PEDIATRIC NEWBORN MEDICINE CLINICAL PRACTICE GUIDELINES

Clinical NIRS (Near Infra-Red Spectroscopy) in the NICU

Implementation Date: February 01, 2018

Clinical Practice Guideline: Clinical NIRS (Near Infra-Red Spectroscopy) in the NICU

Points of emphasis/Primary changes in practice:
1- To outline the indications of the clinical use of NIRS in the NICU.
2- To implement an algorithm for incorporating NIRS in the clinical care of neonates.
3- To standardize the process of ordering, applying and documenting NIRS data.

Rationale for change:
Near-infrared spectroscopy (NIRS) is a non-invasive technique which allows for continuous monitoring of tissue oxygen saturation 2-3 cm directly below its sensors e.g., in brain, or kidneys. Feasibility and benefit of continuous NIRS has been demonstrated in neonates with congenital heart disease (CHD), term infants with neonatal encephalopathy, as well as premature infants in the determination of cerebral oxygenation and cerebral autoregulation in the context of systemic hypotension, a hemodynamically significant PDA and blood transfusion management.
A recent clinical trial has shown that continuous monitoring of cerebral NIRS has led to decreased burden of cerebral hypoxia. In the same study, cerebral hypoxia was associated with low brain electrical activity and severe intracranial hemorrhage.

Questions? Please contact: Director of Neonatal Neurocritical Care, Department of Pediatric Newborn Medicine, BWH.

Clinical Guideline Name	Clinical NIRS (Near Infra-Red Spectroscopy) in the NICU
Effective Date	
Revised Date	
Contact Person	Director of Neonatal Neurocritical Care
Approved By	Pediatric Newborn Medicine Clinical Practice Council _12/14/17 CWN PPG _____ BWH SPP Steering _____ Nurse Executive Board/CNO_____
Keywords	NIRS- Cerebral oximetry - Neuromonitoring

This is a clinical practice guideline. While the guideline is useful in approaching the use of NIRS in the intensive care unit, clinical judgment and / or new evidence may favor an alternative plan of care, the rationale for which should be documented in the medical record.

I. Purpose

1- To outline the indications of the clinical use of NIRS in the NICU.
2- To implement an algorithm for incorporating NIRS in the clinical care of neonates.
3- To standardize the process of ordering, applying and documenting NIRS data

II. All CPGs will rely on the NICU Nursing Standards of Care.

III. Patient population

This protocol applies to neonates admitted to the BWH Neonatal Intensive Care Unit who are critically ill and at risk of neurologic compromise. This includes but is not limited to extremely premature infants, those with suspected hypoxic ischemic injury, or stroke, and infants at risk of cerebral injury from cardio-pulmonary risk factors.

IV. Background/Summary Information

NIRS Background

Near-infrared spectroscopy (NIRS) is used to measure tissue oxygen saturation 2-3 cm directly below its sensors e.g., in brain, kidney. Like a peripheral oxygen saturation monitor, NIRS uses the relative transparency of biological tissue to near-infrared light and the wavelength dependent absorption characteristics of hemoglobin, which vary with oxygenation.

By monitoring the intensity of light passing through the brain at two wavelengths, changes in attenuation can be converted into changes in the cerebral concentrations of oxyhemoglobin (HbO2) and deoxyhemoglobin (Hb). These two measures provide a regional oxygen saturation measurement (rSO2) [rSO2%=HbO2/(HbO2+Hb)*100, essentially a mixed tissue saturation, which is approximately 70% venous and 30% arterial. When NIRS is used on the scalp, cerebral regional oxygen saturation (CrSO2) measurement can be established.

Feasibility and benefit of continuous NIRS have been demonstrated in neonates with congenital heart disease (CHD), term infants with neonatal encephalopathy, as well as premature infants in the determination of cerebral oxygenation and cerebral autoregulation in the context of systemic hypotension, a hemodynamically significant PDA and blood transfusion management.

Factors that affect NIRS measurement:

1- **Sensor type:** Normal CrSO2 ranges from 55% to 85% when adult sensors were used (most of available clinical studies). When compared to the newer neonatal sensor, the neonatal sensor measured 10% higher than the adult sensor. [1]

2- **Sensor position**: Although the right to left difference in CrSO2 is small, when used at 4 different sites a difference of up to ±18% was detected. This variability signifies the importance of using CrSO2 as a trend rather than an absolute number. [2]

3- **Gestational age:** CrSO2 in the first day of life is increased in very premature infants when compared to term infants. [3, 4].
However, in contrast, looking specifically within preterm infants < 32 weeks , a positive correlation was noted between GA and CrSO2 measured during the first 3 days of life (1% per week GA) [5].

4- **Time after birth:** Immediately after birth CrSO2 is low and rapidly increases from an average of 44% at 3 min to an average of 76% at 7 minutes of life, after which CrSO2 remains stable. [6]. Alderliesten et al., described an increase in CrSO2 followed by a decrease, creating a parabolic curve with a peak at about 36 h of life. [5] With weekly measurement in premature infants it was noted that CrSO2 decreases, reaching the lowest level at six to eight weeks. [7]

5- **Head position:** Brief changes in head position do not cause significant changes in CrSO2. [8]

6- **Day to day interventions:** ETT suctioning, handling and diaper change can cause significant fluctuation in CrSO2. [9]

Pathological conditions affecting CrSO2 in Preterm Neonates

Factors associated with decreased CrSO2

1- **Hypocarbia**

Hypocarbia is associated with cerebral vasoconstriction and periventricular leukomalacia, perhaps secondary to cerebral ischemia and.[10-13] Acute decrease in end-tidal CO2 was associated with decreased CrSO2. [14]

2- **Anemia**

The hemoglobin concentration correlates with CrSO2 [15, 16]. PRBCs transfusion is associated with increased CrSO2 in anemic premature neonates. [15, 17] Improvement in CrSO2 and symptoms of desaturation spells was more significant in preterm infants with a pre-transfusion CrSO2 < 55% [18].

3- **Hypotension with lack of autoregulation**

The finding of a positive correlation between cerebral oxygenation and arterial pressure has been used as a marker of cerebrovascular pressure passivity with is common in sick premature infants and is associated with intracranial hemorrhage. [19-23] A decrease of absolute mean blood pressure is not always associated with lower CrSO2 and is not necessarily associated with worse neurodevelopmental outcome. However CrSO2 < 50% is associated with worse neurodevelopmental outcome. [24] Whether CrSO2 can be used as a marker to treat low blood pressure needs to be studied. However, when used, it must be combined with other parameters to fully evaluate the significance of the low BP, e.g., blood lactate, capillary refill, urine output, and cardiac output. [25]

4- **Thoracic Hyperinflation**

Since mechanical ventilation can alter intrathoracic pressure, affect venous return and thereby cardiac output, it can have significant effect on the cerebral circulation. [26, 27] NIRS has a potential to detect the affects of mechanical respiratory support on the cerebral circulation. [28-30]

5- **PDA**

Although studies have shown that hemodynamically significant PDA is associated with decreased CrSO2 [31, 32], reports regarding the effect of either medical or surgical treatments of PDA on CrSO2 have been inconsistent. [33-35]

6- **Apnea**

CrSO2 decreased significantly during apneic spells associated with bradycardia compared to spells with no bradycardia. [36]

7- **Germinal Matrix-Intraventricular Hemorrhage GM-IVH**

Multiple studies have reported increased CrSO2 in the first hours of life in premature infants who later developed GM-IVH [37-39]. However, patients already identified with IVH are noted to have lower CrSO2. [40-42]

8- **Hydrocephalus**

In preterm infants with post-hemorrhagic ventricular dilatation (PHVD), ventricular decompression was associated with an increase in CrSO2. [43, 44]

Factors associated with increased CrSO2

1- **Hypercarbia**

An acute increase in end-tidal CO2 in premature infants was associated with increased CrSO2. [14] Hypercarbia is associated with cerebral vasodilatation and with the development of germinal-matrix/ intraventricular hemorrhage [45, 46].

2- **Hyperoxia**

CrSO2 correlates with systemic O2 saturation (SaO_2). Because of concern for oxygen toxicity, the FiO2 should only be changed to maintain systemic SaO2 within unit specific target ranges. [25]

3- **Hypoglycemia**

Hypoglycemia can be associated with increased cerebral blood flow. [47] Whether NIRS can be used as a marker of significant hypoglycemia is yet to be determined.

4- **Inotropes with lack of autoregulation**

Use of inotropes in premature infants may be associated with increased mortality and morbidity. [48] NIRS was used to monitor increasing cerebral blood flow with the use of inotropes. [49] NIRS can be used as a bedside tool to monitor the effect of these medications on cerebral perfusion and oxygenation and potentially could lead to interventions to limit their adverse effects.

Full Term Neonates

1- **Neonatal Encephalopathy**

In neonates with neonatal encephalopathy increased CrSO2 between 24-48 h is associated with adverse outcomes. [50] Combining CrSO2 and aEEG had the highest predictive value for MRI detected brain injury and worse outcome. [51, 52] The predictive value of higher CrSO2 to predict outcome is significant as early as 10 hours of life. [53]

2- **Congenital Heart Diseases**

Congenital heart disease is associated with worse long term neurodevelopmental outcomes. [54] Brain monitoring of these infants carries the potential for early detection and possible interventions to improve such outcomes. [55] Non-cyanotic CHD infants have an average CrSO2 of 70% while those with cyanotic CHD have CrSO2 values ranging from 40 to 70%. [56] In patients without pre-existing brain damage, decreased preoperative CrSO2 is associated with worse neurodevelopmental outcome up to 3 years of age. [57]

V. Guideline

Indications for the use of NIRS at BWH NICU

1- Routine monitoring of extremely premature infants < 28 weeks GA for the first 72 hours of life
2- Neonates with significant anemia requiring transfusion (before, during and after)
3- Infants receiving inotropes or hydrocortisone for BP support (before, during and after inotropes)
4- Infants on significant respiratory support (e.g., high pressures, HFV, iNO)
5- Preterm infants with PDA to evaluate for hemodynamic significance
6- Infants with hydrocephalus (especially before, during and after therapeutic LP or surgical intervention)
7- Infants with neonatal encephalopathy receiving therapeutic hypothermia (through the period of cooling, and re-warming)
8- Neonates with CNS injury/ abnormality e.g., seizures, infarct/stroke, vascular malformations such as Vein of Galen malformation and AV malformation.
9- Case by case per NICU attending request

Starting the NIRS Study

- Identify infants indicated for NIRS monitoring
- Provider enters an order in Epic requesting "NIRS-Continuous Monitoring" to be started with the indications outlined.

Role of the bedside nurse in NIRS monitoring

- Equipment set up and lead placement is completed by the NICU bedside nurse
- Skin care: Can use either adhesive probe or wraps around probe to keep it in place without directly sticking to skin; will be determined based on age of neonate and skin condition **(Appendix- I)**
- Neonatal probes are placed unilaterally over the frontal cortex and can be used bilaterally if clinically indicated
- Bedside nurse documents CrSO2 in EMR. NIRS can be added to the patient chart under: **Flowsheets> NICU Vitals** by using the function (**Add Rows)** and search for NIRS.
- CrSO2 will be documented hourly and skin condition will be observed and documented with each routine neonatal care.
- Bedside nurse will mark significant events on the NIRS device.
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NIRS Interpretation:

- CrSO2 reflects the balance between brain tissue perfusion and oxygen extraction.

- CrSO2 has a wide range of normal and is reported to be between 55% and 85% (with 10% higher if using neonatal probe). A recent clinical trial has shown that continuous monitoring of cerebral NIRS enabled a decreased burden of cerebral hypoxia. [58] Although, in the same study cerebral hypoxia was associated with low brain electrical activity and severe intracranial hemorrhage [59], it is not yet clear that maintaining premature infants within this range improves long term outcome.

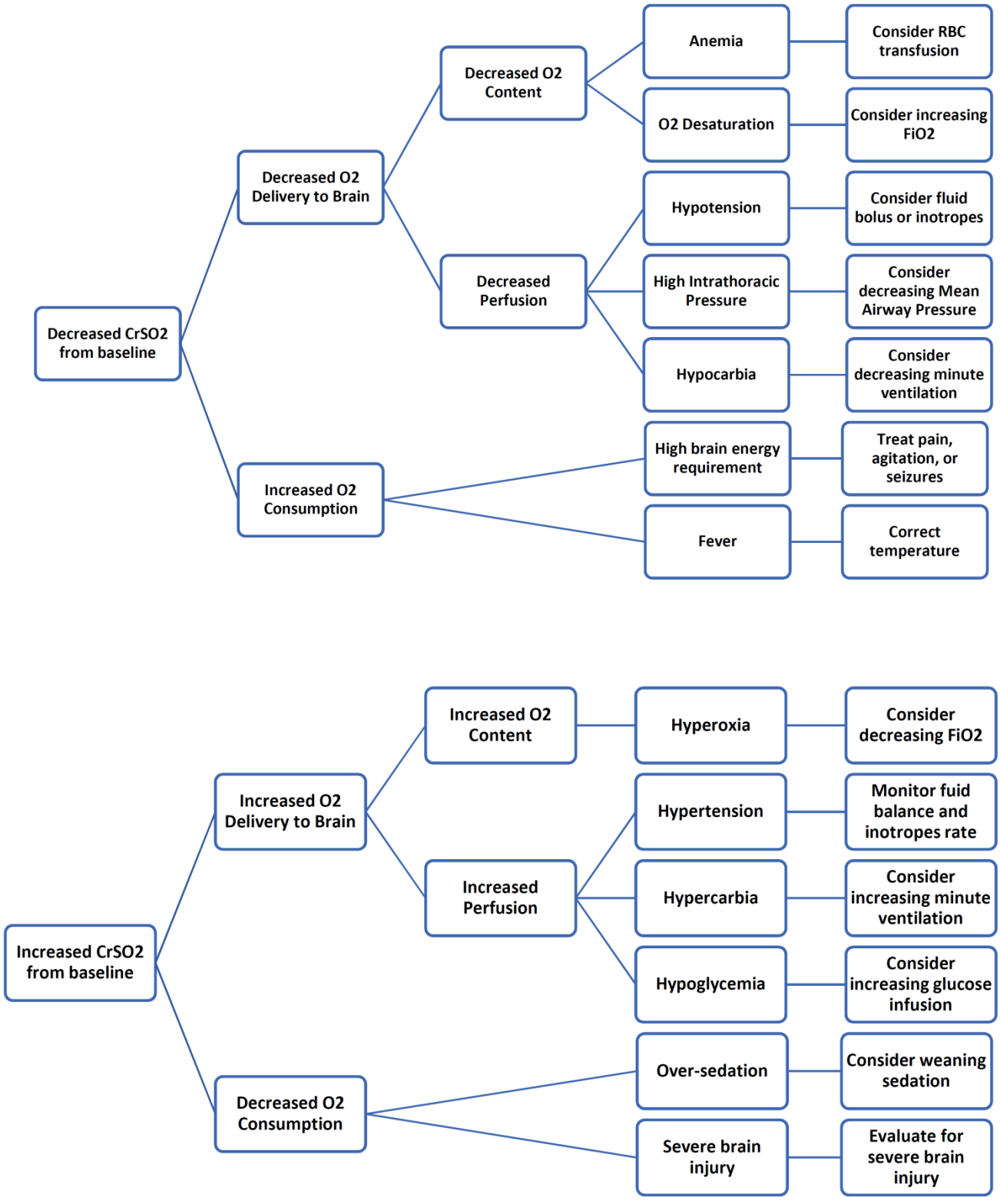
- It is important to note and document the baseline measurement of each individual patient. Significant rises/falls from patient's baseline (e.g., > 20%) may represent underlying status changes more accurately than the absolute number.

- A decrease in CrSO2 could be associated with decreased cerebral O2 delivery/ perfusion or increased O2 consumption. **A patient with significantly decreased CrSO2 relative to baseline or absolute CrSO2 < 60 %** needs to be evaluated for anemia, hypoxia, hypotension, chest hyperinflation, hypocarbia and treated accordingly**. (Figure 1)**

- An increase in CrSO2 could be associated with increased cerebral O2 delivery/ perfusion or decreased O2 consumption. **A patient with significantly increased CrSO2 relative to baseline or absolute CrSO2 > 90%** needs to be evaluated for hyperoxia, hypercarbia, hypoglycemia, over sedation or severe brain injury**. (Figure 1)**

- **In patients with no physiologic explanation for the abnormal CrSO2, no direct interventions (e.g., manipulating FiO2) should be attempted solely to correct the CrSO2 value.**

Figure 1: Suggested Algorithm for Interpreting Neonatal CrSO2



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