging a spin-echo DCE-MRI (TR/TE=1000/60 ms) measurement was performed applying intravenously 0.2 ml/kg Gd-DTPA with a flow rate of 5 ml/s into the antecubal vein.

The decay of arterial labeling, $M(t)$, can be described with a delay time t and a transit time Δt by the following equation when $t > \Delta t$ [2]:

$$M(t) = M_0 e^{\frac{-(t-\Delta t)}{T_1}} e^{\frac{f}{\lambda}(t-\Delta t)},$$

where T_1 is the tissue relaxation time, f is the flow, λ is the blood partition coefficient, and M_0 is the initial magnetization due to labeling at the time $t = 0$. Using two delay times, t_1 and t_2, perfusion can be quantified:

$$f = \lambda\left(\frac{\ln(M(t_1)/M(t_2))}{t_1 - t_2} - \frac{1}{T_1}\right)$$

Results and Discussion

The signal-to-noise ratio of CASL with a small number of repetitions as applied here was not sufficient to visualize the perfusion within the normal brain. On the other hand the extremely high perfusion within the AVM could be successfully quantified for perfusion values ranging form 0.1 up to 2 ml/(s ml). Whereas DCE-MRI yielded a better estimate of perfusion distribution within the brain, it failed to represent perfusion within the AVM adequately. The maximal estimated perfusion values represented by DCE-MRI ranged at 0.03 ml/(s ml). In conclusion CASL is a completely non-invasive method allowing repeated measurements as needed for treatment monitoring. Additionally, it quantifies the therapeutic effect and might be used for treatment assessment and planning.

References

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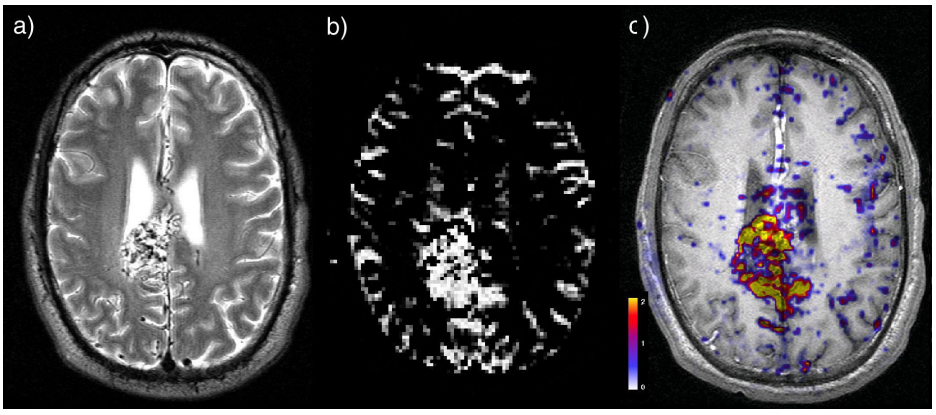

Fig.: Patient with AVM: a) T2-weighted image, b) SE-DCE-MRI, c) quantified perfusion in ml/(s*ml) overlayed to T1-weighted image.