Topic Expert Group: **Medical care and clinical practice**

Neurological monitoring in the high-risk infant: Near-infrared spectroscopy (NIRS)

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Target group

- Term and preterm infants at risk for brain injury:
  - Infants with hypoxic-ischaemic encephalopathy (HIE)
  - Infants with peri-intraventricular haemorrhage (PIVH)
  - Infants with encephalopathy for other causes (e.g. metabolic)
  - Infants with suspected or verified seizures
  - Infants requiring intensive care and/or surgery
  - Infants with suspected/confirmed congenital central nervous system (CNS) anomalies
- Parents

User group

Healthcare professionals, neonatal units, hospitals, and health services

Statement of standard

In order to improve evaluation and outcomes of newborn infants at risk of brain injury, management includes neurological monitoring using a structured, age-appropriate neurological assessment and a range of devices to evaluate brain haemodynamics, oxygen transport, brain function, and imaging, as required.

Rationale

Infants requiring neonatal intensive care constitute a high-risk population for developing brain injury, particularly full term and preterm infants exposed to hypoxia-ischaemia, CNS infections, or with congenital anomalies.

In the first hours after birth, there is imbalance between blood flow and oxygen supply to the brain due to haemodynamic adaptation during transitional circulation, particularly in the very preterm infant. (1) Low and fluctuating cerebral blood flow are associated with adverse outcomes. (2,3) Experimental models and observational studies confirm that both hyper- and hypoxaemia may cause irreversible brain injury. (4–6) The vulnerability of this population, the severity of underlying clinical conditions, and the complexity of care make continuous, cot-side, and non-invasive monitoring tools valuable. Near-infrared spectroscopy (NIRS) derived regional tissue oxygen saturation of haemoglobin ($rStO_2$) is an absolute value, which corresponds to mixed blood saturation, used in the clinical setting as a surrogate measure for venous oxygen saturation (SvO_2). (7) Indirect assessment of cerebral blood flow has been shown to correlate with $rStO_2$. (8) This non-invasive, continuous monitoring system may help to adjust interventions that have effects on blood and oxygen supply to the brain. (9) Bilateral brain monitoring may detect differential perfusion between hemispheres. Yet, sound evidence supporting routine use of NIRS monitoring is still lacking.

Benefits

Short-term benefits

- Reduced burden of cerebral hypo- and hyperoxia in preterm infants in the first 72 h after birth (10,11)
- Early detection of infants at risk of peri-intraventricular haemorrhage (PIVH) (12–14)
- Support in decision-making in post-haemorrhagic ventricular dilatation (PHVD) (15,16)
- Improved neuroprotection after asphyxia using combined NIRS and MRI measurements of brain perfusion (15)
- Improved maintenance of theoretically safe cerebral oxygenation levels in infants with congenital heart defects (16)

Long-term benefits

- Reduced all-cause mortality in extremely preterm infants (10)
- Improved long-term outcomes in extremely preterm infants (17)

Components of the standard

Component	**Grading of evidence**	**Indicator of meeting the standard**
For parents and family		
1. Parents are informed by healthcare professionals about the role of near-infrared spectroscopy (NIRS) monitoring.	B (High quality)	Patient information sheet
For healthcare professionals		
2. A unit guideline on neurological monitoring including NIRS is adhered to by all healthcare professionals, to include • Newborn infants during resuscitation at birth (≤15 min) (11,18,19) • Extremely preterm infants in the first 72 h after birth (9,10,20) • Infants at risk of or with peri-intraventricular haemorrhage (PIVH) (12-14); infants who develop post-hemorrhagic ventricular dilatation (PHVD) (21,22) • Asphyxiated newborn infants undergoing therapeutic hypothermia (23–26) • Infants undergoing surgery with cardio-pulmonary bypass (16,27–29)	A (High quality) B (High quality)	Guideline
3. Training on NIRS monitoring is attended by all responsible healthcare professionals. (9,20,27,28,30)	A (High quality) B (High quality)	Training documentation

4.	Teams with a focus of interest on neuro-critical care, including neonatologists, neurologists, neuro-physiologists, nurses, radiologists, radiographers, and physicists are established.	B (High quality)	Guideline
For neonatal unit			
5.	A unit guideline on neurological monitoring including NIRS is available and regularly updated including standardised operational procedures. (7,9,20,30)	A (High quality) B (High quality)	Guideline
For hospital			
6.	Training on NIRS monitoring is ensured. (7,20,27,28,30)	A (High quality) B (High quality)	Training documentation
7.	Facilities for NIRS monitoring are provided.	B (High quality)	Audit report
8.	An interdisciplinary team for neuro-critical care of high-risk infants in the NICU is supported.	B (Moderate quality)	Audit report
For health service			
9.	High-risk infants are transferred to NICUs with appropriate neuro-monitoring systems and expertise. (31–33)	A (High quality)	Audit report, guideline

Where to go – further development of care

Further development	**Grading of evidence**
For parents and family	
N/A	
For healthcare professionals	
• Monitor perioperative near-infrared spectroscopy (NIRS) in infants with non-cardiac complex neonatal surgery. (34,35)	A (Low quality)
For neonatal unit	
N/A	
For hospital	
N/A	
For health service	
N/A	

Getting started

Initial steps

For parents and family

- Parents are verbally informed by healthcare professionals about the role of near-infrared spectroscopy (NIRS).

For healthcare professionals

- Attend training on NIRS monitoring.
- Identify leading healthcare professionals with a focus of interest on neonatal neurological monitoring.

For neonatal unit

- Develop and implement a unit guideline on neurological monitoring including NIRS.
- Develop parental information material about NIRS monitoring also including parent perspectives.
- Provide resources for specific training on NIRS monitoring.

For hospital

- Support healthcare professionals to participate in training on NIRS monitoring.

For health service

- Create systems to effectively transfer high-risk infants to NICUs with appropriate neuro-monitoring systems and expertise.

Description

The near-infrared spectroscopy (NIRS) sensor is placed at the forehead avoiding cavities, superior sagittal sinus, intra or extra-cranial huge blood collections, or vascular malformations, if known. Scalp oedema will also influence the quality of the NIRS signal. In the smallest newborn infants and those with poor perfusion states sensor position is rotated to avoid tissue injury related to compression or heat. (7,20)

Commercial NIRS devices incorporate similar technology but different wavelengths and computational algorithms translating changes in light absorption into $rStO_2$ absolute values. (7) Systematic approach has evidenced huge differences in $rStO_2$ according to device or probe (30,36), so that device-specific reference ranges or limits have to be used.

Neonatal resuscitation after birth: Clinical assessment of the newborn infant carries high inter-observer variability particularly when scoring preterm or term infants in need of resuscitation. (37) Oxygen saturation targeting and the use of supplemental oxygen during transition remain controversial topics. (38) The use of pulse oximetry or heart rate monitoring during resuscitation has not led to improvements on the short or long-term outcomes. (39) $rStO_2$ and fractional oxygen extraction reference ranges and percentile charts for the interpretation of cerebral oxygenation during immediate transition to avoid hypo- and hyperoxia of the brain during resuscitation appears promising. (11,18,19) Yet, routine interventions based on $rStO_2$ during resuscitation need development and evaluation.

Extremely low gestational age newborn infants: Recent studies have shown an association of cerebral $rStO_2$ levels and clinical outcomes. (40) Low $rStO_2$ on the first day of life associates surrogated measures of compromised systemic blood flow and risk of intraventricular haemorrhage. (12) Impaired cerebral blood flow autoregulation assessed by NIRS and arterial blood pressure monitoring associates abnormal systemic (and cerebral) blood flow distribution, death and severe brain injury. (41,42)

Cerebral oxygenation can be stabilised in the preterm infant during the first 72 hours from birth by the combined use of $rStO_2$-NIRS monitoring and a pathophysiological, brain oriented treatment guideline with no record of severe adverse events. (9,10) The quality of evidence supporting some of the listed statements in the intervention algorithm is generally low, however, are all routinely used in clinical care of these patients. (9) Although important early surrogate outcomes, such as aEEG at day 3 of postnatal life or neuroimaging, did not significantly differ between the study groups (43,44), post hoc analyses showed that early burden of cerebral hypoxia was significantly associated with low brain electrical activity and severity of intracranial haemorrhage. (19) So far, definitive evidence of benefit for improvement of long-term clinical outcomes is needed as the technology is not cheap, requires manipulation and additional staff time, and may have unwanted effects. (10)

*PIVH: C*orrelations between NIRS-derived data immediately after birth and during the transitional circulation and the development of PIVH have been reported. (12–14) Timing of neurosurgical intervention in PHVD could be critical for neurodevelopment (45), and may be guided by standardised ventricular measurements by cranial ultrasound combined with cerebral NIRS and cranial Doppler. (21,22) This approach provides a better understanding of the pathophysiology and the effect of interventions on the long-term outcomes.

HIE: Cerebral hypoperfusion during the first hours after birth is followed by hyperperfusion, even during treatment with moderate hypothermia. Potential differences according to the severity of brain injury (moderate vs severe) have been identified. (15,46) NIRS measurements of oxygenation and MRI measurements of brain perfusion show good correlation. (15) Among neonates with HIE, NIRS demonstrates evolving patterns of brain oxygenation that predict favourable and adverse outcomes both in non-cooled (46) and in those who undergo therapeutic hypothermia. (23,24) As yet, widespread recommendation of NIRS monitoring alone to guide important clinical decisions in asphyxiated newborn infants cannot be made. Used in combination with amplitude-integrated EEG increases the outcomes predictive capacity compared to either modality alone. (24–26)

Congenital heart disease (CHD): NIRS may be a useful adjunct particularly during cardiopulmonary bypass to optimise perfusion. NIRS-derived measures of systemic oxygen balance correlate with global circulatory measures and biochemical indicators of shock. (27) Algorithms have been developed to guide interventions based on $rStO_2$ values during the perioperative period. (28) However, the current literature on the use of NIRS alone does not demonstrate improvement in neurologic outcome. (29) Prospective data evaluating NIRS findings and relevant outcomes in this population is difficult to compare, because of the variable disease physiology, variable baseline values, and small sample sizes. These issues prevent extrapolation to wider CHD population.

Other complex surgical procedures conducted during the neonatal period, such as congenital diaphragmatic hernia or oesophageal atresia (34,35), might be additional scenarios where NIRS may guide surgeons and anaesthesiologists during the intervention procedures. A NIRS value out of normal range, or a huge change even within the normal range, may trigger the assessment of the patient's condition when used in combination with other monitoring tools.

Source

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