

# Near-Infrared Spectroscopy (NIRS): Validation and Technical Aspects in Documentation of Brain Death

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## Abstract

Declaration of brain death follows a certain set of examinations. Most common confirmatory tests are the EEG, transcranial Doppler sonography or cerebral angiography. This case report describes special dynamic features of near infrared spectroscopic (NIRS) parameters in a 46-year-old intensive care patient after severe head injury.

## INTRODUCTION

Brain death is declared when brainstem reflexes, motor responses, and respiratory drive are absent in a normothermic, nondrugged comatose patient with a known irreversible massive brain lesion and no contributing metabolic derangements [1,2].

There is fairly uniform agreement regarding the criteria for the clinical evaluation of brain death, although there is considerable variation in the use of additional physiologic tests. In Europe 11 of 25 guidelines require a confirmatory test for the diagnosis [1].

Due to its noninvasive nature and the portability of the equipment, near-infrared spectroscopy (NIRS) has gained widespread recognition as a technique for monitoring oxygenation of brain tissue in infants and adults [3]. In the present case report we describe special dynamic features of NIRS-parameters in a 46-year-old intensive care patient after severe head injury.

## MATERIALS AND METHODS

### SUBJECT

One patient (46 years, male) from the intensive care unit after severe head injury was investigated in the preterminal phase using different neuromonitoring equipment (NIRS, ultrasound Doppler sonography) [4].

### NEAR-INFRARED SPECTROSCOPY (NIRS)

One of the most important NIRS-device from the clinical point of view was first described in 1977 by F.F. Jöbsis in the U.S. [5]. Ten years passed since a near infrared

oxygenation monitor (NIRO monitor) was launched in Japan. Since then, a number of improvements in NIRO monitors were implemented.

The system we used contains 4 laser diodes for measuring wavelengths of 775, 825, 850 and 904 nm. With a temporal resolution of 0.5 sec the near infrared spectroscope (NIRO 300; Hamamatsu Photonics, Hamamatsu, Japan) reflects cerebral changes in oxygenated ( $[O_2Hb]$ ) and deoxygenated hemoglobin ( $[HHb]$ ), total hemoglobin ( $[cHb = [O_2Hb + [HHb]$ ) and oxidated cytochrome c oxidase aa3 ( $[CtOx]$  in  $\mu\text{mol}$ , calculated with Lambert-Beer's Principle [3].

In order to measure tissue oxygenation index (TOI =  $O_2Hb/cHb$ ) values, a special probe has been developed. An emission probe made of fiber optics irradiates laser beams, and a detection probe which is placed several centimeters from the emission probe detects faint light that has passed through tissues. The detection probe has a light sensor (photodiode) consisting of three small sensors. The TOI values are calculated from the slope of light attenuation along the distance from the emitting point [6].

### TRANSCRANIAL DOPPLER SONOGRAPHY

Cerebral blood flow profiles were measured using a Multi-Dop T device (DWL Electronic Systems, USA). A bilateral and multidirectional TCD monitoring arrangement to simultaneously and continuously monitor blood flow velocities in different extra- and intracranial arteries has been developed [7].

## RESULTS

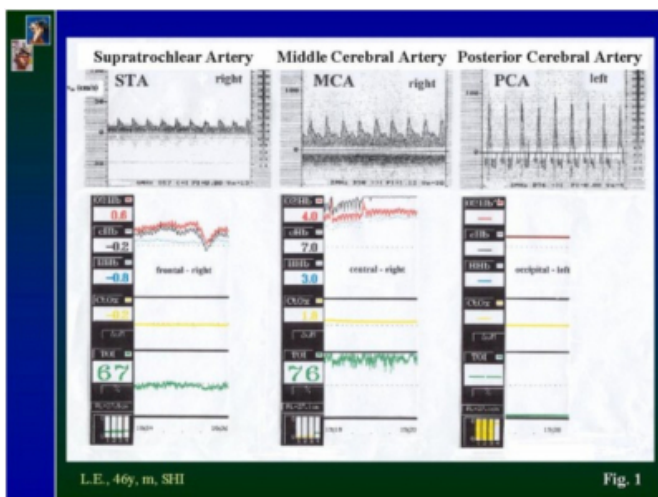
## CASE REPORT

After severe head injury and admission to the intensive care unit, the clinical status deteriorated and the patient developed the clinical criteria of brain death. The patient showed complete areflexia of the cranial nerves and no signs of integrated spinal motor function. Clinical EEG was diagnosed as isoelectric and no components of brainstem auditory evoked potentials could be recorded.

TCD showed residual perfusion in the right and left middle cerebral arteries. In addition residual blood flow profiles in the right supratrochlear artery were found. However, in the left posterior cerebral artery a systolic spike pattern was observed (compare Fig. 1 and [4]).

### Figure 1

Figure 1: Transcranial Doppler sonographic recordings in different arteries (upper panel) and corresponding results of near-infrared spectroscopy (NIRS) of the frontal, central and occipital region in a 46-year-old comatose male.

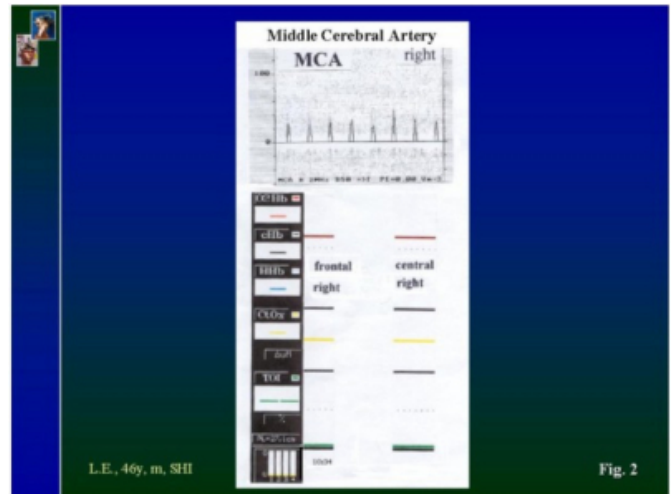


Using locations for the optodes over the frontal and vertex region with an optode distance of 3 cm, clear signals for the NIRS parameters could be detected. The TOI was calculated with 67 % over the frontal region and 76 % over the vertex region. However, no signals were recordable over the occipital region.

After 3 days the TCD-profiles in the MCA showed systolic spikes and at the same time the measurement criteria for the NIRS measurement over the frontal and central region could not be fulfilled (see Fig. 2).

### Figure 2

Figure 2: From top to bottom: TCD recording in the right middle cerebral artery (MCA) showing a systolic spike pattern; over the frontal and central region no NIRS parameters could be observed.



## DISCUSSION

Metabolic changes accompanying brain death have not been studied extensively. Pevsner et al. [8] were one of the first to indicate that cerebral metabolism decreases in brain death and suggested that this could be a reliable prognostic finding.

The diagnosis of brain death is essentially clinical, while all the investigative techniques mainly have the role of ancillary tests, being capable of giving an “objective” confirmation of death.

The National Library of Medicine's search service (PUBMED) was used to identify published articles addressing near infrared spectroscopy and brain death. The majority of the authors of this articles showed that it is very difficult at the moment to monitor patients with increased intracranial pressure using near infrared spectroscopy [9,10,11,12].

Kytta et al. [12] for example stated that the diagnosis of brain death cannot be made based on the NIRS technology. The presence of extracranial contribution may limit its potential value even in other applications [12]. Although NIRS could be useful in the management of severe head injury, high regional cerebral oxygen saturation or regional cerebral tissue oxygen values should be interpreted with great caution because they cannot show at the moment the intracranial heterogeneity of arterial and venous oxygen saturation.

Further, large studies are required to confirm and validate the findings and to clarify the time-course in the development of brain death and changes of near-infrared spectroscopic parameters due to changes in cerebral metabolism.

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