Impaired fMRI Activation in Patients with Primary Brain Tumors

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Introduction

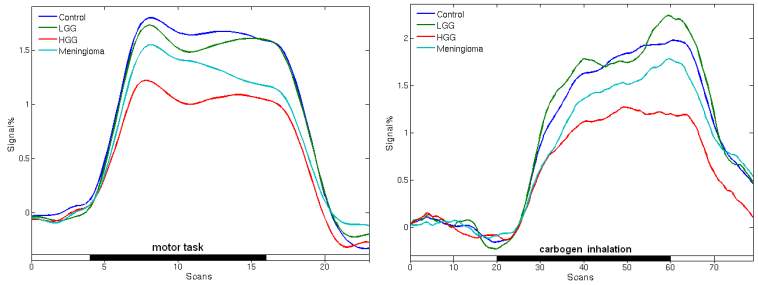
In spite of the validation of fMRI in clinical practice, several clinical studies showed that fMRI activations were decreased in the vicinity of brain lesions such as stroke (1) and tumors (2, 3). Because these changes may provide false negative results, the reliability of fMRI application remains debated. The purpose of this study was to identify morphological, pathological, and perfusion parameters that may account for the variance of motor-related activations using BOLD fMRI in patients with brain tumor. Carbogen inhalation, a gas mixture of CO_2 (7%) and O_2 (93%), was used to estimate BOLD signal over the brain, independently of motor-related neural activity.

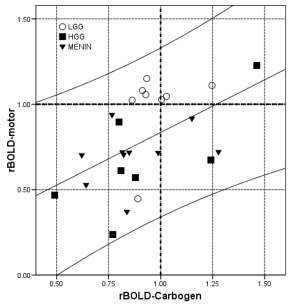
Materials and methods

25 patients referred for resection of primary frontal or parietal neoplasms (low grade glioma (LGG) (n=8); high grade glioma (HGG) (n=7); meningioma (n=10)) without macroscopic tumoral infiltration of the primary sensorimotor cortex (SM1) were examined preoperatively using BOLD fMRI during simple motor tasks. Overall cerebral BOLD signal was estimated using vasoreactivity to carbogen inhalation. Using bolus of gadolinium, cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT), and time to peak (TTP) were estimated using dedicated software to perform deconvolution analysis. Statistical analyses were performed at the individual level using SPM5. Statistical maps were calculated for the movement condition using the canonical hemodynamic regressor and thresholded at T>3.1. To model the BOLD response to carbogen inhalation, 20 healthy right-handed volunteers were scanned during the carbogen task. In a 1cm^3 region-of-interest centered on maximal T-value in SM1 contralateral to movements, interhemispheric asymmetry was evaluated using interhemispheric ratios for BOLD and perfusion parameters.

Results

During motor tasks contralateral to the tumor, ipsitumoral sensorimotor activations were decreased in HGG and meningiomas, correlated to the distance between the tumor and SM1. For all tasks, onsets of BOLD responses were similar. However, BOLD amplitudes were decreased in the SM1 ipsilateral to HGG and meningiomas compared to LGG and healthy hemisphere, in both motor (left figure) and carbogen inhalation (middle figure) tasks.





Whereas CBV was decreased in ipsitumoral SM1 for HGG, it remained normal in meningiomas. Changes in basal perfusion could not explain motor activation impairment in SM1. Decreased interhemispheric ratio of the BOLD response to carbogen was the best predictor to model the asymmetry of motor activation. The equation of the regression line (right figure) was expressed by: rBOLD-motor=B·rBOLD-carbogen+C; with B=0.62±0.22 (β=0.51; p<0.01), and C=0.22±0.21 (p=0.3). Moreover, 94.9±4.9% of all motor activations overlapped significant BOLD response to carbogen inhalation.

Discussion and conclusion

Our results suggest that peritumoral BOLD fMRI is affected by the distance and the pathology. In case of LGG, a pathological condition which may have a benefit of complete surgical resection, BOLD signals elicited by motor tasks and carbogen inhalation were normal. However, obvious impairments were detected in HGG, that might have been due to a vasomotor disorder, common to both neural and CO_2 stimuli. In HGG, a loss of autoregulation was likely. A loco-regional dysfunction of the brain-blood barrier (BBB) could be also advanced because common functional properties of brain perfusion, which rely on the BBB integrity, seemed altered. In meningiomas, abnormal but uncorrelated responses to neural and CO_2 stimuli associated with a maintained perfusion in the ipsitumoral SM1 that might correspond to a compensatory vasodilatation, preserved vascular properties are likely but, at least, partially exhausted to compensate the mass effect and a potential steal phenomenon of these hypervascularized lesions (2,3)

References

1. Krainik, A., M. Hund-Georgiadis, S. Zysset and D. Y. von Cramon "Regional impairment of cerebrovascular reactivity and BOLD signal in adults after stroke." *Stroke* 2005; 36(6): 1146-52.
2. Holodny, A. I., M. Schulder, W. C. Liu, J. Wolko, J. A. Maldjian*, et al.* "The effect of brain tumors on BOLD functional MR imaging activation in the adjacent motor cortex: implications for image-guided neurosurgery." *AJNR Am J Neuroradiol* 2000; 21(8): 1415-22.
3. Chen, C. M., B. L. Hou and A. I. Holodny "Effect of age and tumor grade on BOLD functional MR imaging in preoperative assessment of patients with glioma." *Radiology* 2008; 248(3): 971-8.