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Research Article

In Vivo MRI versus NIRS data propose the latter as most suitable Methodology to Monitoring Cocaine Influence upon Brain Oxygenation

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Abstract:

In a recent work, comparison of the effects of cocaine treatment upon Near Infrared Spectroscopy (NIRS) as well as Magnetic Resonance Imaging (MRI) parameters were monitored in vivo in rat brain. Data gathered proposed correspondence of evaluation between the two methodologies when monitoring cerebral blood volume.

Haemoglobin (HbO2) and deoxy-haemoglobin (HHb) can also be directly monitored and here they have been evaluated and NIRS versus MRI results compared in function of central blood oxygenation.

Keywords: magnetic resonance imaging; and near infrared spectroscopy; rat brain; haemoglobin; deoxy-haemoglobin

Introduction

Magnetic Resonance Imaging (MRI) and Near Infrared Spectroscopy (NIRS) are in vivo non-invasive methodologies largely applied in CNS research.

In a recent work, comparison of the effects of cocaine treatment upon NIRS as well as MRI parameters were monitored in vivo in rat brain (Crespi et al. 2018a). In particular, relative cerebral blood volume (rCBV) in MRI analysis and the sum of haemoglobin (HbO2) + deoxy-haemoglobin (HHb) that is considered equivalent to blood volume i.e. HbT in NIRS investigation Rovati et al. 2003; Chia-Wei Sun, Ching-Cheng Chuang 2012) were evaluated.

Data gathered proposed correspondence of evaluation between the two methodologies with some discrepancy within the time course of the cocaine effect upon blood volume (Crespi et al. 2018a and see figure 3).

Since the absorption spectra of near-infrared light differ for the oxygenating-deoxygenating states of haemoglobin i.e. HbO2 and HHb, these two compounds can be directly monitored (Jobsis 1977; Crespi et al. 2005; Obrig 2014). Therefore, here they have been evaluated and NIRS versus MRI results compared in function of central blood oxygenation.

Methods

Materials and methods have been extensively described in a previous work (Crespi. 2007; Crespi et al. 2018a), briefly:

Two groups (n=6 each) of adult male rats (230-250 g) have been anaesthetised following the animal preparation requested either for MRI studies (Marota et al. 2000; Schwarz et al. 2004) as well as for NIRS analysis (Crespi et al. 2018a).

Following a 5 min period of control/control measurements, "NIRS and MRI rats" received saline vehicle (NaCl 0.9% 1.4 ml i.v. in the femoral vein at a rate of 1 ml/min) and approximately 10 min later recordings were stopped. Then a second control/control period of 5 min was performed before the injection of cocaine (0.5 mg/kg) and measurements continued approximately other 10 min. The dose of cocaine used here has been established as providing a widespread central rCBV response (Marota et al. 2000; Mandeville et al. 2001).

The time of recordings i.e. 10min following saline and cocaine treatment was determined based upon the evidence of maximum effect upon rCBV and HbT occurring between 3 and 8min post treatment (Schwarz et al. 2004; Crespi et al. 2018a and see figure3).

Results

Table 1 shows the raw MRI and NIRS data expressed in micromole/L obtained in the associated two groups of animals i.e. receiving saline (control group) or cocaine treatment. In particular the data are mean concentration in the time interval 3 to 8 min after injection of saline or cocaine. They are compared to the related measurements performed during the 5 min control/control period, which are considered as zero micromole/L. In particular HbO2 data are presented for the saline group of animals while HbO2 and HHb values are shown for the cocaine group of rats.

SALINE	HbO2	
RAT	MRI	NIRS
R1	0,014988	0,332
R2	-0,02264	-0,153
R3	0,011694	0,863
R4	0,035937	-0,577
R5	0,018212	-0,763
R6	-0,00443	0,735

COCAINE	HbO2	
RAT	MRI	NIRS
R1	-0,00846	2,486
R2	0,015487	1,270
R3	0,05222	1,762
R4	0,095576	2,248
R5	0,067933	3,058
R6	0,004291	2,960

COCAINE	HHb	
RAT	MRI	NIRS
R1	-0,00846	-2,819
R2	0,015487	-2,374
R3	0,05222	-2,644
R4	0,095576	-2,502
R5	0,067933	-3,038
R6	0,004291	-0,524

The resultant figure 1 shows:

TOP: influence of saline treatment upon MRI and NIRS measurements of HbO2 levels,

MIDDLE: influence of cocaine treatment upon MRI and NIRS measurements of HbO2 levels,

BOTTOM: influence of cocaine treatment upon MRI and NIRS measurements of HHb levels.

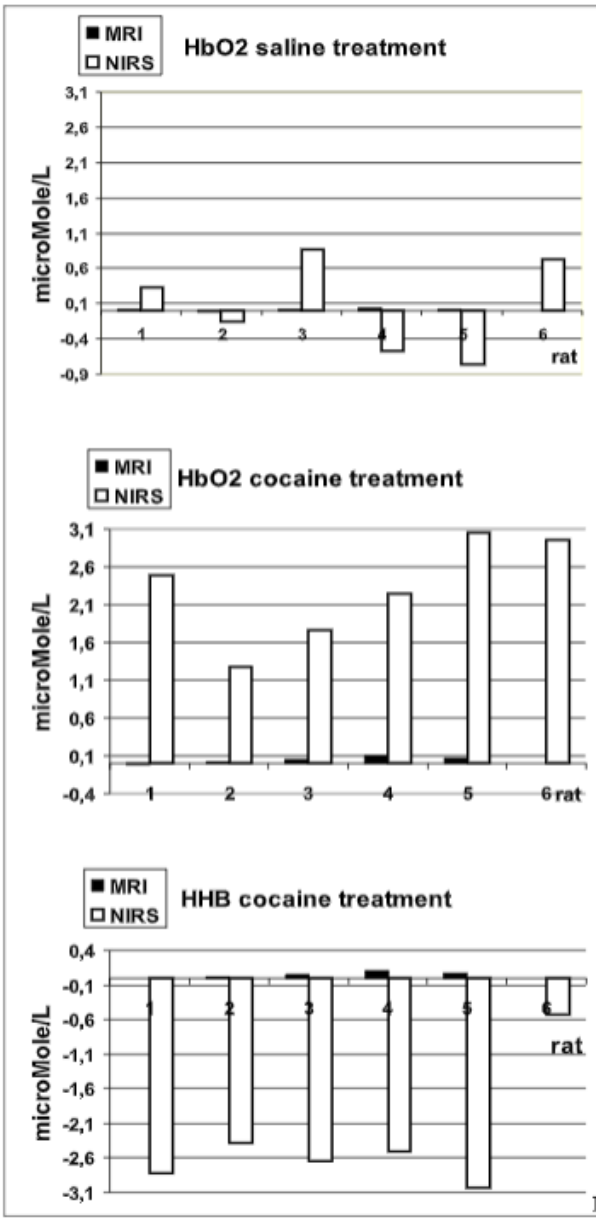


Figure 2 shows the influence of saline (vehicle) or the influence of cocaine treatment upon NIRS measurements of HbO2. Data are presented as micromole/L and compared to the measurements performed during the 5 min control/control period, measurements considered as zero micromole/L.

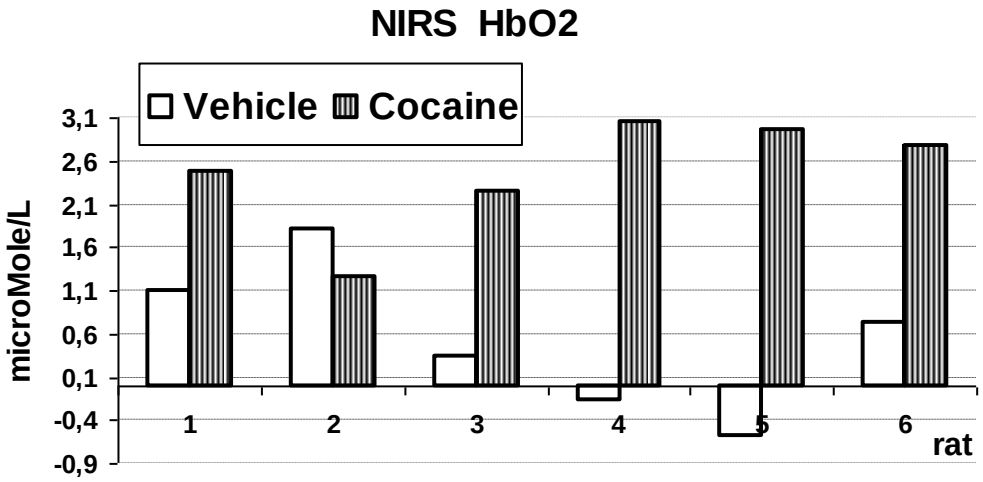
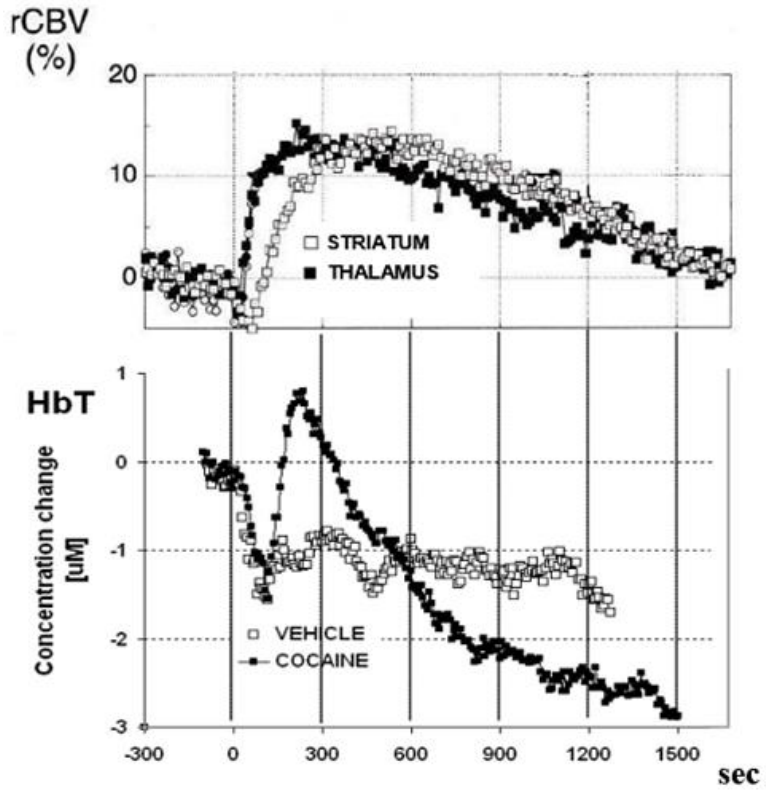


Figure 3: Typical Time-Course of response of MRI rCBV (top) or NIRS HbT (bottom) after 0.5 mg/kg cocaine infusion performed at time 0 min and relative to a 5 min baseline obtained immediately before cocaine infusion and considered as zero micromoles/L (from ref. Crespi F, et al. 2018a with permission).



Discussion

Oxygen is essential to sustaining normal brain functions and adequate deliver of oxygen must be maintained to attain the high rate of oxygen consumption by the brain (Masamoto et al., 2007).

Furthermore, the efficacy of non-invasive NIRS has been supported within either physiologic (i.e. via oral insufflations of exogenous oxygen (O2) or carbon dioxide (CO2) or pharmacologic (i.e. via administration of drugs of abuse) preclinical studies (Crespi et al. 2006, Crespi 2013).

This further support the concept of "pharmacological NIRS" (phNIRS) (Crespi 2007; Crespi 2025) as indeed the effect of cocaine treatment on NIRS parameters is equivalent in different conditions.

And together with the feasibility to overcome the major limitation of actual in vivo methodologies i.e. invasiveness, NIRS is proven suitable for translational medicine applications (Crespi 2021a) such as the feasibility of monitoring the influence of alcohol as well as smoking in man (Crespi et al., 2018b; Crespi, 2021b).

Again, the soundness of such methodology has been further confirmed in Near infrared spectroscopy (NIRS) is becoming a widely used research instrument that supply a non-invasive, non-ionizing way to measure

haemoglobin levels and oxygen saturation in the living tissue (Crespi et al. 2006; Crespi 2021a).

parallel experiments using NIRS and MRI (REF). In particular, and as also reminded here in figure 3,

The increase of the MRI and NIRS data following cocaine infusion were comparable within the same period of time, i.e. within the first 5min post treatment.

This however is the only parameter with comparable MRI and NIRS values as indeed HbO2 as well as HHb levels change significantly only under NIRS measurements with an evident opposite effect following cocaine injection. In contrast no evident changes are monitored via MRI analysis performed as described earlier (Schwarz et al. 2004). This may indicate that while MRI rCBV and NIRS HbT are influenced in a similar manner by cocaine, only NIRS can detect the cocaine influence upon HBO2 and HHb, significantly. Consequently, it can be assumed that MRI and NIRS are complementary within detection of relative cerebral blood volume aand in addition that NIRS is more efficient on the detection of variation of cerebral HbO2, therefore in the evaluation of brain oxygenation and consequently of brain metabolis

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