Evaluation of a new qBOLD approach to map local blood oxygen saturation in arteriovenous malformation patients

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Introduction
Quantitative Blood Oxygen Level Dependent [1,2] allows quantitative evaluation of cerebral tissue hemodynamic parameters, such as the blood volume (BVf), deoxyhemoglobin concentration or local oxygen saturation (lSO2). An approach that combines separate estimates of T2, T2*, BVf, and B0 inhomogeneities has recently been proposed and validated in rats [2]. The aim of this study is to evaluate this approach in patients bearing an arteriovenous malformation (AVM) and evaluate the oxygenation status in the tissue surrounding the AVM nidus.

Materials and Methods
Groups. Three AVM patients were studied after written informed consent was obtained.

Acquisition. The imaging protocol was carried out on a 3T TX Achieva MR scanner (Philips Healthcare®) using a whole-body RF transmit and 8-channel head receive coils. In addition to a 3DT1 sequence used for tissue segmentation (TR/TE=9.8/4.6ms, resolution=0.5x0.5x1mm), three sequences were acquired with a FOV of 224x20x184mm: a 3D multi gradient echo (GE) sequence to obtain a T2* estimates (25 slices, 23 echoes, TR=164msec, ∆TE=7ms, resolution=1x1x0.8mm); a multiple spin-echo experiment for T2 mapping (5 slices, TR=1282 ms, 32 echoes, ∆TE=9ms, resolution=2x2x4mm); a perfusion sequence with injection of a bolus of Gadolinium-DOTA (0.1mmol/kg, Guerbet, France) to map BVf based on the first passage approach (TR=1041ms, dynamic scan time=1.04sec, resolution=2x2x4mm).

Data Analysis. To correct for macroscopic magnetic field inhomogeneities, the 3D gradient echo sequence was spatially averaged. The final spatial resolution was that of the multiple sin-echo sequence. T2 and T2* maps were obtained by fitting a monoexponential decay to the corresponding MR images. Relative BVf maps were obtained by fitting a gamma-variate function to the change in 1/T2* over time during Gd-bolus passage. To obtain quantitative BVf maps, the mean brain blood volume was normalized to 5%. To obtain quantitative BVf maps, the mean brain blood volume was normalized to 5%. lSO2 maps were eventually calculated pixelwise using [2]: lSO2=1- (4/3.πγB0Δχo.T2*.Hct).T2*.T2/T2* - 1/T2* - 1/T2, where 1/T2* = 1/T2* - 1/T2, ∆χo=0.264ppm is the difference in magnetic susceptibilities between fully oxygenated and fully deoxygenated hemoglobin, Hct=0.42 is the hematocrit fraction, γ is the gyromagnetic ratio, B0=3T is the strength of the magnetic field. Then, using SPM8, gray (GM) and white matter (WM) masks were obtained from the 3DT1 images [3]. The masks were realigned and resliced to match the T2 map (1b). Seven regions of interest (ROIs) were manually delineated: one in the AVM nidus, 3 in the middle cerebral artery territory and 3 in the posterior cerebral artery territory. For each territory, the 3 ROIs were: one proximal to the nidus (Mprox and Pprox), one distal to the nidus (Mdist and Pdist), one in the contralateral territory (Mcontro and Pcontro).

Figure 1. T2-weighted imaging over which the regions of interest (ROIs) have been overlaid (a). T2 (b), T2* (c), R2' (d), BVf (e), lSO2 (f) maps obtained in one patient at 3T.

(a) Axial T2                (b) T2 map                      (c) T2* map                      (d) R2' map                      (e) BVf map                      (f) lSO2 map

Figure 2. T2, T2*, BVf, R2' and lSO2 values (a) obtained for one subject and (b) averaged for all subjects.

Results
Fig. 1 shows representative parametric maps obtained from one patient. The noise level in maps is low. Maps reflect the gray/white matter anatomy. Average T2* and T2 values measured in Mcontro (54.1±4ms and 97.5±5.7ms) and in Pcontro (52.4±3.6ms and 91.8±1.8ms) correspond to what has been reported in the literature [3]. T2*, T2 increase when the distance to the nidus decreases. BVf increase in the nidus (Fig. 1e). lSO2 values in the nidus, near and from a distance to the nidus were 82±2.8%, 52.1±3.5%, 40.1±6.5% respectively.

Discussion / Conclusion
Because the large blood volume of AVM nidus steals blood from the surrounding tissue, this latter is expected to be persistently hypoxic and balanced by increased angiogenesis. In the nidus, the lSO2 is high, which is consistent with the high BVf. As expected, the lSO2 decreases when the distance to the nidus increases. BVf and lSO2 maps could provide useful information on angiogenesis and tissue oxygenation level around the nidus in addition to macrovascular structures obtained with angiography thus improving AVM therapeutic orientation.

References