Dynamic susceptibility contrast imaging study of the healthy brain using multiparametric classification

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Background / Aims:
The characterization and quantification of dynamic susceptibility contrast (DSC) imaging is important for clinical interpretation, though this calls for a reliable healthy brain tissue reference. Few DSC studies have examined the healthy brain, and existing studies were largely limited to manual definition of the region of interest. The current study aimed to improve tissue classification using an unsupervised multiparametric clustering method, and to characterize the vascular properties of several areas in the healthy brain, providing a reference point for diagnosis.

Methods:
Subjects and Scan parameters: 25 healthy subjects were included. MRI scans were performed on a 3.0T scanner. The DSC images were acquired using a 2D GE-EPI sequence with 78/92 repetitions, matrix/FOV=128x128/240mm, TR/TE=1300/30msec during the injection of a double dose of Gadolinium (Gd-DOTA) (0.4ml/Kg).
Data analysis: Cerebral blood volume and flow (CBV/CBF), mean transient time (MTT) and time to peak (TTP) maps were calculated by the Perfusion graphical user interface software[1] using a singular value decomposition algorithm. A signal recovery (SR) map was calculated using FSL software[2].
The anterior, middle and posterior cerebral arteries (ACA, MCA, PCA) territories were defined on the MNI standard space[3], creating a vascular territories template. The defined template was aligned to each subject's DSC EPI space.
A multiparametric unsupervised classification was performed for each subject using the FSL automated segmentation tool based on a hidden Markov random field model and an associated Expectation-Maximization algorithm[4]. The input data consisted of the five calculated DSC maps, and the number of classes was set to three. Voxels which did not strictly belong` to any one class (probability<80%) were excluded. rCBV and rCBF maps were calculated relative to the mean weighted value of each class from the whole brain.

Results and Discussion:
Multiparametric classification: Three brain clusters were defined, visually classified and approved by a senior neuro-radiologist as white matter (WM), gray matter (GM) and dura & blood vessels (BVas) (Fig. 1). The clustering into three groups was evaluated using one way ANOVA, comparing the five perfusion parameters among the clusters in each subject. Significant differences were detected between all perfusion parameters (see Fig. 2 for the CBV, CBF and SR).

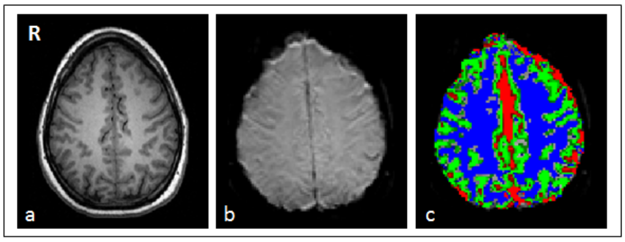
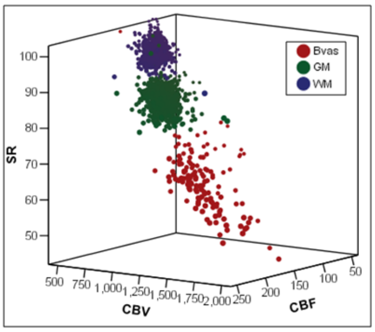


Figure 1: Results obtained from a 23 year old healthy subject; T_1 SPGR image (a); DSC image (b); and the DSC clustering results (c); BVas cluster (red); GM cluster (green) and WM cluster (blue).

Differences between brain tissues: The 3 brain tissues were well differentiated in their time curves, with stronger susceptibility effect and lower SR correlating with increased tissue vascularity (BVas>GM>WM) (Fig. 3). Significant differences were detected between the 3 tissue types for rCBV, rCBF and SR parameters ($p<0.001$). The BVas was also significantly different from the GM for the TTP and from the GM and WM for the MTT ($p\leq0.05$). The ratios between brain tissues for the rCBV, rCBF and MTT parameters were: $rCBV_{GM/WM}=2.12$, $rCBF_{GM/WM}=1.87$ and $MTT_{GM/WM}=1.12$. Significant prolonged TTP values were detected in males compared with females in the WM and GM tissues. A significant negative correlation was detected with age only for the MTT parameter in the BVas.

Figure 2: Three dimensional scatter plot of the CBV, CBF and SR of a representative subject.



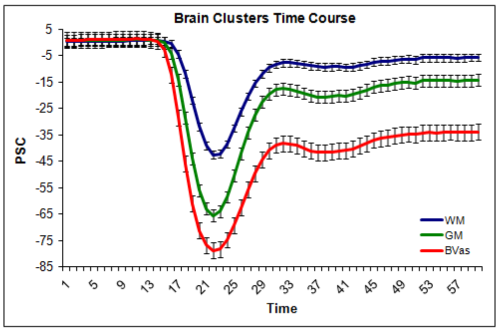


Figure 3: Time course and standard deviations obtained from all subjects (n=25) from the three brain tissues.PSC= percent signal change; Time = repetitions

Differences between vascular territories: Significantly higher rCBV values were detected in the PCA territory compared with the other two territories, in the BVas and WM and compared with the ACA in the GM. Significantly prolonged MTT and TTP values were detected in the PCA compared with the ACA and MCA for the BVas. In addition, a lower rCBV and rCBF was detected in the ACA compared with the other two territories both in the WM and GM.

Conclusion: The unsupervised clustering method, based on the calculated perfusion parameters, and the defined vascular territories template, were used to characterize the vascular properties of several brain areas. This method enabled tissue classification and revealed differences in perfusion parameters between brain tissues and between vascular territories. This clustering method can be used for data normalization (relative to one of the clusters) which is essential for clinical interpretation. Future studies may use this easily replicable method and the defined vascular template for the study of brain perfusion in patients with various vascular brain pathologies.

References: [1]www.cfin.au.dk/software; [2]http://www.fmrib.ox.ac.uk/fsl, [3]Moeller ; Pocket Atlas of Sectional Anatomy,[4]Zhang et al. IEEE, 2001.