Investigation of tumor activity and anatomy by SWI during the inhalation of carbogen and air

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Introduction

Imaging the brain's vasculature using a recently developed high resolution BOLD MR technique called susceptibility weighted imaging (SWI) is continuing to gain importance both from a research perspective and a clinical perspective [1]. Originally developed for the visualization of small venous vessels the range of applications has since been extended to imaging of different pathologies. SWI has dramatically improved the ability to diagnose what is often occult otherwise. Breathing of pure oxygen (100% O_2) causes a decrease in cerebral blood flow by 20% to 30% due to vasoconstriction. This vasoconstrictive effect is avoided if the vasodilator carbon dioxide (CO_2) is added to oxygen (typically 5%), which leads to an increase in cerebral blood flow of about 50%. Several BOLD sensitive methods have been used to investigate the response to the application of exogenous hyperoxic contrast agents, such as carbogen or oxygen [2]. We employ SWI together with the breathing of carbogen (5% CO_2, 95% O_2) to investigate the response of cerebral tumors to this breathing gas and to assess tumor anatomy at high resolution.

Methods

Five patients with cerebral tumors (four glioblastoma multiforme (WHO grade IV), one astrocytoma (WHO grade II) were studied using a 3D gradient echo, first order velocity compensated sequence (TE = 45 ms, TR = 67 ms, $\alpha = 25°$, FOV = 256×92×64 mm^3, typical matrix = 512×192×64) on a 1.5 T MR scanner while breathing air and carbogen. BOLD venograms were computed from the data acquired during the breathing of air. Signal changes between the two breathing conditions were investigated in several manually defined ROIs (typically 5-7) for each tumor.

Results

The glioblastomas showed strong but heterogeneous signal changes between carbogen and air breathing with changes between -5.0 ± 0.4% in the surrounding edema / gliosis and +22.4 ± 4.9% at the perimeter of the tumors. The astrocytoma displayed a small signal decrease during carbogen breathing (-4.1 ± 0.1% to -6.8 ± 0.3% in the surrounding edema; -3.1 ± 0.1% in the tumor center).

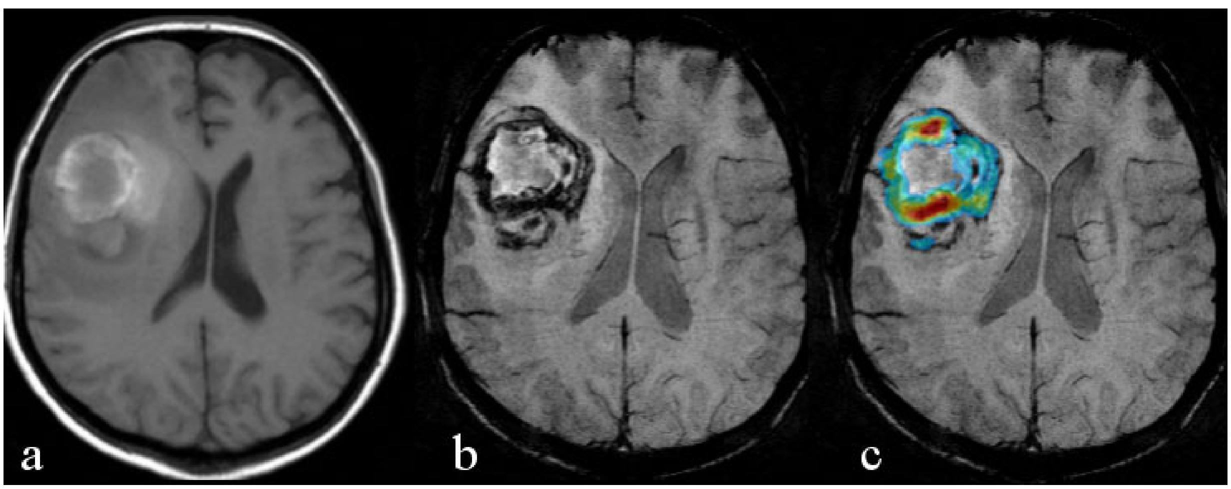

Fig 1. (a) T1-weighted, contrast agent enhanced scan. (b) Venogram acquired during air breathing. (c) Same venogram with overlaid signal increases during carbogen breathing. The heterogeneity of the tumor is clearly seen in the venogram (b). This heterogeneity appears also on the map of signal changes where the active perimeter is clearly distinguished from the inactive center of the tumor (c).

Discussion

Combining SWI with hypercapnia provides high resolution images of cerebral anatomy and allows for regional assessment of tumor activity. The high spatial resolution compared to previous studies [2] and the ability to visualize cerebral vasculature may justify the longer acquisition times, which can be reduced by employing higher field strengths and/or parallel imaging techniques. A reduction of scan time and the application of lower concentrations of CO_2 may also help reduce the risk of motion artifacts which currently represents the main drawback of this method. Systematic studies on different tumor types accompanied by intra-operative oxygenation measurements and an evaluation of histologic specimen may allow for a better classification of brain tumors or areas with abnormal blood supply.

References: [1] Haacke EM, Xu Y, Cheng YCN, Reichenbach JR. Susceptibility Weighted Imaging (SWI). Magn Reson Med 2004;52:612618. [2] Griffiths JR, Taylor NJ, Howe FA, Saunders MI, Robinson SP, Hoskin PJ, Powell ME, Thoumine M, Caine LA, Baddeley H. The response of human tumors to carbogen breathing, monitored by Gradient-Recalled Echo Magnetic Resonance Imaging. Int J Radiat Oncol Biol Phys 1997.