Quantitative Measurements of Cerebral Oxygen Extraction Fraction for Rabbits with Carotid Occlusion Using MRI

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Purpose

Cerebral oxygen extraction fraction (OEF) is critically important to assess the brain oxygen metabolism under both normal and disease states [1]. Quantitative measurements of cerebral hemodynamic and oxygen metabolism are primarily performed using positron emission tomography (PET) [2]. However, PET examinations are invasive and require an onsite cyclotron. A MR based approach has been proposed to estimate OEF noninvasively in normal healthy human subjects [3]. In this study, a gradient echo sampling of the spin echo (GESSE) sequence [4] was implemented to measure cerebral OEF in a rabbit carotid artery occlusion model. We aim to evaluate whether the MR based method can be utilized to detect changes of oxygenation under a pathophysiological condition.

Materials and Methods

Three New Zealand rabbits weighting 2.8-3.4 kg were studied with an approved animal protocol. Carotid occlusion was induced surgically in all animals. MR images were acquired on a 3.0 T whole-body MR scanner (Signa Excite™; GE Medical Systems, Milwaukee, Wisconsin, USA) with 8-channel head array coil in rabbits before and 72 hours after carotid artery occlusion. Similar to [4], a GESSE sequence was employed to acquire images with varying R2 and R2' weighting that allow simultaneous estimates of R2*, R2 and R2' from this single scan. The imaging parameters of this GESSE sequence were as follows: TR=1500ms; TE=56ms, # of echo = 32, echo spacing = 3.748ms, index of spin echo = 7, readout bandwidth = 62.5kHz, field-of-view=256×256mm^2; a matrix size=128×128; slice thickness=7.5mm. An analytical signal model, which characterizes the deoxyhemoglobin-induced MR signal alteration [5], was employed to estimate OEF. A region of interest (ROI) was manually defined to encompass the whole brain of rabbits to obtain OEF values prior to and 72 hours post carotid artery occlusion. Paired student t test was employed to test whether OEF was significantly altered post carotid artery occlusion.

Results

A representative SE image from the GESSE data acquisition and the estimated OEF maps before and 72 hours post carotid artery occlusion were demonstrated in Fig 1. Global increase of OEF was detected in all rabbits. The average OEF before carotid occlusion operation was 36.2% ± 3.3% in the brain parenchyma of rabbits, and increased significantly 72 hours after carotid occlusion to 55.14% ± 10.38%, as shown in Fig.2. (p = 0.04).

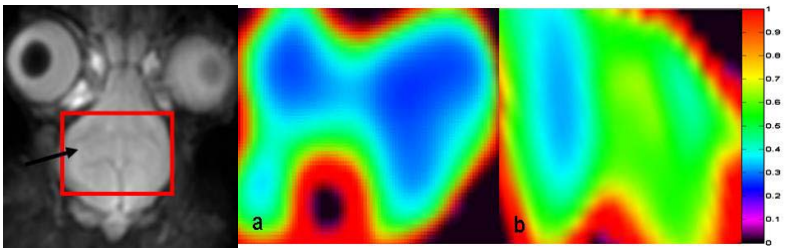

Fig. 1. Representative SE images and the OEF maps obtained (a) before and, (b) 72h after carotid occlusion in the same rabbit. The OEF maps were shown for the region marked by the red box in SE image.

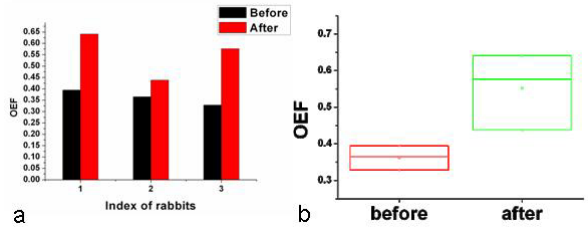

Fig. 2. The mean OEF in three rabbits before and 72h after carotid occlusion operation Significance elevated OEF was obtained (P <0.05)).

Conclusion :

Carotid artery occlusion impairs the supply of blood flow to brain tissue and may lead to a hypoxic state. It is expected that OEF may increase due to insufficient blood flow under this pathological condition. In agreement of this concept, our study demonstrated a consistent and significant increase of OEF in rabbits post carotid artery occlusion, suggesting that this MR based method can be utilized to detect pathophysiological changes in cerebral oxygenation.

Reference

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