Near-Infrared Spectroscopy (NIRS) or Cerebral Oximetry

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Recommendations

Level I

There are insufficient data to support a Level I recommendation for this topic.

Level II

There are insufficient data to support a Level II recommendation for this topic.

Level III

NIRS can be used to detect upcoming intra- and extracerebral haematomas.

46.1 Overview

Near-infrared spectroscopy (NIRS) measures the oxygenation of the haemoglobin in the cerebral tissue lying just underneath a probe. The probe is most often placed on the forehead, since hair follicles affect the readings. Some doubts have been raised whether NIRS specifically measures the cerebral tissue or is contaminated by signals from extracerebral tissues. Furthermore, as haemoglobin absorbs infrared light, NIRS is affected by underlying blood of extravascular origin, such as in subdural haematomas, contusions, subarachnoid blood, as well as changes in intravascular cerebral blood volume (CBV). These factors are difficult to decipher, and at present, the use of NIRS in TBI patients is controversial. However, by using more than one sensor and by focusing on trends, NIRS readings might be of value in this patient group.

Tips, Tricks and Pitfalls

- NIRS probes can be placed over hair follicles, but the melatonin in the hair affects the absorption of infrared light.
- NIRS from one single probe is too difficult to interpret.
- In patients with unilateral brain pathologies, a symmetrically placed contralateral probe should be used as reference.
- Never use the NIRS reading as the only monitoring device; changes in a NIRS reading should be controlled with other techniques.
- Keep in mind that patients with total brain infarctions can still have a normal NIRS value.

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T. Sundstrøm et al. (eds.), *Management of Severe Traumatic Brain Injury*,
https://doi.org/10.1007/978-3-030-39383-0_46

46.2 Background

Oximetry is a method for monitoring the oxygenation of haemoglobin. With near-infrared spectroscopy (NIRS) it is possible to measure oxygen saturation (SO_2). Jobsis (1977) was the first to report on this, and in 1985 came the first report on cerebral oximetry in humans (Ferrari et al. 1985). A proportion of the near-infrared light passing through tissues is absorbed. The absorption of light relates to the amount and properties of the material through which the light is passing based on the Beer–Lambert law. Tissues such as skin, bone and brain are transparent to the near-infrared spectrum, whereas the two chromophores oxy- and deoxyhaemoglobin are not. Since the absorption characteristics of oxy- and deoxy-haemoglobin are different at different wavelengths, it is possible to quantify the cerebral oxygenation of the blood with its venous/arterial relationship of 70%/30%, by choosing two or more wavelengths where the absorption of oxy- and deoxyhaemoglobin is maximally and minimally separated, i.e. between 700 and 850 nm (wavelength - nanometers).

At 810 nm, the absorption of NIR is equal for oxy- and deoxyhaemoglobin, and hence it is theoretically possible to measure the total amount of haemoglobin at this wavelength. With knowledge of the amount of haemoglobin, it is possible to calculate the CBV continuously when knowing the haemoglobin concentration. However, so far this technique is too unstable to be used in clinical practice (Canova et al. 2011).

An infrared beam penetrating into a tissue scatters in such a way that some of it is reflected back to the surface from where it is emitted. To this end, most apparatuses use reflectance-mode NIRS in which the optical sensors are placed ipsilateral to the transmitter; they exploit the fact that photons transmitted through a sphere will traverse an elliptical path in which the mean depth of penetration is proportional to the separation of the transmitter and the optical sensor.

Though small, some absorption does occur both in normal cerebral and extracerebral tissues. Extracerebral tissue is not a homogenous layer, but a composite of all the layers of the scalp, bone and dura. Each of these layers with individual optical absorption characteristics may affect the results in a non-foreseeable manner. Especially melatonin, in hair and hair follicles, absorbs near-infrared light to a high degree. The effect on the oximeter reading from these extracerebral layers is hence poorly understood (Young et al. 2000), and in adults, the infrared beam has to pass a thick layer of extracranial tissue twice. In order to minimize the influence of the extracerebral tissue and extracerebral circulation, different algorithms have been applied, and a number of techniques have been developed, but still without complete success (Al-Rawi and Kirkpatrick 2006).

46.2.1 Normal Values of NIRS

The normal value for cerebral oximetry or cerebral regional oxygen saturation (rSO_2) is 58–82% (Kim et al. 2000). The wide normal range makes it more optimal to follow the trend in the particular patient rather than absolute values, and compare with contralateral measurements.

46.2.2 Factors Affecting NIRS

An oximeter reading using NIRS is highly influenced by the venous blood since 70% of the normal cerebral blood volume (CBV) is of venous origin. A venous saturation is giving an indication of the relationship between cerebral blood flow (CBF) and cerebral metabolism (CMR). The change in cerebral venous oxygenation is described in detail in Sects. 43.2.4 and 43.2.5. An increased ICP will compromise CBF, thereby lowering NIRS. But with a normal venous outflow, an increased ICP will compress the thin-walled veins reducing the venous part of the CBV. As a result, the NIRS reading should theo-

retically increase as it would be more influenced by the arterial side. In fact Zuluaga et al. (2010) found NIRS during increased ICP to generally decline, but dispersed to both higher and lower values.

46.2.3 TBI and Pathologic Brain

A major problem with NIRS is the diverse influence of underlying brain pathologies. In dead or non-metabolizing tissue, the NIRS can show either high or low values (Dunham et al. 2002), depending on the status of the sequestered blood. Extravasated blood can contain a varying degree of oxyhaemoglobin, whereas in cerebral contusions, the non-metabolizing tissue does not affect the oxyhaemoglobin content even though the flow through such a region is low (see Fig. 46.1). In fact, NIRS has been used to detect the development of intra- and extracerebral haematomas using a wavelength of 760 nm, at which the absorption is increased at the haematoma side compared to the normal side (Gopinath et al. 1995), resulting in an increased NIRS reading at the haematoma side. In TBI the different underlying pathologies, haemoglobin level, manipulation with CMR and CBF and differences in ICP are factors that make a NIRS reading difficult to interpret and therefore problematic to use in TBI patients (Weigl et al. 2016).

46.2.4 CBF Measurements with NIRS

By using a contrast medium and looking at its passage and amount, it is possible to calculate the mean transit time (MTT) and CBV and thereby calculate the local CBF under the probe. Indocyanine green is an ideal contrast medium in conjunction with NIRS, as it has an absorption peak at 805 nm. However, a correlation to CBF has been found in some (Kuebler et al. 1998; Keller et al. 2003), but not all studies (Newton et al. 1997), and the method is not widely used.

46.3 Specific Paediatric Concerns

In healthy children, the normal range for cerebral oximetry is 60–80% (95% confidence interval, average is 68%). There are no studies investigating NIRS and TBI in children.

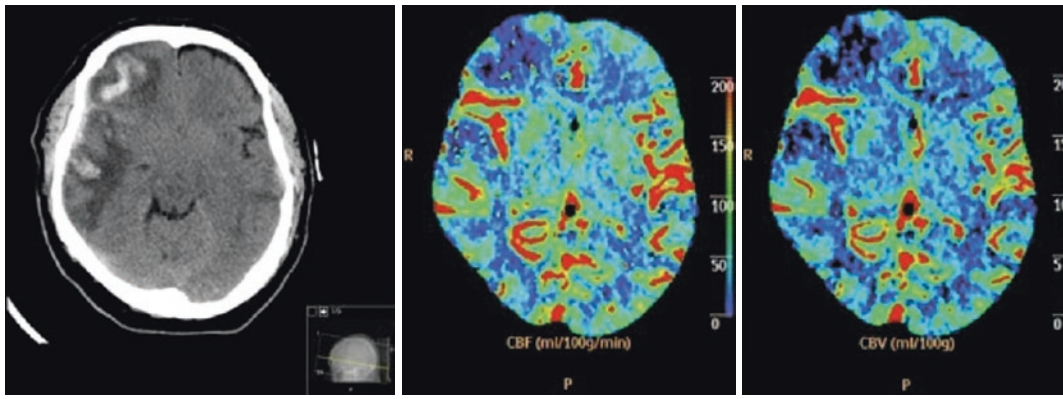

Fig. 46.1 A CT scan showing contusions in the right frontal and temporal regions (*left picture*). CBF (*middle picture*) and CBV (*right picture*) were measured simultaneously with CT perfusion. Cerebral oximetry probes were placed in a symmetrical manner bifrontally where the right sensor was placed over the frontal contusion (*left picture*). The reading was 94% over the contusion and 71% over the left side. The local CBF was low in the contused area (*middle picture*) as was the CBV (*right picture*). The reason for the high saturation in the contusion is most probably due to the extravasated blood, but can also be influenced by the non-metabolizing tissue in the contusioned area, even though both CBF and CBV were low

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