Near-infrared spectroscopy during respiratory support at birth

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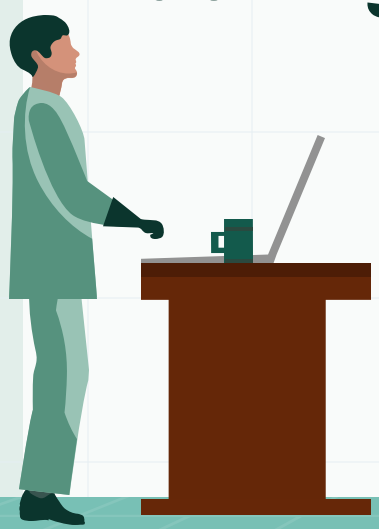
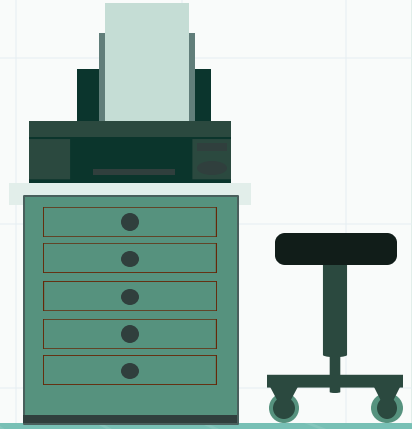
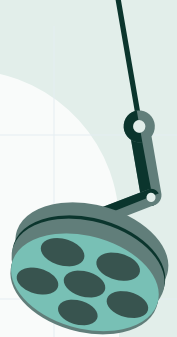




PULSE OXIMETRY: ITS USES AND LIMITATIONS IN MONITORING OXYGEN DELIVERY

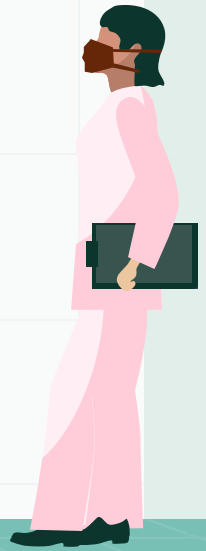


- Principles of Pulse Oximetry: Pulse oximeters measure the differential absorption of red and infrared light by oxyhemoglobin and deoxyhemoglobin
- Most manufacturers report an SD of the difference between Spo, and actual Sao, of 3 points for neonates. However, because 1 SD on each side of the mean includes approximately 68% of the measurements, nearly one-third of the measurements will fall outside that range.
- Average times
- Pulse oximeter algorithms
- Relationship between SaO_2 and PaO_2
- Fetal vs. adult hemoglobin
- Alarm limits

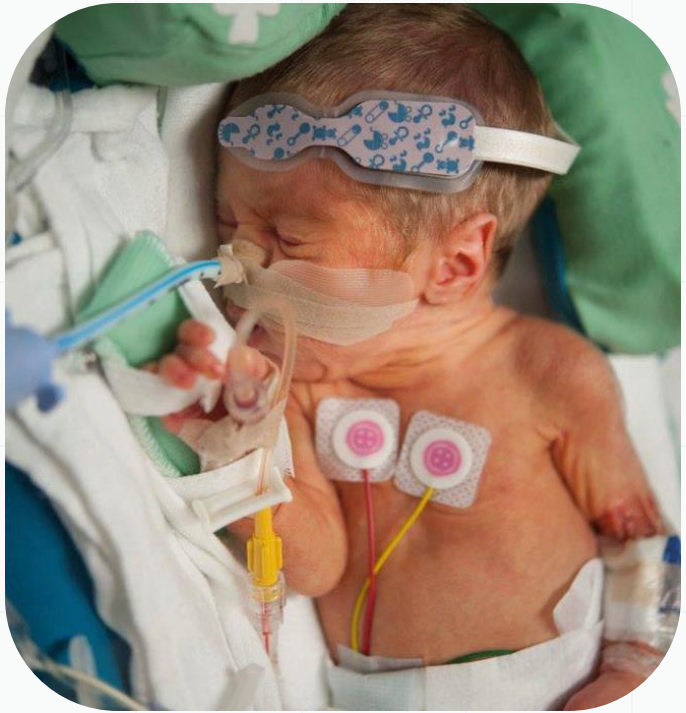
References : Neonational care a compendium of AAP clinical practice guidelines and policies (second edition)

History of NIRS Use in Neonates

1. Early Scientific Foundations (1970s–1980s)
2. First Neonatal Applications (Late 1980s–1990s)
3. Technological Progress (1990s–2000s)
4. Emergence of Regional Oxygen Saturation (rSO_2) Monitoring (2000s)
5. Integration Into Neonatal Care (2010-2019)
6. Modern Era: Multimodal Monitoring (2020s– NOW)

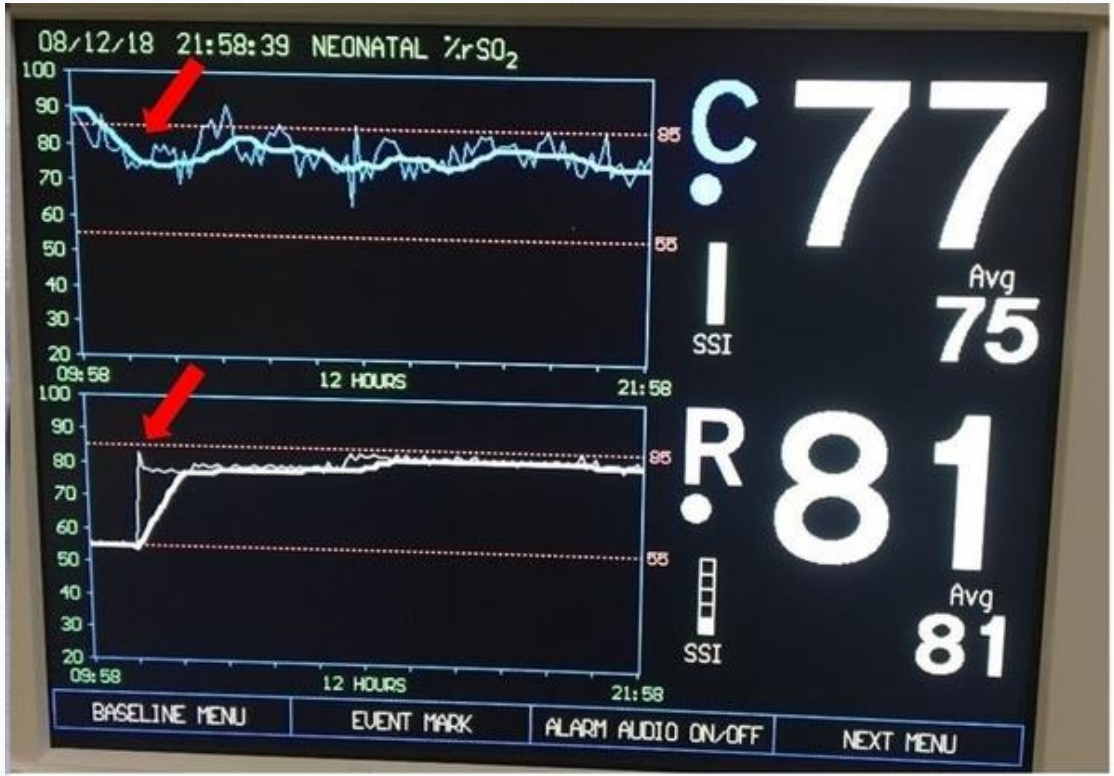


References : Volpe's neurology of the newborn by joseph J.Volpe (seventh edition - vol.2)



Clinical Need and Rationale

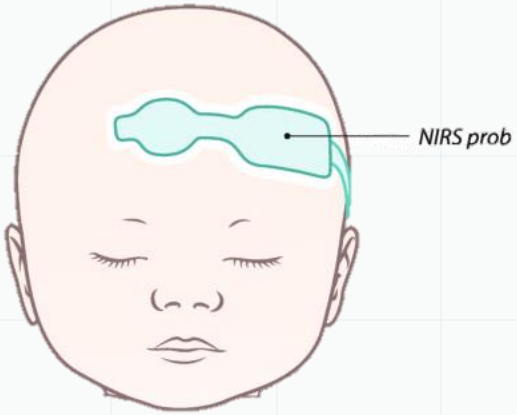
- The Clinical Problem (The Brain at Risk)
- Limitations of Standard Monitoring (SpO_2)
- The Rationale for NIRS Monitoring

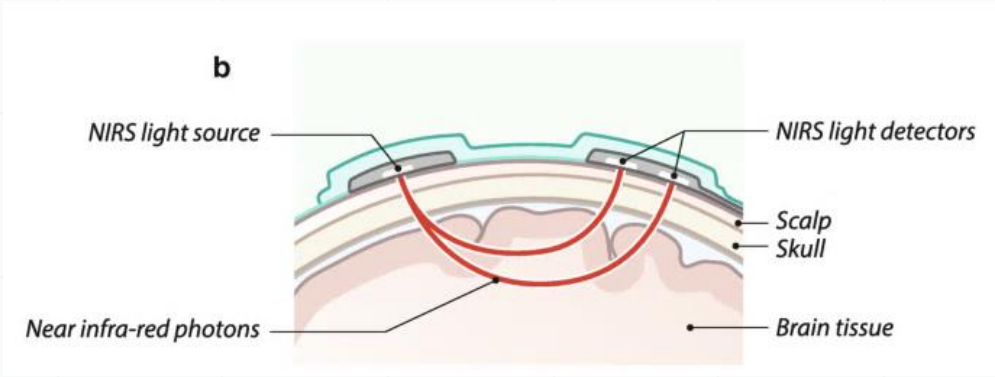

08/12/18 21:58:39 NEONATAL %rSO2
100
90
80
70
60
50
40
30
20
85
55
09:58
12 HOURS
21:58
C
77
Avg
75
SSI
R
81
Avg
81
SSI
BASELINE MENU
EVENT MARK
ALARM AUDIO ON/OFF
NEXT MENU

NIRS: Measuring Cerebral Oxygen Balance

- Near-Infrared Spectroscopy (NIRS): A non-invasive optical technique.
- Uses light wavelengths (700-1000 nm) to penetrate tissues (skull, brain).
- Measures the differential absorption of light by oxygenated hemoglobin $HbO_2$and deoxygenated hemoglobin Hb.
- Provides a reading of cerebral regional tissue oxygen saturation $CrSO_2$in real-time.

References : Volpe's neurology of the newborn by joseph J.Volpe (seventh edition- vol.2)


NIRS prob


b
NIRS light source
NIRS light detectors
Scalp
Skull
Near infra-red photons
Brain tissue

Monitoring

- Typically, CrSO2 is between 55% and 85%. A prescriber order is placed for NIRS monitoring including the location of sensors and goal physiologic parameter of not more than a 20% change from baseline.
- Monitor trends and document NIRS values hourly (see Figure 1: Root monitor display).
- Notify provider if sustained value below 55% or > 20% change from baseline.
- Assess skin under sensor daily and replace sensor every 4 days and as needed.

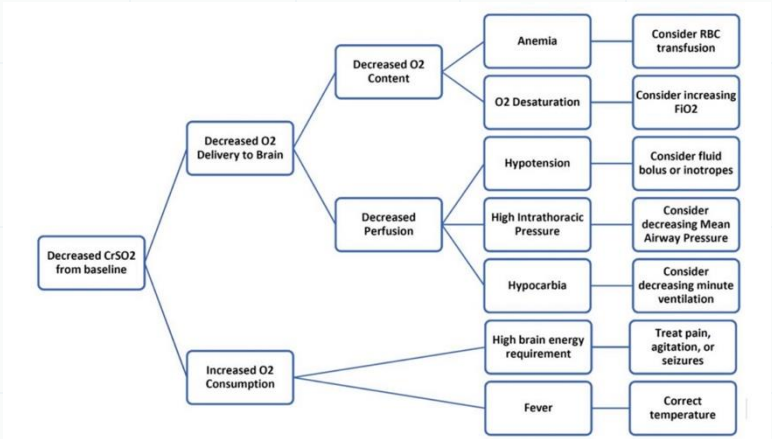
References :reginal oximetry monitoring in neonatal ICU . Retrieved 11/10/2023

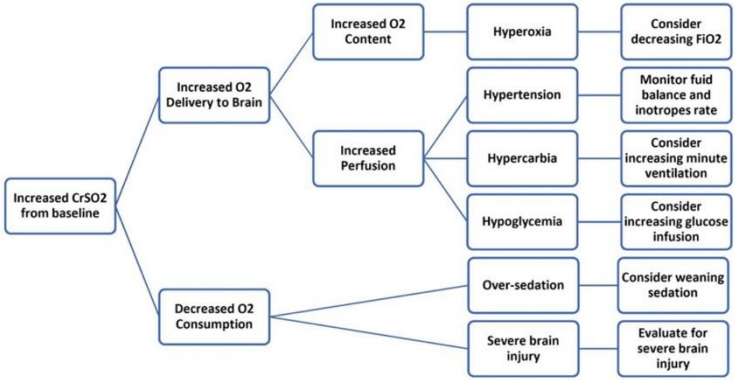
Evaluation

- Regional O2 saturation represents the balance between tissue perfusion and oxygenation. Typical cerebral saturation (CrSO2) is between 60-80%, assuming that the arterial saturation (oxygen delivery to the organ) is 90% or more. Renal saturation often is higher than cerebral saturation (since the brain consumes more oxygen than the kidney) except in some cardiac conditions such as PDA where there is ductal steal effect.
- When evaluating CrSO2 consider the following and utilize the Suggested Algorithm for Interpreting Neonatal CrSO as indicated:

1. A sustained decrease in CrSO2 from baseline could be related to decreased O2 delivery/ perfusion, or increased oxygen consumption
2. Factors that may contribute to a decrease in CrSO include anemia, hypoxia, hypotension, high intrathoracic pressure, hypocarbia, or conditions that increase brain energy such as pain/agitation, seizures, and fever
3. A sustained increase in CrSO2 from baseline could be related to increased 02 delivery/ perfusion, or decreased oxygen consumption
4. Consider evaluating the patient for hyperoxia, hypercarbia, hypoglycemia, over-sedation, or significant brain injury
5. This measurement is used in addition to monitoring of other physiologic parameters, physical assessment, and laboratory values in the care of critically ill patients. In patients with no physiologic explanation for the abnormal CrS02, we do not recommend direct interventions be attempted solely to correct the CrS02 value.

References : American journal of perinatology utility of abdominal near infrared spectropsy(NIRS) in management of neonates – a review.





References :reginal oximetry monitoring in neonatal ICU . Retrieved 11/10/2023

Comparison of NIRS and Pox

Feature	Near-Infrared Spectroscopy (NIRS)	Pulse Oximetry
Measurement site	Deep tissues (brain, kidney, intestine)	Skin or nail bed (hand or foot)
Measured parameter	Regional oxygen saturation (rSO_2)	Arterial oxygen saturation (SpO_2)
Type of blood assessed	Mixed (mainly venous, ~70–80%)	Arterial blood only
Main clinical purpose	Assess tissue perfusion and oxygenation	Monitor systemic oxygenation and ventilation
Neonatal application	Evaluate cerebral oxygenation, detect ischemia	Routine NICU and resuscitation monitoring
Response to changes	Sensitive to local perfusion/metabolism	Sensitive to systemic oxygenation changes
Measurement principle	Near-infrared light reflection from tissues	Red and infrared light absorption by arterial Hb
Limitations	Affected by motion or skin thickness; needs calibration	Affected by poor perfusion or ambient light

References : American journal of perinatology utility of abdominal near infrared spectropsy(NIRS) in management of neonates – a review.

Near-infrared spectroscopy during respiratory support at birth: a systematic review

(Arch Dis Child Fetal Neonatal Ed: first published as 10.1136/archdischild-2025-328577 on 29 April 2025.)

WHAT IS ALREADY KNOWN ON THIS TOPIC

In preterm infants, a low cerebral regional tissue oxygen saturation during the first 15 min after birth may be associated with the development of intraventricular haemorrhage.

WHAT THIS STUDY ADDS

The evidence could not rule out benefit or harm from using cerebral regional tissue oxygen saturations in addition to standard monitoring to guide respiratory support in preterm infants in the first 15 min after birth.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

Future research should first focus on identifying interventions that are effective in modifying cerebral regional tissue oxygen saturation and then assessing clinical and resource implications.

Defining the Scope (PICOST)

•**P (Population):**Newborn infants (term or preterm) requiring respiratory support (CPAP or IPPV) at birth.
•**I (Intervention):**CrSO2 monitoring PLUS a specific, documented treatment guideline (for adjusting FiO2 and/or respiratory parameters).
•**C (Comparison):**Routine care (Clinical assessment, Pulse Oximetry (SPO2), ECG monitoring, etc.)
•**O (Outcomes):**Primary Outcome (The Guideline Driver): Survival without neurodevelopmental impairment (NDI) at 18–24 months of age.
•**Secondary Outcomes:** Survival, Severe IVH (Grade 3/4), PVL, and acute physiological measures (e.g., time outside the target CrSO2).

Near-infrared spectroscopy during respiratory support at birth: a systematic review
(Arch Dis Child Fetal Neonatal Ed: first published as 10.1136/archdischild-2025-328577 on 29 April 2025.)

Methodology: Finding and Selecting the Evidence

•**Exhaustive Search Strategy:**
Systematic search across major medical databases: MEDLINE, EMBASE, and Cochrane CENTRAL.
Search was supplemented by checking conference abstracts (e.g., PAS, ESPR) for the newest data.
No language restrictions applied, ensuring global evidence inclusion (critical for ILCOR).

•**Reviewer Rigor (Quality Control):**
•The entire selection process (screening and eligibility assessment) was performed by two independent reviewers.
•This essential step minimizes selection bias and ensures the integrity of the evidence synthesis.

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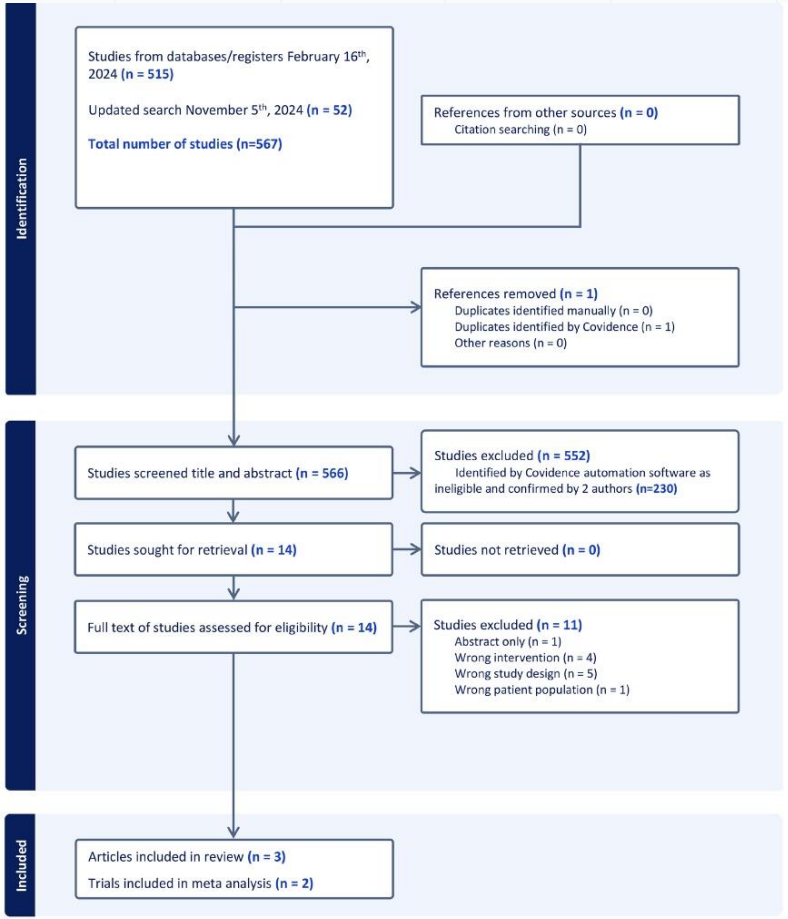

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Outcome	Study	RoB from the randomisation process	RoB due to deviations from the intended interventions	Missing outcome data	RoB in measurement of the outcome	RoB in selection of the reported result	Overall RoB
Survival	Pichler 2016	Low	Low	Low	Low	Low	Low
	Pichler 2023	Low	Low	Low	Low	Low	Low
IVH grade III/IV	Pichler 2016	Low	Low	Low	Unclear	Low	Unclear
	Pichler 2023	Low	Low	Low	Unclear	Low	Unclear
PVL	Pichler 2016	Low	Low	Low	Unclear	Low	Unclear
	Pichler 2023	Low	Low	Low	Unclear	Low	Unclear
$crSO_2$ <10th percentile	Pichler 2016	Low	Low	Unclear	Low	Low	Unclear

$crSO_2$, cerebral regional oxygen saturation; IVH, intraventricular haemorrhage; PVL, periventricular leukomalacia; RoB, risk of bias.

First author, (year) country	N, gestation	NIRS device (type)	Methods	NIRS treatment guideline	Randomisation	Summary of results
Pichler *et al* (2016)[6] Austria, Canada	60 <34$^{0/7}$ weeks	Invos 5100 Cerebral/Somatic Oximeter monitor; Somanetics Corp, Troy, Michigan	Pilot RCT. **Primary outcomes**: $crSO_2$ <10th percentile or >90th percentile. **Secondary outcomes**: mortality and/or cerebral injury (cerebral ultrasound) and general movement assessment at term. In one centre, ultrasound was performed by a neonatologist, in the other centre by a radiographer. Analyses were by intention-to-treat.	When SpO_2 was 10th–90th percentile, the resuscitation team used $crSO_2$ to provide respiratory support via face mask. FiO_2 was increased by 10%–20% every 60 s if $crSO_2$ remained <10th percentile. Respiratory support via face mask was decreased or discontinued or FiO_2 was reduced by 10%–20% if $crSO_2$ remained stable >10th percentile for 60 s or if $crSO_2$ was >90th percentile.	1:1 block-randomisation. A sealed, opaque envelope with the allocation was opened by a researcher before the birth of an eligible infant. For multiple births, only the first infant was randomised.	Infants were predominantly delivered by Caesarean section (>80%). Delayed cord clamping was routinely performed for >30 or >60 s. Including only infants with a complete dataset for $crSO_2$, there was a significantly lower burden of cerebral hypoxia in % minutes $crSO_2$ in the intervention group (a relative reduction in cerebral hypoxia of 55.4%). The difference was not significant when all infants were included. Two infants in the control group died. One infant in each group had severe IVH and two infants in each group had PVL. Four infants had abnormal general movements in the intervention group, and six in the control group (p=0.45). Oxygen supplementation was lower in the intervention group in the first minutes. No severe adverse reactions were observed.
Pichler (2023)[12] Six countries in Europe and Canada	607 <32$^{0/7}$ weeks	Invos 5100 Cerebral/Somatic Oximeter monitor, Medtronic, Minneapolis, Minnesota	Multicentre, multinational, phase III RCT. **Primary outcome**: a composite of survival without cerebral injury (cerebral ultrasound: any IVH or cystic PVL, or both, at term equivalent age/before discharge). **Secondary outcomes**: individual components of the primary outcome mortality and cerebral injury, culture-proven infection/sepsis, NEC, BPD, ROP and PDA requiring intervention. Cerebral ultrasound was 'performed locally, and therefore despite every effort, full masking to group allocation could not be guaranteed'.	The treatment guideline was the same as in Pichler 2016[7] plus: if there was a history or clinical signs of blood loss, 10 mL/kg of intravenous fluids were considered.	A web-based randomisation service and a block size of 10. 1:1 allocation and stratification according to trial site. For multiple births, only the first infant was randomised.	252/304 (82.9%) infants in the intervention group survived without cerebral injury compared with 238/303 (78.5%) in the control group (RR 1.06, 95% CI 0.98 to 1.14). Twenty-eight neonates died (intervention group 12 (4.0%) vs control group 16 (5.3%): RR 0.75 (0.33 to 1.70). Predefined secondary outcomes did not differ significantly between the two groups. FiO_2 was slightly higher in the intervention group than the control group. Significantly more infants received intravenous fluids in the intervention group (12 (4.0%) vs 2 (0.7%), p=0.007). In four infants, administration of intravenous fluids was indicated by $crSO_2$. Invasive respiratory support (intubation) was indicated in nine infants by $crSO_2$, with an associated trend towards a higher rate of mechanical ventilation during the first day after birth in the intervention group. No serious adverse reactions or serious adverse device-related events were observed. In the follow-up study,[18] 171 infants with a median GA of 29.4 and 28,7 weeks in the intervention and control group, respectively. 90.2% in the intervention group survived without cerebral injury compared with 80.9% in the control group (RR 1.12, 95% CI 0.99 to 1.26), p=0.084. 90.2% in the intervention group survived with normal fidgety movements compared with 89.9% in the control group (RR 0.96, 95% CI 0.31 to 2.62), p=0.938.

BPD, bronchopulmonary dysplasia; $crSO_2$, cerebral regional oxygen saturation; FiO_2, fraction of inspired oxygen; GA, gestational age; IVH, intraventricular haemorrhage; NEC, necrotising enterocolitis; NIRS, near-infrared spectroscopy; PDA, patent ductus arteriosus; PVL, periventricular leukomalacia; RCT, randomised controlled trial; ROP, retinopathy of prematurity; RR, relative risk; SpO_2, peripheral oxygen saturation.

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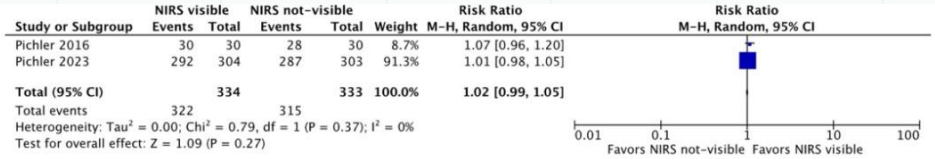
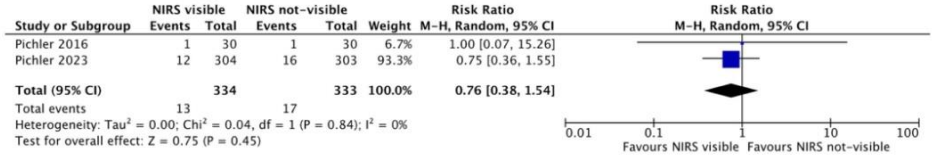
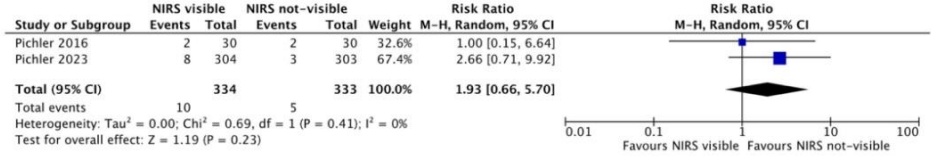


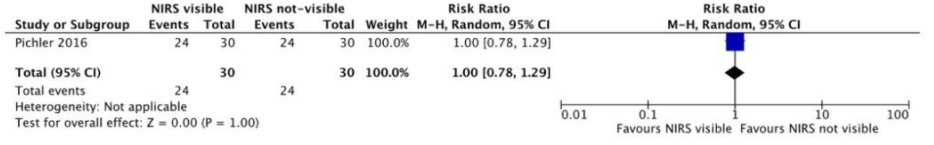
Panel b) Severe intraventricular hemorrhage



Panel c) Periventricular hemorrhage



Panel d) Regional cerebral oxygen saturation <10th percentile



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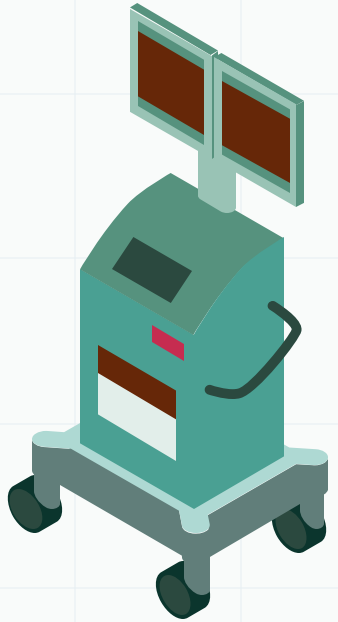
Results: Study Flow and Patient Demographics

The limited available evidence could not rule out benefit or harm from delivery room monitoring of cerebral oxygen saturation using NIRS with a dedicated treatment guideline in preterm infants. Future research in this area needs to address the effectiveness of interventions to improve crSO2, as well as human factors and costs.



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هرکه شود صید عشق

کی شود او صید مرگ

–مولانا