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Simultaneous Measurement of Local Cortical Blood Flow and Tissue Oxygen Saturation by Near infra-red Laser Doppler Flowmetry and Remission Spectroscopy in the Pig Brain

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Summary

In the current study we evaluated the combined use of Near-infrared Laser-Doppler flowmetry (NiLDF) and Remission Spectroscopy (RS) for measurement of regional perfusion and oxygen saturation of the cerebral cortex. An epidural probe for combined measurements of NiLDF and RS was placed above the parietal or frontal cortex of nine anesthetized juvenile pigs. Cerebral perfusion pressure (CPP) was stepwise decreased by intracisternal infusion of artificial CSF at clamped arterial blood pressure (baseline, CPP50, CPP40, CPP30mmHg, ischemia). Subsequent reperfusion was followed for 3h. Regional cerebral blood flow (rCBF) was measured with colored microspheres (CMS) and compared with corresponding NiLDF values during CMS injection. Cerebral venous oxygen saturation was measured in blood samples withdrawn from the sagittal sinus and compared with simultaneous recordings of tissue oxygenation during blood withdrawal.

Linear regression analysis resulted in a significant correlation ($p<0.001$) for changes in regional perfusion during CPP decrease and reperfusion, as measured with CMS and NiLDF ($r=0.92$, $n=39$). A significant correlation was also found for tissue oxygen saturation - as measured with RS - and cerebral venous oxygen saturation ($p<0.001$, $r=0.85$, $n=67$). Although the problem of spatial variability remains to be solved, the combined use of NiLDF and RS allows continuous and non-invasive monitoring of changes of key parameters of oxygen metabolism within the cerebral cortex.

Keywords

Cerebral blood flow, tissue oxygenation, Laser-Doppler flowmetry, colored microspheres.

Introduction

The prevention and treatment of secondary insults after traumatic brain injury require an extensive neuromonitoring including measurement of CBF and tissue oxygenation[1]. Laser-Doppler flowmetry (LDF) - alone or combined with other monitoring devices, e.g. ICP, tran-

scranial doppler - has been used to monitor changes of CBF in neurosurgery and neurointensive care [2 3].

Tissue oxygen spectrometry and LDF have been used to study the relationship between CBF and concentration of reduced hemoglobin during functional activation in the cat cortex [4]. Until now both methods have not been evaluated to measure simultaneously changes of local perfusion and oxygen saturation within a similar tissue volume during CPP changes . Therefore, in the current study we evaluated the combined use of NiLDF and RS for measurement of regional perfusion and oxygen saturation of the cerebral cortex during gradual CPP decrease.

Materials and Methods

Nine female pigs (6-8 weeks old, 17 ± 2 kg) were anesthetized i.v. α - chloralose. All pigs were paralyzed with pancuronium bromide (0.2 mg kg^{-1} h^{-1}), and were mechanically ventilated. Arterial catheters were inserted through the left and right saphenous artery (PU, 1.4 mm o.d.) for blood pressure monitoring and withdrawal of arterial blood samples. A catheter was inserted into the left atrium for injection of colored microspheres (CMS) and a cuff was placed around the trunk of the pulmonary artery for arterial blood pressure control. Trepanations were made for insertion of a sagittal sinus catheter (2.5 Ch, PU; advanced to the confluens sinuum) and placement of an epidural multiple glass fiber probe above the left frontal or parietal cortex. The probe was connected with a 4-channel NiLDF Monitor and a remission spectrometer (Optoflow®, AbTisSpek®, LEA Medizintechnik, Giessen, Germany). For ICP measurement a fiberoptic catheter (Camino) was placed within the left parietal cortex. All probes were fixed with skull screws and dental acrylic.

Experimental protocol: After recovery from surgery and measurement of baseline values the MABP was clamped at about 80mmHg and CPP was stepwise decreased to 50, 40 and 30 mmHg, and zero (ischemia) (15 min each stage) by intracisternal infusion of artificial CSF.

Subsequently, reperfusion was followed for 180 minutes. For measurement of regional CBF (rCBF) CMS (2-3 x 10^6) were injected at baseline and CPP50, CPP40, CPP30 and at 120 min of reperfusion. After injection of CMS arterial and sagittal sinus blood samples for measurement of oxygen saturation, blood hemoglobin and blood gases were drawn. At the end of the experiment the animals were killed and the brain tissue samples were processed for CMS counting and calculation of rCBF as described elsewhere [5].

Changes of physiological parameters between experimental stages were compared using the one way repeated measures ANOVA. Dunn`s method was used for pairwise multiple comparison of single stages with baseline values. The correlation of CBF measurements and oxygen saturation measurements was tested by linear regression analysis and calculation of the Spearman correlation coefficient and the coefficient of determination.

Results

Physiologic variables of all animals are summarized in table 1. Fig 1 summarizes all CBF measurements obtained with CMS and NiLDF. The correlation coefficient of CBF_{CMS} and CBF_{NiLDF} measurements was best with a fiber separation (illuminating – detecting fiber) of 4 mm (fig. 1a; $r=0.75$; $p<0.001$). Moreover, when regional CBF_{CMS} and local CBF_{NiLDF} values were normalized (baseline = 100%), the correlation coefficient increased to $r=0.92$ (fig.1b). As shown in fig. 2 there was also a significant correlation of local tissue oxygen saturation as measured with RS - and oxygen saturation of mixed cerebral venous blood ($p<0.001$).

Discussion

In the current study the use of NiLDF and RS was evaluated for continuous measurement of regional CBF and tissue oxygenation . The correlation coefficient which was obtained in our study is comparable with values reported from other investigators [6] [7]. Although the Oto-flow®-system allows a considerable larger fiber separation when compared with other LDF monitors, measurement of absolute blood flow values seems not possible. This may be due to

the spatial variability of blood flow measurements using single fibers [8, 9]. Moreover, local tissue oxygenation was significantly correlated with cerebral venous oxygen saturation.

In summary, we have shown that the combined use of NiLDF and RS allows continuous optical monitoring of key parameters of oxygen metabolism within the cerebral cortex under clinically relevant conditions. The combined use of both methods may be an adjunct to more global or intermittent measurements of CBF and cerebral oxygen metabolism.

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