Comparison of BOLD signal changes in the fetal brain at 3T with local pO2 measurements

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Introduction: It has recently been shown, that fetal MRI using the blood oxygen level dependent (BOLD) technique is able to demonstrate changes in the fetal tissue oxygenation during hypoxia (1). Methods to assess fetal tissue oxygenation would be desirable to detect the fetus at risk with the option of initiating precautionary or therapeutic management (e.g. induction of preterm delivery). To consider fetal BOLD MRI as a test modality in fetal surveillance, it is necessary to compare BOLD signal changes with defined changes of maternal and fetal tissue oxygenation.

So far it has been difficult to study continuous changes in fetal intracerebral oxygenation tensions (pO_2). Direct in vivo measurements of pO_2 have been subject to error, because of oxygen consumption at the tip of the sensing probe. Recently however, a non-O_2-consuming fluorescent fibre optic probe has been developed and used to measure pO_2 in the adult and fetal brain (2, 3).

The purpose of this study was to compare BOLD signal changes (SI) with local intracerebral oxygen tension measurements in the fetal brain during hypoxia in a sheep model.

Methods: A T2*-weighted single-shot gradient-echo EPI sequence (TE 30 ms, FOV 180 mm, acquired resolution 2.25 x 2.25 mm, reconstructed resolution 1.4 x 1.4 mm, acquired matrix 80 x 80 and reconstructed matrix 128 x 128, slice thickness 5 mm, interslice gap 1 mm, flip angle 90°) was used to measure BOLD SI changes in the fetal sheep brain during control, hypoxia and recovery. 9 pregnant ewes were examined with a 3T scanner (Intera, Philips Medical Systems, Netherlands). Measurements were performed during a control period with normal oxygen saturation, hypoxia and recovery induced by reduction and subsequent increase of oxygen in the ventilated gas mixture. Regions of interest were placed in the fetal cerebrum to measure SI. The changes in the relaxation rate (ΔR2*) were estimated for each plateau by $\Delta R2^* = \frac{\ln\left(\frac{SI(t)}{SI_{control}}\right)}{TE}$ (4).

Before scanning, the fetuses were chronically instrumented with a probe (REF BF/OFT/2.0, Oxford Optronics Ltd., Oxford, UK) in the left hemisphere to continuously measure the local intracerebral oxygen tension (pO_2). The differences between the control and hypoxic/recovery pO_2–values were calculated (ΔpO_2). Linear regression analysis was used and a correlation coefficient (r) was calculated to indicate the correlation between ΔR2* and ΔpO_2.

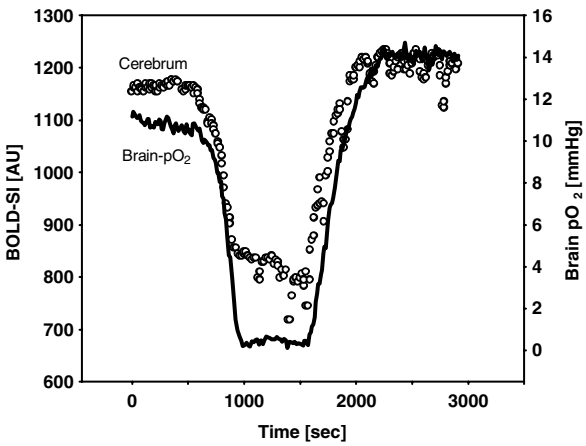

Figure 1: Scatterplot of an experiment with an initial control period, hypoxia after reduction of the $MatSO_2$ and recovery. Time course of BOLD signal intensities of the cerebrum (○) and local brain pO_2 (—).

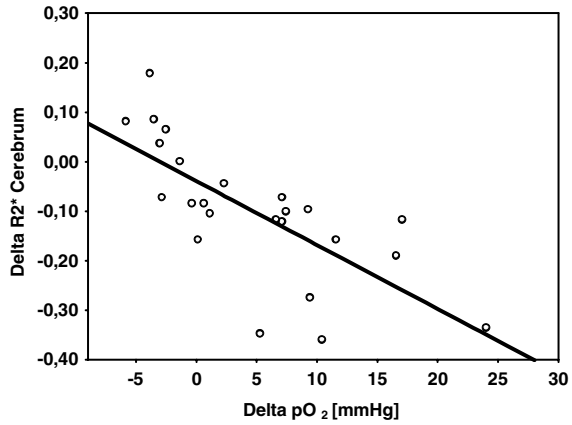

Figure 2: Linear regression of ΔR2* with ΔpO_2 of the cerebrum for all experiments.

Results: Figure 1 illustrates the close relation between cerebral BOLD-SI and local brain pO_2 during hypoxia and recovery.

BOLD measurements were obtained during control (n=12), hypoxia (n=12) and recovery (n=12). Mean values of relative SI%($\frac{SI(t)}{SI_{control}}$) and pO_2 were reduced from 100% BOLD-SI% and 13 mmHg pO_2 [95% confidence interval 10-17] to 83% SI% [78-89] and 2 mmHg [1-4] and increased to 100% [93-106] and 15mmHg [11-19] during recovery. ΔR2* and ΔpO_2 were correlated significantly (r=-0.72; p=0.00007) (Figure 2).

Discussion and Conclusions: BOLD SI changes reflect changes of local brain pO_2 values. R2* changes in the brain correlate with local brain pO_2 values. Therefore R2* provides information about fetal brain tissue oxygenation, which is important for fetal surveillance.

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References:

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