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 (lSO_2). An approach that combines separate estimates of T_2, T_2*, BVf, and B_0 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

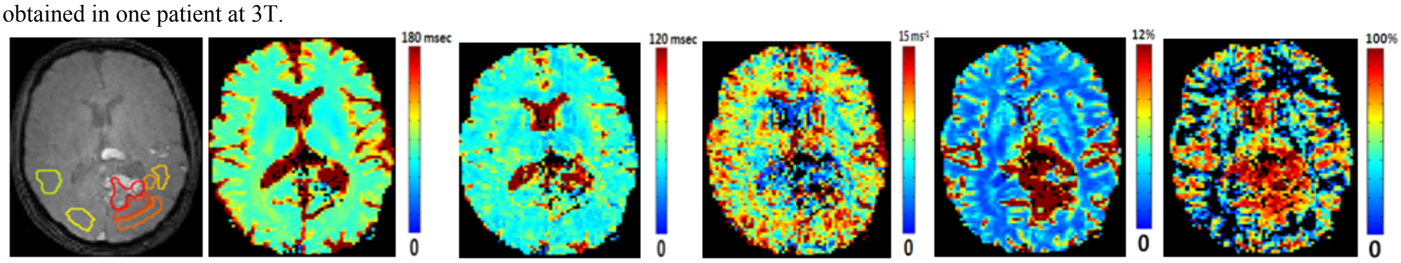
Groups. Three AVM patients were studied after written informed consent was obtained.

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 $3DT_1$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, ΔTE=7ms, resolution= 1x1x0.8mm); a multiple spin-echo experiment for T2 mapping (5 slices, TR=1282 ms, 32 echoes, ΔTE=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%. lSO_2 maps were eventually calculated pixelwise using [2]:

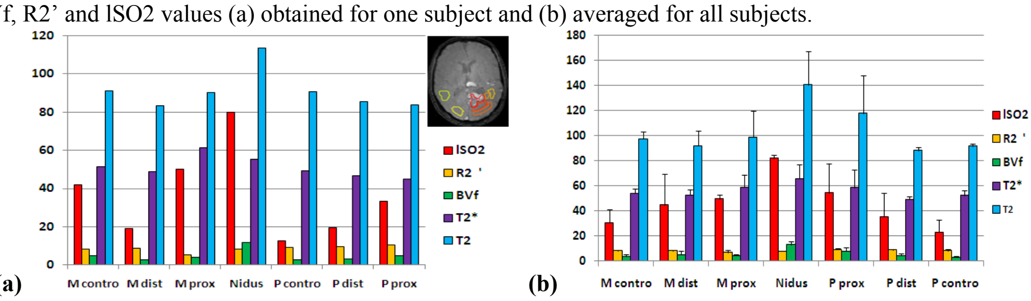
lSO_2=1- (4/3.π.γ.Bo.$\Delta\chi_0$.Hct.T_2 '.BVf)-1 where $1/T_2' = 1/T_2^* - 1/T_2$, ΔX0=0.264ppm is the difference in magnetic susceptibilities between fully oxygenated and fully deoxygenated hemoglobin, Hct=0.42 is the hematocrit fraction, γ is the gyromagnetic ratio, B_0=3T is the strength of the 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 T_2 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 (M_{prox} and P_{prox}), one distal to the nidus (M_{dist} and P_{dist}), one in the contralateral territory (M_{contro} and P_{contro}).

Figure 1. T_2-weighted imaging over which the regions of interest (ROIs) have been overlaid (**a**). T_2 (**b**), T_2* (**c**), R_2' (**d**), BVf (**e**), SO_2 (**f**) maps obtained in one patient at 3T.



(a) Axial T_2 **(b) T_2 map** **(c) T_2* map** **(d) R_2' map** **(e) BVf map** **(f) SO_2 map**

Figure 2. *, T_2, 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 T_2* and T_2 values measured in M_{contro} (54.1±4ms and 97.5±5.7ms) and in P_{contro} (52.4±3.6ms and 91.8±1.8ms) correspond to what has been reported in the literature [3]. T_2*, T_2 increase when the distance to the nidus decreases. BVf increase in the nidus (Fig. 1e). lSO_2 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 lSO_2 is high, which is consistent with the high BVf. As expected, the lSO_2 decreases when the distance to the nidus increases. BVf and lSO_2 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

(1) He et al. MRM 2007. (2) Christen et al. NMR in biomed, 2011. (3) Wansapura et al. NMR 1999.