Hôpitaux universitaires Paris-Sud
Antoine-Béclère Bicêtre Paul-Brousse

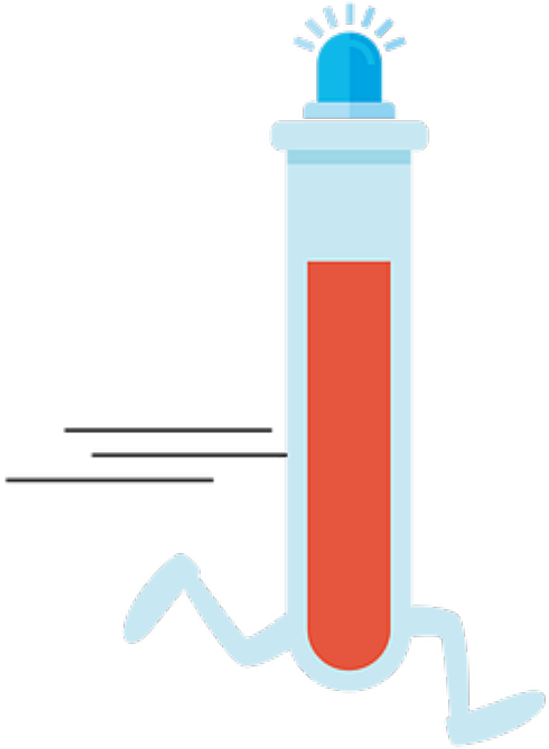
Mesure des gaz du sang transcutané en réanimation pédiatrique

Nadya Yousef

Réanimation néonatale
GHU Paris Sud - APHP

UNIVERSITÉ PARIS SUD

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS



Aucun conflit d’intérêt

Slides Daniele Deluca and CORE2ED

Ways to monitor respiratory function

Arterial/Capillary blood gas

Chest X-rays

Pulso-oxymetry

Respiratory rate

Refill time

Perfusion Index

aEEG/EEG

TC Monitoring

Quantitative Lung Ultrasound

EIT/Segmentography

Biophysical monitoring

NIRS

Electrical cardiometry

TO Doppler

Intensive Care Med (2017) 43:1764–1780
DOI 10.1007/s00134-017-4920-z

CONFERENCE REPORTS AND EXPERT PANEL

Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC)

Martin C. J. Kneyber[1,2*], Daniele de Luca[3,4], Edoardo Calderini[5], Pierre-Henri Jarreau[6], Etienne Javouhey[7,8], Jesus Lopez-Herce[9,10], Jürg Hammer[11], Duncan Macrae[12], Dick G. Markhorst[13], Alberto Medina[14], Marti Pons-Odena[15,16], Fabrizio Racca[17], Gerhard Wolf[18], Paolo Biban[19], Joe Brierley[20], Peter C. Rimensberger[21] and on behalf of the section Respiratory Failure of the European Society for Paediatric and Neonatal Intensive Care

espnic
European Society of Paediatric and Neonatal Intensive Care

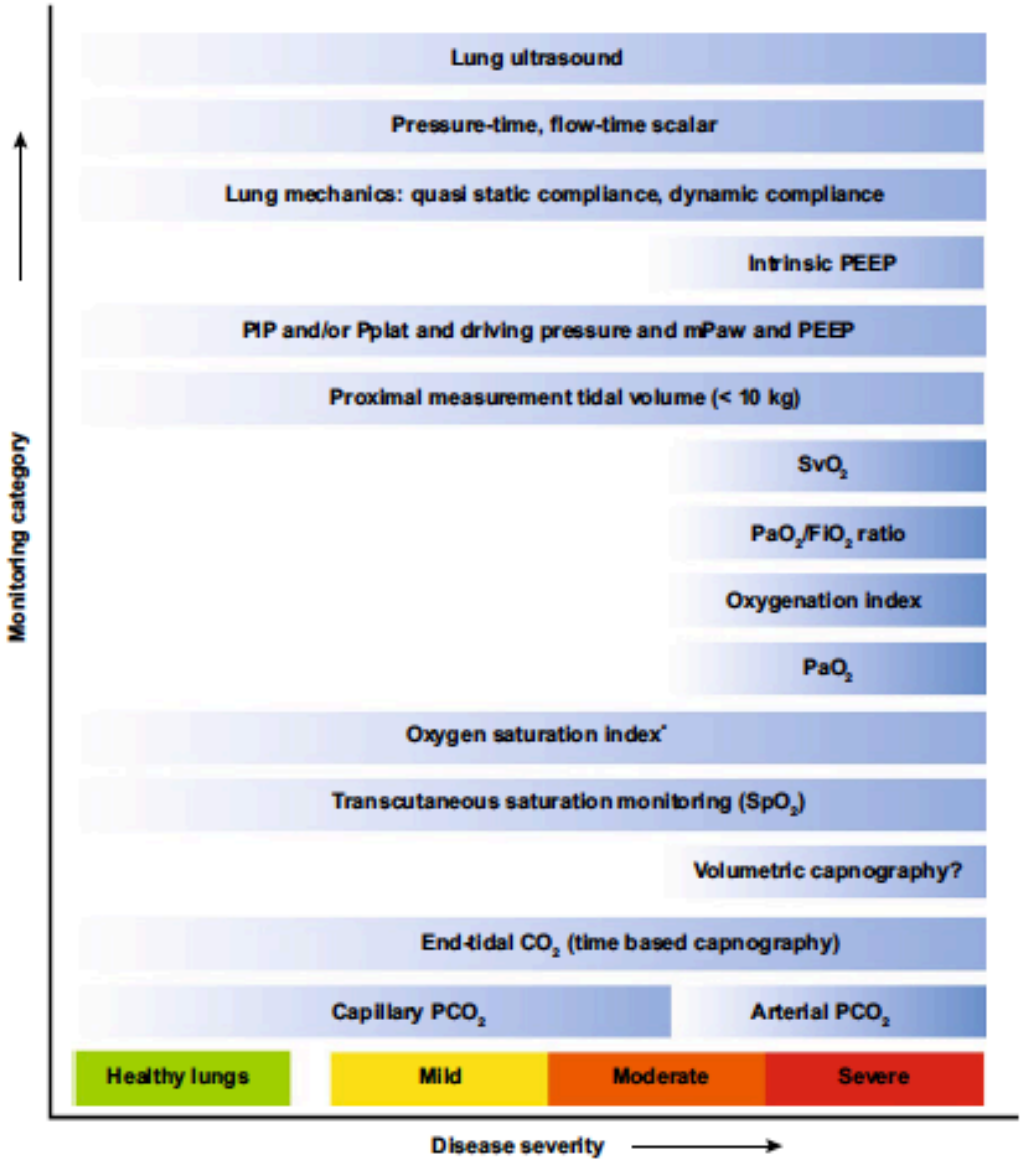


Fig. 3 Graphical simplification of the recommendations on "monitoring" in the context of healthy lungs, obstructive airway, restrictive and mixed disease. It is also applicable for cardiac patients, patients with congenital of chronic disease and patients with lung hypoplasia syndromes. The *colour gradient* denotes increasing applicability of a specific consideration with increasing disease severity. *Absence of the colour gradient* indicates that there is no relationship with disease severity. The *question mark* associated with specific interventions highlights the uncertainties because of the lack of paediatric data. *PIP* peak inspiratory pressure, *Pplat* plateau pressure, *Vt* tidal volume, *PEEP* positive end-expiratory pressure, *mPaw* mean airway pressure, SvO_2 venous oxygen saturation

Kneyber M, De Luca D et al, Intensive Care Med 2017

Venous pCO_2 measurements are of limited use in providing reliable information about CO_2 elimination. In the absence of evidence, we suggest that transcutaneous CO_2 measurements may be considered in very young children and neonates (*strong agreement).*

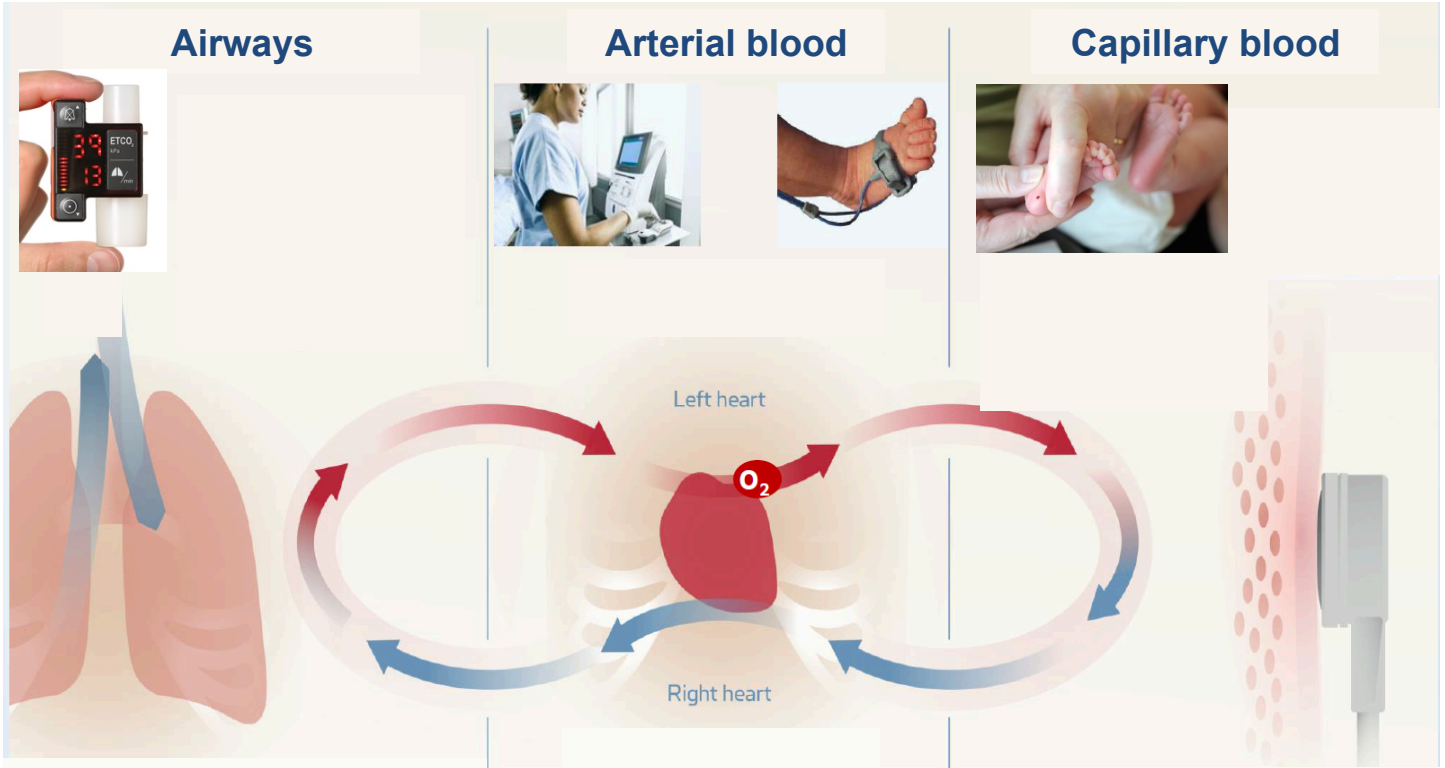
We recommend using indwelling arterial lines in more severely ill patients on invasive ventilation, allowing PaO_2 measurements for an accurate assessment of oxygenation and measurements of pH and lactate *(strong agreement)*. We recommend monitoring central venous saturation (SvO_2) and/or arterial lactate in invasively mechanically ventilated patients with severe lung injury to assess the presence or absence of oxygen debt *(strong agreement)* and as an indirect complementary marker for assessing cardiac output *(strong agreement)*

We recommend adhering to the PALICC guidelines for patients who meet the paediatric ARDS criteria (i.e. SpO_2 generally 92 – 97% when PEEP is less than 10 cmH_2O and 88 – 92% when the PEEP is 10 cmH_2O or higher) *(strong agreement)*.

espnic
European Society of Paediatric and Neonatal Intensive Care

Kneyber M, De Luca D et al, Intensive Care Med 2017

Blood gases can be monitored in the airways, or in arterial or capillary blood



- End-tidal monitoring of pCO_2

- Blood gas analysis of pO_2 and pCO_2 in arterial blood
- Pulse oximetry to monitor O_2 saturation

- Blood gas analysis of pO_2 and pCO_2 in capillary blood
- TCM of pO_2 and pCO_2

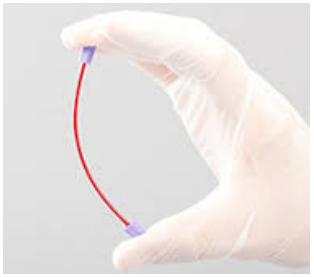
CO_2, carbon dioxide; O_2, oxygen; pCO_2, carbon dioxide partial pressure; pO_2, oxygen partial pressure.

The hierarchy of blood gas measures techniques in the NICU

HIERARCHY

1. Arterial lines

2. Transcutaneous measurements (well calibrated)*



3. Arterialised capillary blood gas

What are we measuring and how?

Method	Technique
O_2 Uptake, Transport and Release	ABG Arterial (Venous) (Capillary)
Partial Pressure of CO_2 in Blood	ABG Arterial (Venous) (Capillary)
Analyse pH (HCO_{3-}, BE)	ABG Arterial (Venous) (Capillary)
Non Invasive Oxygen Supply (Skin)	Transcutaneous O_2 ($PtcO_2$)
Non Invasive Partial Pressure of CO_2 in skin	Transcutaneous CO_2 ($PtcCO_2$)
Non Invasive Partial Pressure of $CO_{2\ in}$ the Lung	End Tidal CO_2 ($PetCO_2$)
Percentage of used Oxygen Transport Capacity	Pulse Oximetry (SpO_2)

BLOOD GASES CAN BE MONITORED INTERMITTENTLY OR CONTINUOUSLY

COR2ED
THE HEART OF MEDICAL EDUCATION

Intermittent: blue
Continuous: orange

Blood gas analysis

- Blood for analysis of partial pressure of O_2 and CO_2 in arterial blood can be obtained via arterial puncture or an arterial catheter
- Blood for analysis of partial pressure of O_2 and CO_2 in capillary blood can be obtained by a heel stick

Pulse oximetry

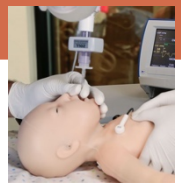
- Most commonly used method for monitoring oxygenation
- Non-invasive
- No accurate detection of hyperoxemia
- No pCO_2 monitoring

TCM

- Continuous, non-invasive monitoring of cutaneous pO_2 and pCO_2

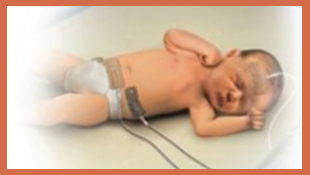
End-tidal CO_2 monitoring

- Measures CO_2 in the exhaled air, at the relatively flat portion of the expiratory phase
- Suitable for use in larger children (⩾ 2 kg) without lung disease, in specific situations, such as elective surgery, transport or hypothermia
- Not suitable for use in extremely premature children, as it adds dead space
- Poor correlation between end-tidal and arterial pCO_2 levels[1]



Near-infrared spectroscopy (NIRS)

- Measures cerebral oxygen saturation



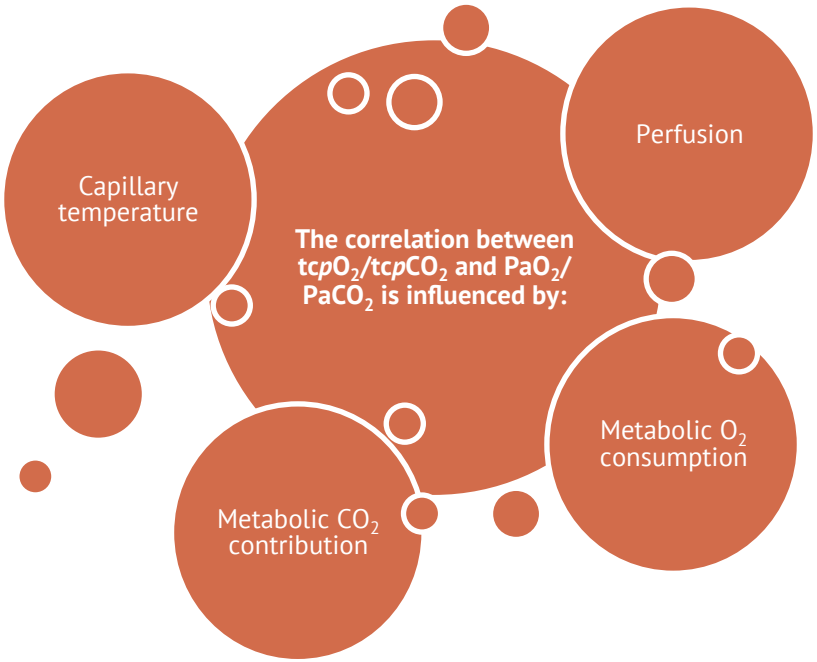
1. Tobias JD, et al. Anesth Analg. 1997;85:55-8.

CO_2, carbon dioxide; O_2, oxygen; pCO_2, carbon dioxide partial pressure; pO_2, oxygen partial pressure; TCM, transcutaneous monitoring; tcpCO_2, transcutaneous partial pressure of carbon dioxide; tcpO_2, transcutaneous partial pressure of oxygen.

tcpO_2/tcpCO_2 AND PaO_2/$PaCO_2$ ARE STRONGLY RELATED, BUT TELL A DIFFERENT STORY

COR2ED
THE HEART OF MEDICAL EDUCATION

- In hemodynamically stable patients, there is good correlation between transcutaneous (TC) and arterial values[1,2]
- However, tcpO_2 and tcpCO_2 are influenced by perfusion and metabolism
- **TCM is valuable for trend analysis of pO_2 and pCO_2**



1. Huch R, et al. J. Perinat Med. 1973;1: 183-91. 2. Used with permission from: Aly S, et al. Am J Perinatol. 2017;34:480-485.
CO_2, carbon dioxide; O_2, oxygen; $PaCO_2$, partial pressure of carbon dioxide in arterial blood; PaO_2, partial pressure of oxygen in arterial blood; pCO_2, carbon dioxide partial pressure; pO_2, oxygen partial pressure; TCM, transcutaneous monitoring; tcpCO_2, transcutaneous partial pressure of carbon dioxide ; tcpO_2, transcutaneous partial pressure of oxygen..

SENSOR TEMPERATURES HAVE SPECIFIC INDICATIONS AND PRACTICAL CONSIDERATIONS

COR2ED
THE HEART OF MEDICAL EDUCATION

Temperature skin surface / sensor core		40 / 41°C	42 / 43°C	43 / 44°C
Patient group		• Extremely low birth weight neonates • Extremely immature neonates	• Low birth weight neonates • Preterm neonates	• Preterm neonates • Term neonates • PICU patients
Max. time at one location		• 4-6 hours	• 3 hours	• 15-20 minutes in preterm neonates • 3-4 hours in term neonates and PICU patients
Accuracy	tc*p*CO_2	• Accurate for long-term trend observation	• Accurate for short-term trend observation	• Accurate for short-term observation and snapshot monitoring • Accurate for predicting $PaCO_2$ • Accurate for calculating tc*p*CO_2 index
	tc*p*O_2	• Generally not accurate, as the capillary bed will not be sufficiently arterialized • May provide a long-term trend outlook in extremely immature neonates, as their skin is very thin	• Accurate for short-term trend observation in preterm neonates • Accurate for long-term trend monitoring • Accurate for detection of hyper/hypoxemia	• Accurate for short-term observation and snapshot monitoring • Accurate for predicting PaO_2 • Accurate for calculating tc*p*O_2 index • Accurate for calculating oxygenation index
Limitations		• Low temperature limits accuracy for tc*p*O_2 • Long response time for tc*p*CO_2	• In patients with vulnerable skin, the sensor site may need to be changed in shorter intervals	• In preterm neonates, the maximum time at one location is short, so only useful for intermittent monitoring

HFV, high frequency ventilation; $PaCO_2$, partial pressure of carbon dioxide in arterial blood; PaO_2, partial pressure of oxygen in arterial blood; PICU, paediatric intensive care unit; tc*p*CO_2, transcutaneous partial pressure of carbon dioxide; tc*p*O_2, transcutaneous partial pressure of oxygen.

THE OXYGENATION INDEX CAN BE CALCULATED USING tcpO_2

COR2ED
THE HEART OF MEDICAL EDUCATION

- The oxygenation index is an indicator of lung injury

- **Oxygenation index=FiO2 (%) × MAP (cmH2O)/PaO2 or tc*p*O2 (mmHg)**

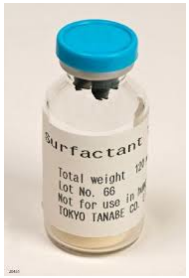
- According to the Montreux definition of neonatal ARDS, the oxygenation index can be calculated using arterial or, if arterial values are unavailable, transcutaneous pO_2 values
- Oxygenation index thresholds for ARDS:
  - 4.0–7.9: mild ARDS
  - 8.0–15.9: moderate ARDS
  - ⩾ 16.0: severe ARDS

De Luca D, et al. Lancet Respir Med. 2017;5:657-666.
ARDS, acute respiratory distress syndrome; FiO_2, fraction of inspired oxygen; MAP, mean airway pressure; PaO_2, partial pressure of oxygen in arterial blood; pO_2, oxygen partial pressure; tcpO_2, transcutaneous partial pressure of oxygen.

Why use the oxygenation index (OI) ?

1 — 2-3 — 10-15 — 20 — 30-40

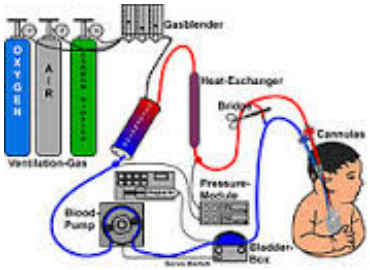
Surfactant



HFOV or other unconventional

iNO

ECMO



	Details
Timeframe	Acute onset (ie, within one week) from a known or suspected clinical insult
Exclusion criteria	RDS, TTN, or congenital anomalies as a primary current acute respiratory condition
Lung imaging	Diffuse, bilateral, and irregular opacities or infiltrates, or complete opacification of the lungs, which are not fully explained by local effusions, atelectasis, RDS, TTN, or congenital anomalies
Origin of oedema	Absence of congenital heart disease explaining the oedema (this includes ductus arteriosus with pulmonary overflow if no acute pulmonary haemorrhage exists). Echocardiography is needed to verify the origin of oedema.
Oxygenation deficit expressed as OI*	Mild ARDS: 4≤OI<8 Moderate ARDS: 8≤OI<16 Severe ARDS: OI≥16

ARDS=acute respiratory distress syndrome. RDS=respiratory distress syndrome. TTN=transient tachypnoea of the neonate. OI=oxygenation index. *OI can be calculated by use of arterial or, if arterial values are unavailable, transcutaneous oxygen tension values, with appropriately calibrated transcutaneous devices. In the case of persistent pulmonary hypertension of the neonate and patent ductus arteriosus, preductal PaO_2 values should be used. The definition applies from birth until 44 weeks, post-menstrual age or until 4 weeks, postnatal age (for neonates born after 40 weeks, post-menstrual age). For the syndrome to be defined all criteria must be fulfilled. OI should be calculated with the most accurate measures available. The syndrome can be diagnosed at any gestational age or birthweight, provided that congenital lung anomalies, RDS, and TTN are excluded as primary respiratory disorder. Criteria for the diagnosis of RDS and TTN, exclusion criteria for neonatal ARDS, and suggestions to improve the reliability of transcutaneous blood gas measurements are provided in the Montreux definition of neonatal ARDS section.

Table 2: The Montreux definition of neonatal ARDS

De Luca D et al, Lancet Resp Med 2017

Age	Exclude patients with peri-natal related lung disease		
Timing	Within 7 days of known clinical insult		
Origin of Edema	Respiratory failure not fully explained by cardiac failure or fluid overload		
Chest Imaging	Chest imaging findings of new infiltrate(s) consistent with acute pulmonary parenchymal disease		
Oxygenation	**Non Invasive mechanical ventilation**		**Invasive mechanical Ventilation**
	Nasal mask CPAP or BiPAP	Oxygen via mask, nasal cannula or High Flow	Oxygen supplementation to maintain $SpO_2 \geq 88\%$ but OI < 4 or OSI < 5[1]
	$FiO_2 \geq 40\%$ to attain SpO_2 88-97%	SpO_2 88-97% with oxygen supplementation at minimum flow[2]: < 1 year: 2 L/min 1 – 5 years: 4 L/min 5 – 10 years: 6 L/min >10 years: 8 L/min	

[1] If PaO_2 not available, wean FiO_2 to maintain SpO2 ≤ 97% to calculate OSI

[2] Given lack of available data, for patients on an oxygen blender, flow for at risk calculation = FiO_2* FlowRate (L/min) (e.g. 6L/min flow at 0.35 FiO_2 = 2.1 L/min)

Figure 2. At risk of pediatric acute respiratory distress syndrome (PARDS) definition. [1]If Pao_2 is not available, wean Fio_2 to maintain $Spo_2 \leq 97\%$ to calculate oxygen saturation index (OSI). [2]Given lack of available data, for patients on an oxygen blender, flow for at-risk calculation = Fio_2 × flow rate (L/min) (e.g., 6 L/min flow at 0.35 Fio_2 = 2.1 L/min). BiPAP = bilevel positive airway pressure, CPAP = continuous positive airway pressure, OI = oxygenation index.

Khemani RG et al, Pediatr Crit Care Med 2015

Lancet Respir Med 2017;
5: 657–66
Published Online
July 4, 2017
http://dx.doi.org/10.1016/
S2213-2600(17)30214-X

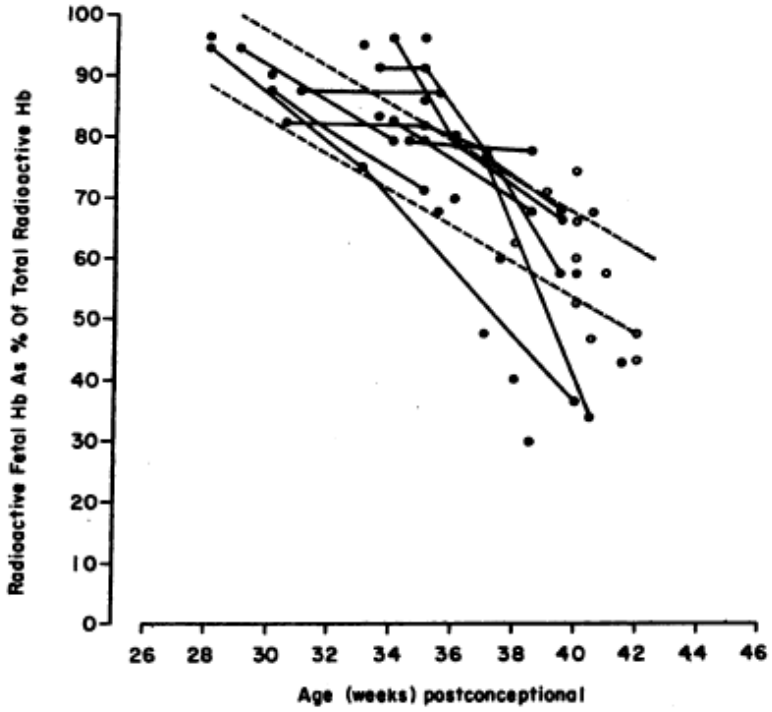
Position Paper

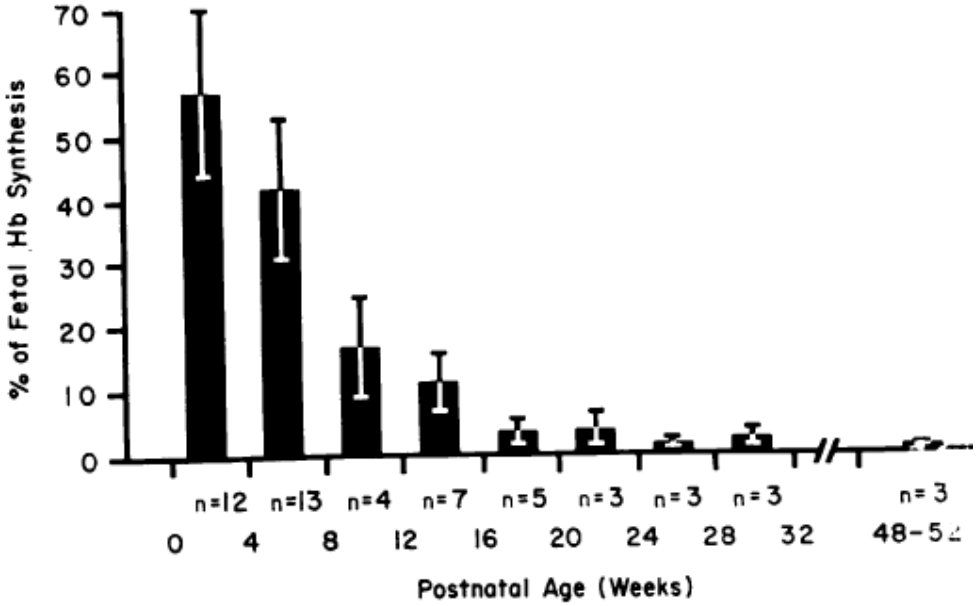
The Montreux definition of neonatal ARDS: biological and clinical background behind the description of a new entity

Daniele De Luca, Anton H van Kaam, David G Tingay, Sherry E Courtney, Olivier Danhaive, Virgilio P Carnielli, Luc J Zimmermann, Martin C J Kneyber, Pierre Tissieres, Joe Brierley, Giorgio Conti, Jane J Pillow, Peter C Rimensberger

interfaces of appropriate size.[64,65] Blood gas values from indwelling arterial lines should be used to calculate oxygenation index. However, obtaining arterial samples might be difficult in some neonates; transcutaneous oxygen tension is a reliable alternative measurement.[66–82] Thus, transcutaneous values are allowed in the calculation of oxygenation index when arterial values are unavailable,

Peculiarities of ARDS definitions



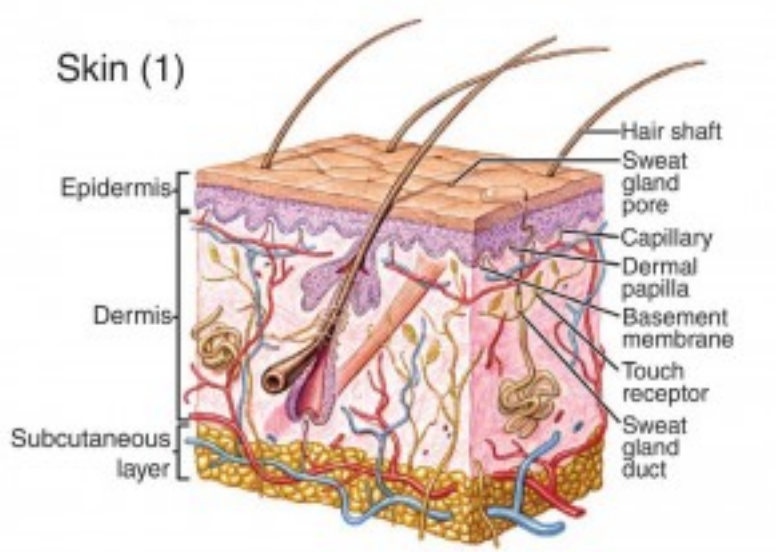


Bard H, J Clin Invest 1975 and 1973

TC Basics

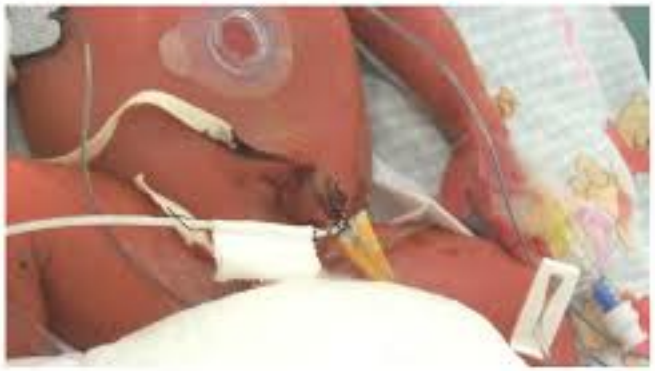
$PtcO_2$ and $PtcCO_2$ are measured in arterialised peripheral tissues

PaO_2 and $PaCO_2$ are measured in the arterial bloodstream

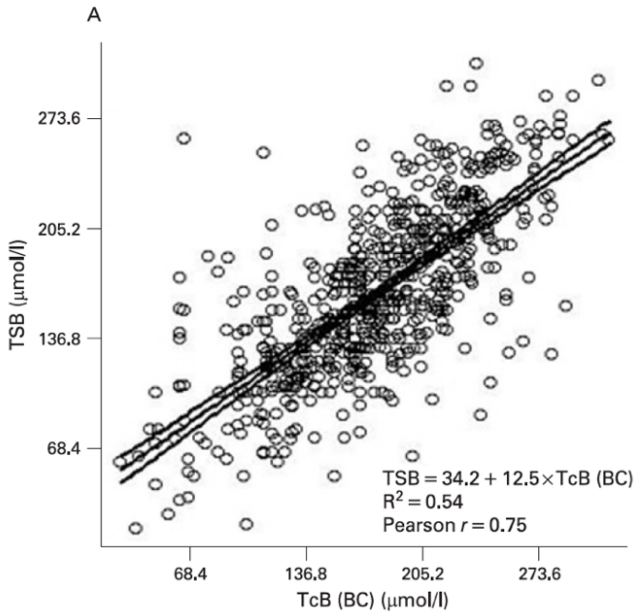


≠

Umbilical Artery Catheter (UAC)



Gives insight into local O_2 consumption and perfusion, cardiac output and acidosis



- TC bilirubinometry is widely used for monitoring a trend in bilirubin values
- Skin bilirubin is a basically related though strictly different from the circulating one
  - However, **there is a well-established linear correlation** between TC and serum bilirubin values

De Luca D et al, Arch Dis Child Fetal Neonatal Ed 2008
AAP. Pediatrics 2005

- pH < 7.02
- Mean BP < 33 mmHg
- Haematocrit < 30%
- Measurements at lower temperature
- Increasing age
- Increasing skin thickness

Under-reading

- Gap $PtcO_2/PaO_2$ <<<

Infections

Table 2. Neonatal Blood Gas Comparison and Clinical Outcome of the 2 Cohorts (N = 123; Blood Gas Measurements = 5,726)

	Pre-P_{tcCO_2} (n = 71)	Post-P_{tcCO_2} (n = 52)	P
Mechanical ventilation, median (IQR) d	7.8 (4.1–33.3)	8.7 (5.6–22)	.57
Use of any HFV, n (%)	32 (45.1)	29 (55.8)	.28
HFV, median (IQR) d	4.3 (2.4–7.8)	3.5 (3–7)	.66
BGs drawn/d of mechanical ventilation, median (IQR)	3.9 (2.6–5.3)	2.9 (2.1–4.0)	.002
BGs drawn/d of HFV, median (IQR)	6.6 (5.5–8)	4.7 (3.3–5.2)	<.001
% of BG P_{CO_2} values outside 35–70 mm Hg range, mean ± SD	19.4 ± 8.7	17.8 ± 8.4	.48
% of arterial BG/patient, mean ± SD	62.6 ± 33.8	64.9 ± 28.8	.71
% of capillary BG/patient, mean ± SD	47.1 ± 31.5	45.7 ± 31.8	.82
% of venous BG/patient, mean ± SD	7.7 ± 13.3	5.1 ± 3.0	.45
Postnatal steroid use, n (%)	3 (4.2)	1 (1.9)	.64
Bronchopulmonary dysplasia, n (%)	25 (35.2)	24 (46.2)	.27
Retinopathy of prematurity, n (%)	5 (7)	3 (5.8)	.66
Necrotizing enterocolitis, n (%)	10 (14.1)	5 (9.6)	.58
Surgical necrotizing enterocolitis, n (%)	6 (8.5)	3 (5.8)	>.99
Intraventricular hemorrhage, n (%)	15 (21.1)	14 (26.9)	.52
Patent ductus arteriosus, n (%)	53 (74.7)	42 (80.7)	.52
Early onset sepsis, n (%)	2 (2.8)	1 (1.9)	>.99
Late onset sepsis, n (%)	12 (16.9)	6 (11.5)	.37
Failed hearing screen, n (%)	5 (7.0)	2 (3.9)	.38
No. of blood transfusions, mean ± SD	6.1 ± 5.4	5.8 ± 3.8	.68
Disposition, n (%)			.43
Home	52 (73.2)	42 (80.8)	
Died	9 (12.7)	3 (5.8)	
Transferred	10 (14.1)	7 (13.5)	
Mortality, n (%)	9 (12.7)	3 (5.8)	.24
Median d of hospital stay (IQR)*	89 (49–107)	95 (81–105)	.21

Mukhopadhyay S et al, Respir Care 2016

Rudiger M, BMC Pediatr 2005

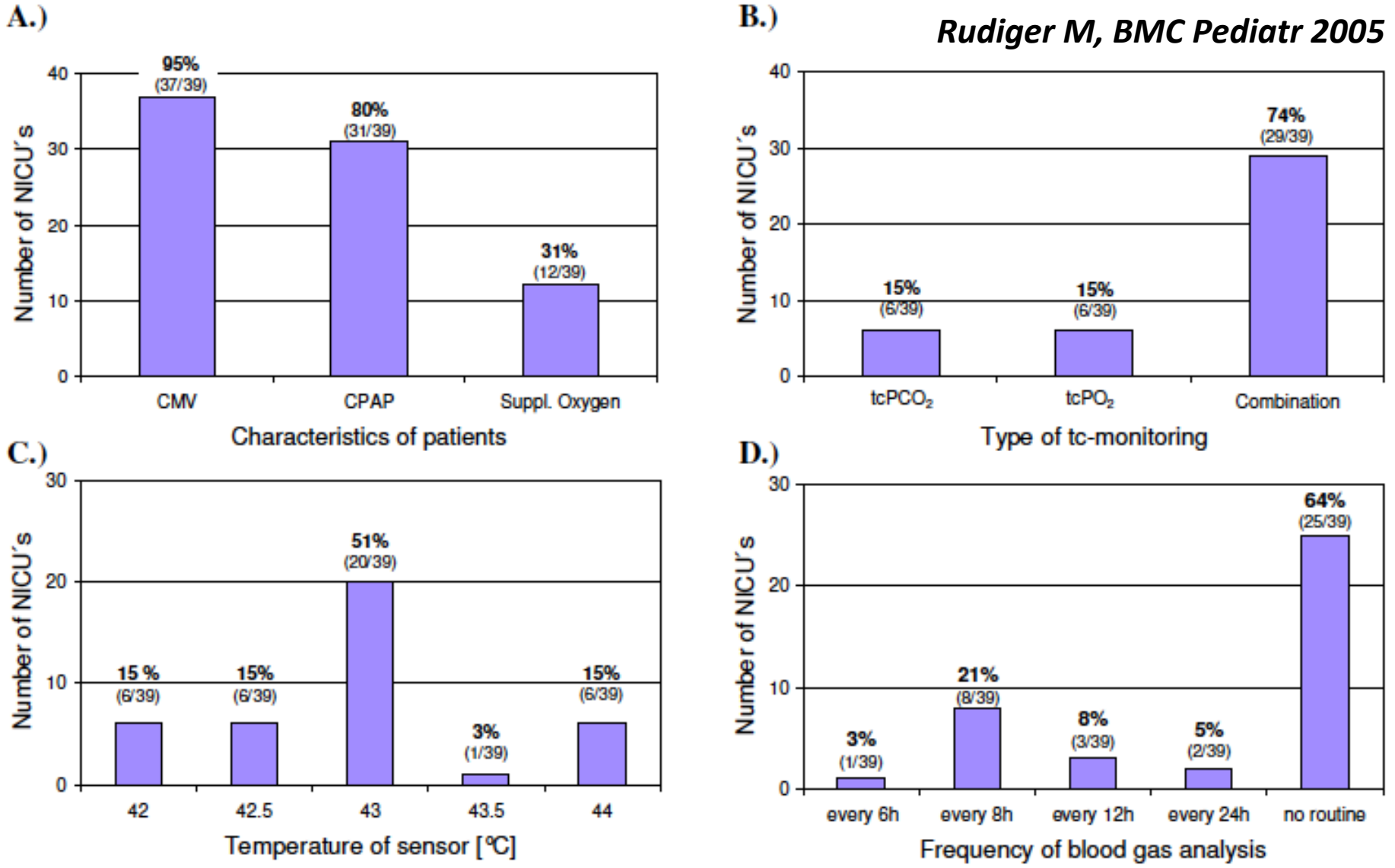
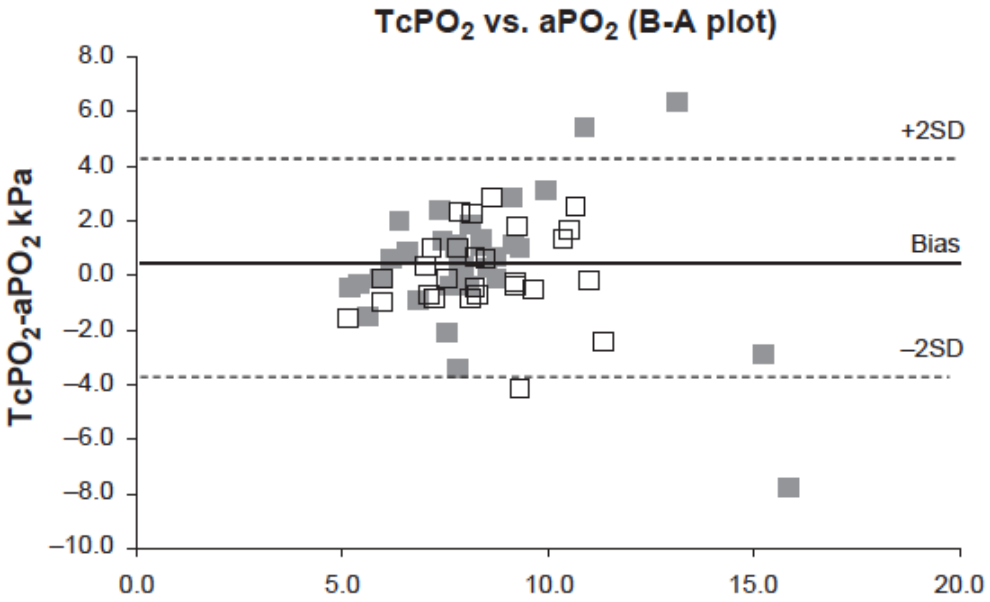
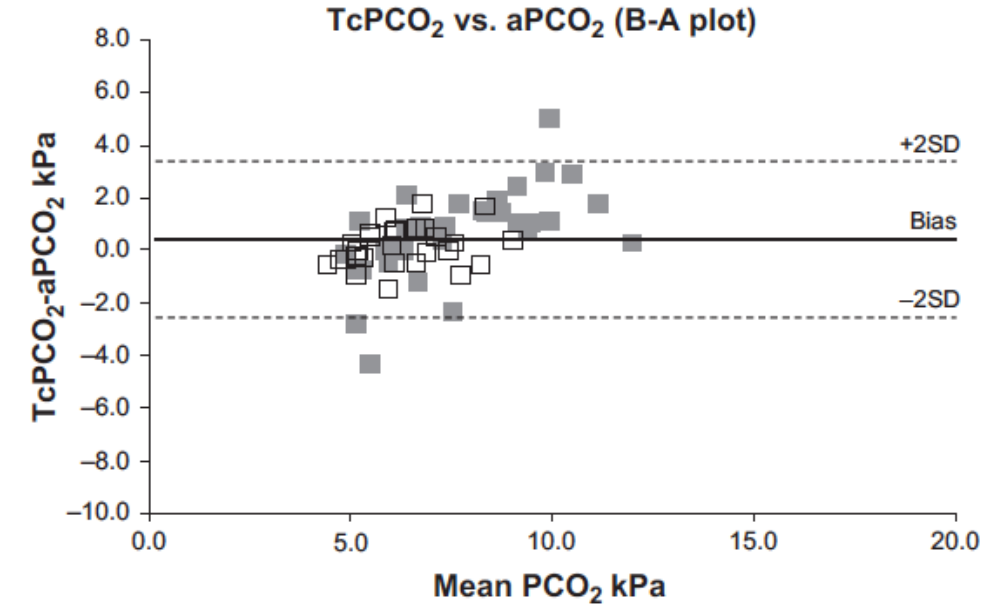


Figure 1

Shown are the number of NICUs. (A) that use tc monitoring on patients on conventional mechanical ventilation (CMV), continuous positive airway pressure support (CPAP) or supplemental oxygen (suppl. oxygen) [multiple answers were possible]; (B) that use a combination of tc PO_2 and tc PCO_2 sensors (Combination), or a single sensor; (C) that use a sensor temperature of 42°, 42.5°, 43°, 43.5° or 44°C; (D) that compare tc values with blood gases routinely every 6, 8, 12 or 24 h or do not have a specified routine.



	Bias (SD)	95% CI
All infants	0.3 (2.1)	−0.2 to 0.9
Body weight		
<1.0 kg	0.4 (2.4)	−0.4 to 1.3
≥1.0 kg	0.2 (1.6)	−0.4 to 0.8
Age		
≤7 day	0.6 (1.9)	−0.1 to 1.3
> 7 day	0.01 (2.2)	−0.3 to 0.9
FiO_2		
<0.30	0.8 (2.2)*	0.06 to 1.6
≥0.30	−0.2 (2.0)	−0.9 to 0.7



	Bias (SD)	95% CI
All infants	0.4 (1.4)*	0.03 to 0.8
Body weight		
<1.0 kg	0.6 (1.8)*	0.02 to 1.2
≥1.0 kg	0.1 (0.8)	−0.04 to 0.3
Age		
≤7 day	0.01 (0.7)	−0.2 to 0.3
>7 day	0.7 (1.8)*†	0.1 to 1.4
FiO_2		
<0.30	0.4 (1.1)	−0.05 to 0.8
≥0.30	0.4 (1.7)	−0.2 to 1.0

Sandberg KL, Acta Paediatr 2011

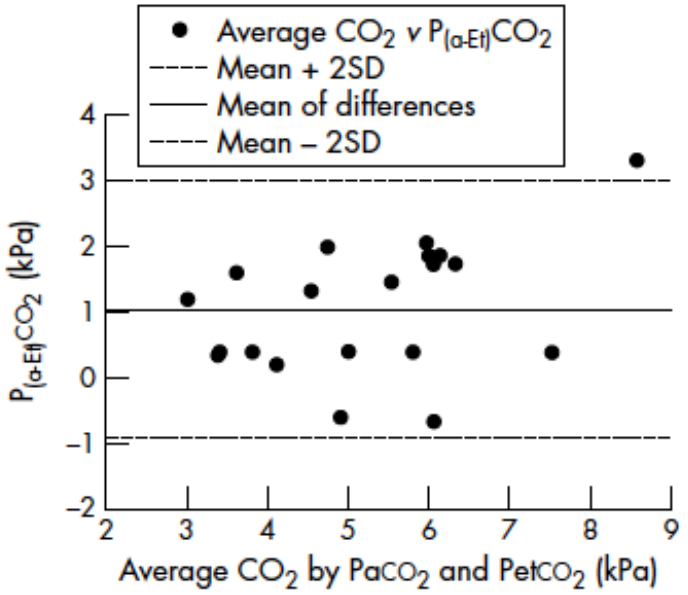


Figure 1 Bland-Altman plot of the difference between $PaCO_2$ and $PetCO_2$ ($P_{(a-Et)}CO_2$) against average CO_2.

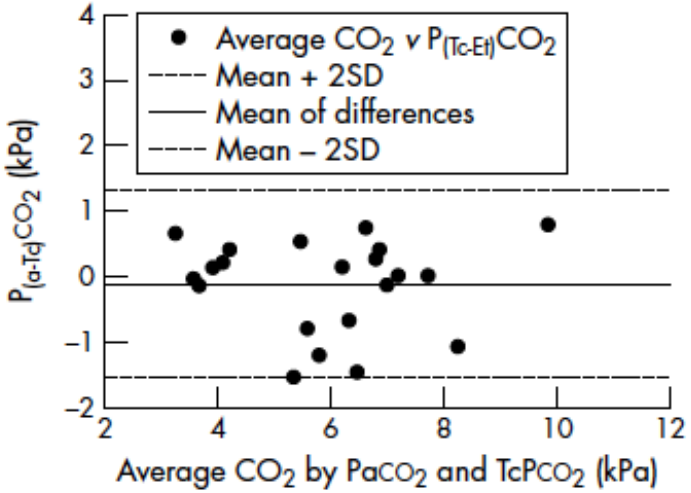


Figure 2 Bland-Altman plot of the difference between $PaCO_2$ and $TcPCO_2$ ($P_{(a-Tc)}CO_2$) against average CO_2.

Table 1 Characteristics of the 21 subjects enrolled in study

	Median	Range
Gestational age (weeks)	35	26–40
Birth weight (g)	2260	930–4600
Age at enrolment (hours)	4.8	1.8–61.2
Transportation time (minutes)	65	20–180

	Mean (SD)	Range
pH	7.32 (0.12)	7.1–7.55
FIO_2	0.52 (0.24)	0.21–1.0
PAO_2/PaO_2 ratio	0.85 (1.3)	0.03–5.9

Primary diagnosis	Number
Respiratory failure	15
Cyanotic heart disease	2
Persistent pulmonary hypertension of the newborn	1
Severe anaemia	1
Birth asphyxia	1
Multiple congenital abnormalities	1

FIO_2, Inspired oxygen fraction; PAO_2/PaO_2 ratio, alveolar-arterial oxygen tension ratio.

Tingay D et al, Arch Dis Child Fetal Neonatal Ed 2005

Why is monitoring pO_2 and pCO_2 so important in the NICU?

Blood gas monitoring requires a personalised approach, based on the severity of the situation

- Technology is complementary to the clinical picture
- It is important to be aware of the limitations of each monitoring modality

TCM is valuable in unstable children and children requiring respiratory support

- tcpO_2 provides information on oxygenation
- tcpCO_2 provides information on ventilation

TCM, transcutaneous monitoring; tcpCO_2, transcutaneous partial pressure of carbon dioxide; tcpO_2, transcutaneous partial pressure of oxygen.

Preterm neonates are vulnerable to changes in blood gas values

High oxygen partial pressure (pO_2)

- Oxidative damage[1] is associated with
  - Acute lung injury and bronchopulmonary disease (BPD)[2]
  - Retinopathy of prematurity (ROP)[3]
  - White matter injury[1]
  - Oxygen organ toxicity[4]

High carbon dioxide partial pressure (pCO_2)

- Increased risk of brain injury[8]
- Increased mortality[9]

Low pO_2

- Centralised blood flow to brain and heart is associated with an increased incidence of
  - Necrotising enterocolitis (NEC)[3]
  - Acute kidney failure[5]
- Pulmonary arterial hypertension (PAH)[6]
- Impaired neurological development[7]
- Increased mortality[8]

Low pCO_2

- Associated with increased incidence of BPD[2,10]
- Causes reduction in cerebral blood flow[10]
  - Increased risk of ischemia
  - Increased risk of white matter injury
  - Increased risk of adverse neurologic outcome
- Limits cerebral metabolism[10]

1. Perrone S, et al. Front Pediatr. 2017;4:143. 2. Northway WH. Arch Dis Child. 1990; 65(10 Spec No):1076–1081. 3. BOOST II United Kingdom, Australia, and New Zealand Collaborative Groups. N Engl J Med. 2013;368:2094-104. 4. Sola A, et al. Acta Paediatr. 2014;103:1009-18. 5. Husain-Syed F, et al. Am J Respir Crit Care Med. 2016;194:402-14. 6. Danhaive O, et al. J Perinatol. 2005;25:495-9. 7. Sweet DG, et al. Neonatology. 2017;111:107-125. 8. Askie LM, et al. Cochrane Database Syst Rev. 2017;4:CD011190. 9. Thome UH, et al. Neonatology. 2018;113:221-230. 10. Erickson SJ, et al. J Paediatr Child Health. 2002;38:560-2.

- **Poor neurodevelopmental outcome in NICU survivors**
  - Serenius F et al. JAMA. 2013;309(17):1810-1820
  - Smith GC et al. Ann Neurol. 2011 Oct;70(4):541-9

- **Generally accepted correlation between arterial pCO_2 pressure and cerebral blood flow**

  Ambalavanan N, Carlo WA. Hypocapnia and hypercapnia in respiratory management of newborn infants. Clin Perinatol 2001; 28(3): 517-531
  Collins et al., Hypocapnia and other ventilation related risk factors for cerebral palsy in low birth weight infants; Pediatr Res. 2001 Dec;50(6):712-9
  - Pryds O et. al. Cebral blood flow reactivity in spontaneously breathing, preterm infants shortly after birth. Acta Paediatr Scand 1990; 79; 391-96

- **Effects of $PaCO_2$ on Cerebral Autoregulation**
  - Pediatr Res. 2005 Nov;58(5):931-5
  - Curley *et al. Critical Care 2010, 14:220*

- **Hypercapnia is associated with IVH**
  - J R Kaiser; Hypercapnia during the first 3 days of life is associated with severe intraventricular hemorrhage in very low birth weight infants; Journal of Perinatology volume 26, pages 279–285 (2006)

- **Hyperoxia reduces Cerebral Blood Flow**
  - Niijima S, et.al. Transient hyperoxia and cerebral blood flow velosity in infants born prematurely and at full term. Arch Dis Child 1988; 63: 1126-30
  - Cerebral perfusion response to hyperoxia; Daniel P Bulte, et al.; Journal of Cerebral Blood Flow & Metabolism (2007) 27, 69–75
  - Daniel P Bulte, Peter A Chiarelli et al., Cerebral perfusion response to hyperoxia; Journal of Cerebral Blood Flow & Metabolism (2007) 27, 69–75

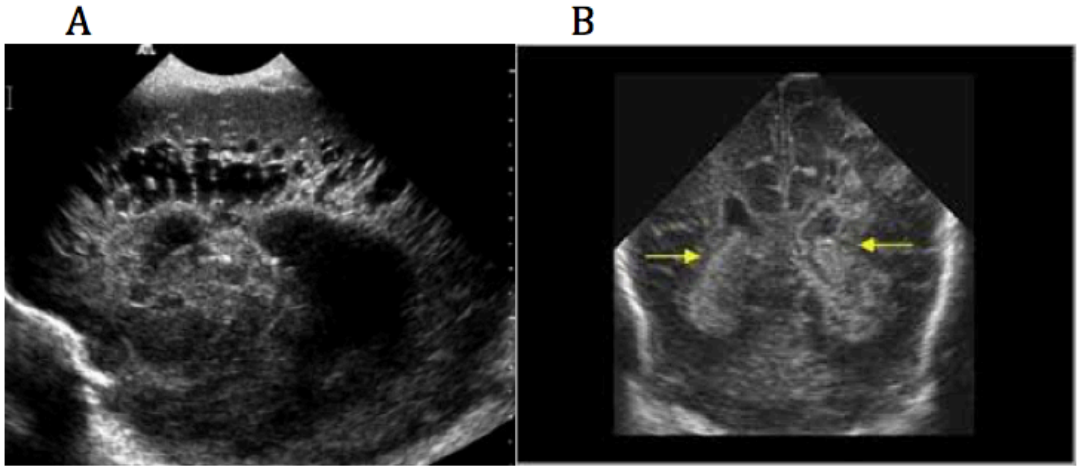
- **Negative effects of altered oxygen levels on the growing lung**
  - Buczynski et al. Semin Perinatol. 2013 April ; 37(2): 69–78
  - Can J Physiol Pharmacol. 2015 February ; 93(2): 119–127

- **Oxygen Toxicity and Retinopathy of Prematurity (ROP)**
  - Fleck,IMcIntosh, -Pathogenesis of retinopathy of prematurity and possible preventive strategies; **Early Human Development, 2008,** Vol.84, Pages 83-88

- **Hyperoxia is an unintended consequence of intervention with high risk of complications**
  - Deuber et al., The Journal of Perinatal & Neonatal Nursing: July/September 2011 - Volume 25 - Issue 3 - p 268–274

The importance of CO_2 monitoring:
CO_2 plays an important role in the cerebral circulation

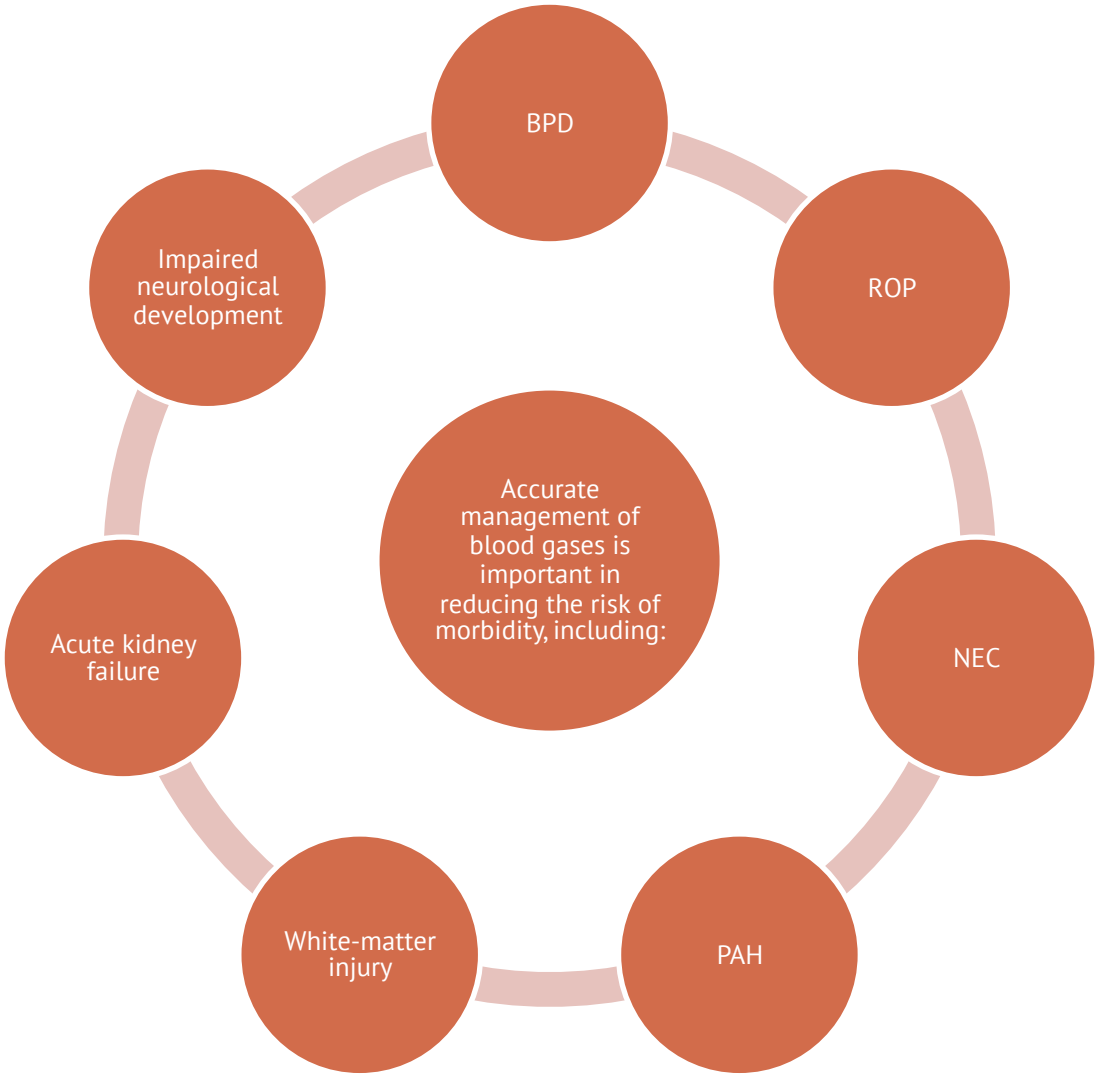
- Due to the **lack of cerebral autoregulation**, preterm infants are at **higher risk of ischemic lesions**, such as periventricular leukomalacia (A) or **white matter injury** when exposed to low $PaCO_2$ (hyperventilation) or high PaO_2 (uncontrolled hyperoxygenation) levels
- Similarly, high $PaCO_2$ or low PaO_2 (respiratory failure, insufficient ventilatory support) may predispose to **cerebral haemorrhage** (B)



CO_2, carbon dioxide; $PaCO_2$, partial pressure of carbon dioxide in arterial blood; PaO_2, partial pressure of oxygen in arterial blood.

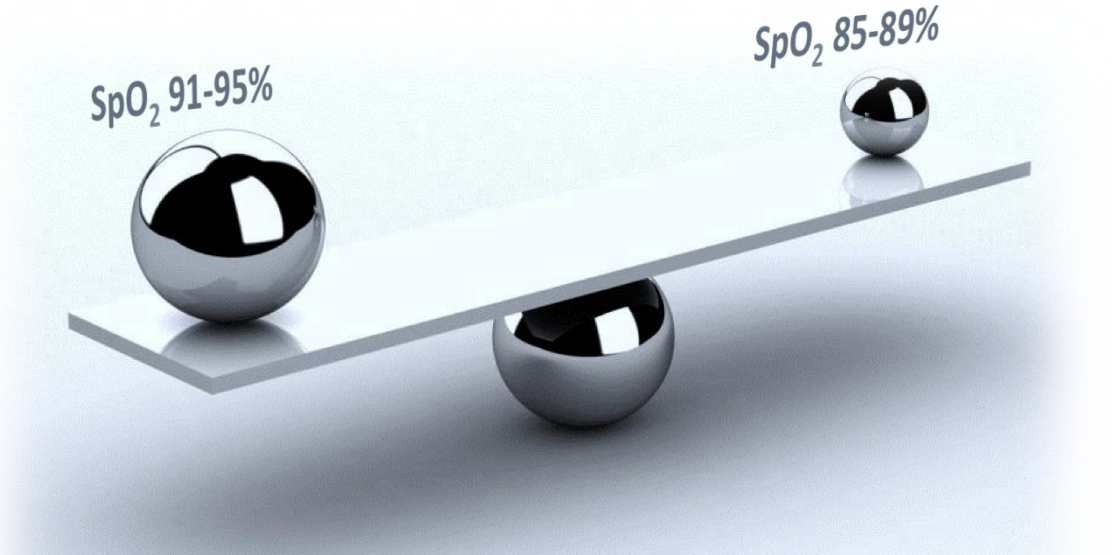
ACCURATE MANAGEMENT OF BLOOD GASES IS IMPORTANT IN REDUCING THE RISK OF MORBIDITY

COR2ED
THE HEART OF MEDICAL EDUCATION



BPD, bronchopulmonary disease; NEC, necrotizing enterocolitis; PAH, pulmonary arterial hypertension; ROP, retinopathy of prematurity.

SpO_2 during supplementary O_2 isn't enough



- SpO_2 > 91% with higher risk of ROP and extended O_2-demand
- SpO_2 < 90% with increased Mortality and Incidence of NEC

- „good" and „bad" saturation limits are very close

Is there an "optimal" Saturation??

Satyan Lakshminrusimha et. Al.: Oxygen Targeting in Preterm Infants, J Perinatology 2015; 35(1):8-15
Augusto Sola, et al.; Safe oxygen saturation targeting and monitoring in preterm infants: can we avoid hypoxia and hyperoxia? Acta Paediatrica. 2014 103, pp. 1009–1018
Saugstad and Auna, Meta-Analysis and systematic review of SpO2 target studies, Neonatology 2014;105:55-53
Askic LM, Henderson-Smart DJ. Restricted versus liberal oxygen exposure for preventing morbidity and mortality in preterm or low birth weight infants. Cochrane Database Syst Rev 2001; 4: CD 001077.v

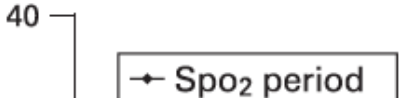


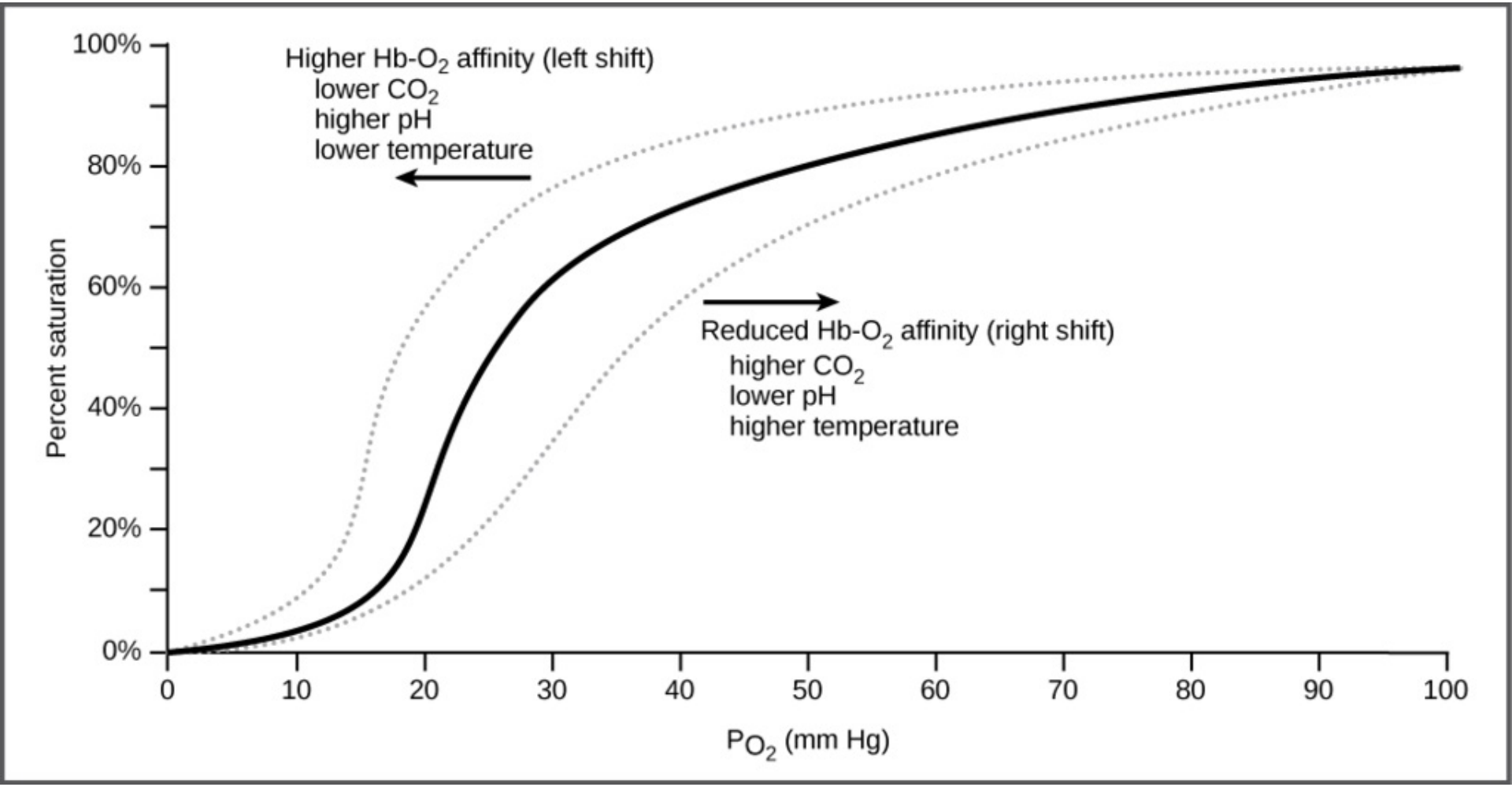
Table 2 Summary data for stability of oxygenation

	Monitor on display to clinical staff		Median difference within patients (Spo_2 period minus $TcPo_2$ period)	Significance (p value)
	$TcPo_2$	Spo_2		
Mean $TcPo_2$ (kPa)	6.91 (6.34 to 7.48)	6.41 (5.54 to 7.20)	−0.33 (−1.1 to −0.03)	0.09
% time with $TcPo_2$ >9.0 kPa	0.14 (0.48 to 3.33)	1.57 (0.31 to 9.53)	2.62 (0.12 to 13.24)	0.01
% time with $TcPo_2$ <6.0 kPa	11.3 (3.94 to 15.4)	31.3 (10.4 to 60.12)	17.41 (3.15 to 40.20)	0.01
Variability (SD) of $TcPo_2$ (kPa)	0.79 (0.41 to 1.00)	1.07 (0.58 to 1.27)	0.28 (0.01 to 0.64)	0.02
Mean Spo_2 (%)	92.8 (90.6 to 94.5)	91.7 (90.3 to 92.1)	−1.16 (−3.24 to 0.71)	0.06
% time with Spo_2 >94%	16.1 (7.07 to 55.47)	12.1 (4.15 to 29.14)	−1.71 (−34.78 to 0.22)	0.06
% time with Spo_2 <86%	0.43 (0 to 7.91)	4.50 (1.34 to 12.35)	1.53 (−0.75 to 5.61)	0.23
Variability (SD) of Spo_2 (%)	2.75 (1.44 to 4.04)	3.33 (1.98 to 4.61)	0.82 (−0.02 to 1.89)	0.01

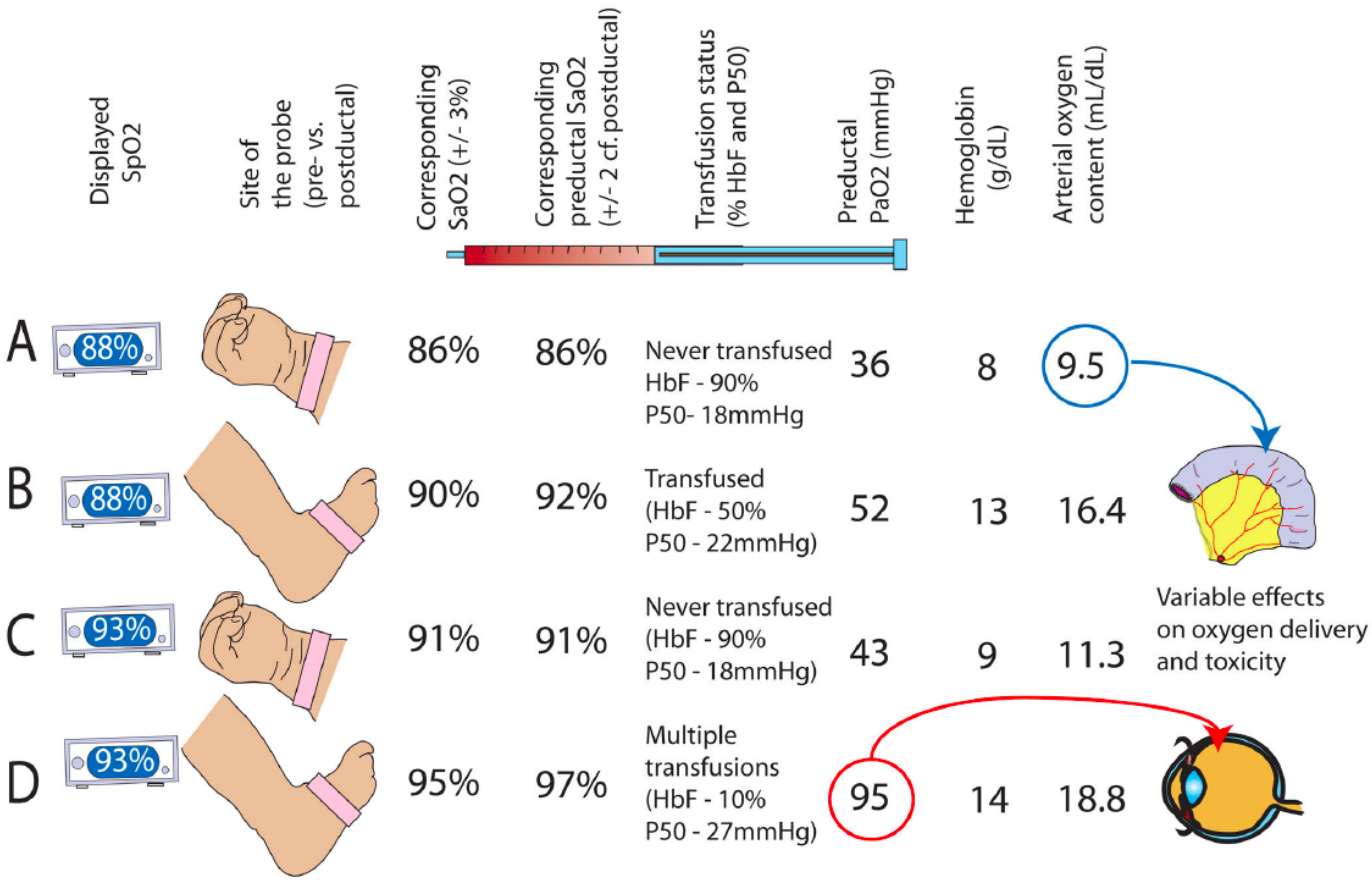
Data are median (interquartile range).

the method of monitoring in clinical use. Combined data from all of the study infants.

Quine D et al, Arch Dis Child Fetal Neonatal Ed 2008


100%
80%
60%
40%
20%
0%
Percent saturation
Higher Hb-O2 affinity (left shift)
lower CO2
higher pH
lower temperature
Reduced Hb-O2 affinity (right shift)
higher CO2
lower pH
higher temperature
0
10
20
30
40
50
60
70
80
90
100
PO2 (mm Hg)

DO NOT trust *only* SpO_2 !!!!!



Lakshminrusimha S et al, J Perinatol 2015

And also !!!!

Table 3. Exposure to $tcPO_2$ ≥80 mm Hg during Weeks 1 through 4 in the 101 Infants Studied.

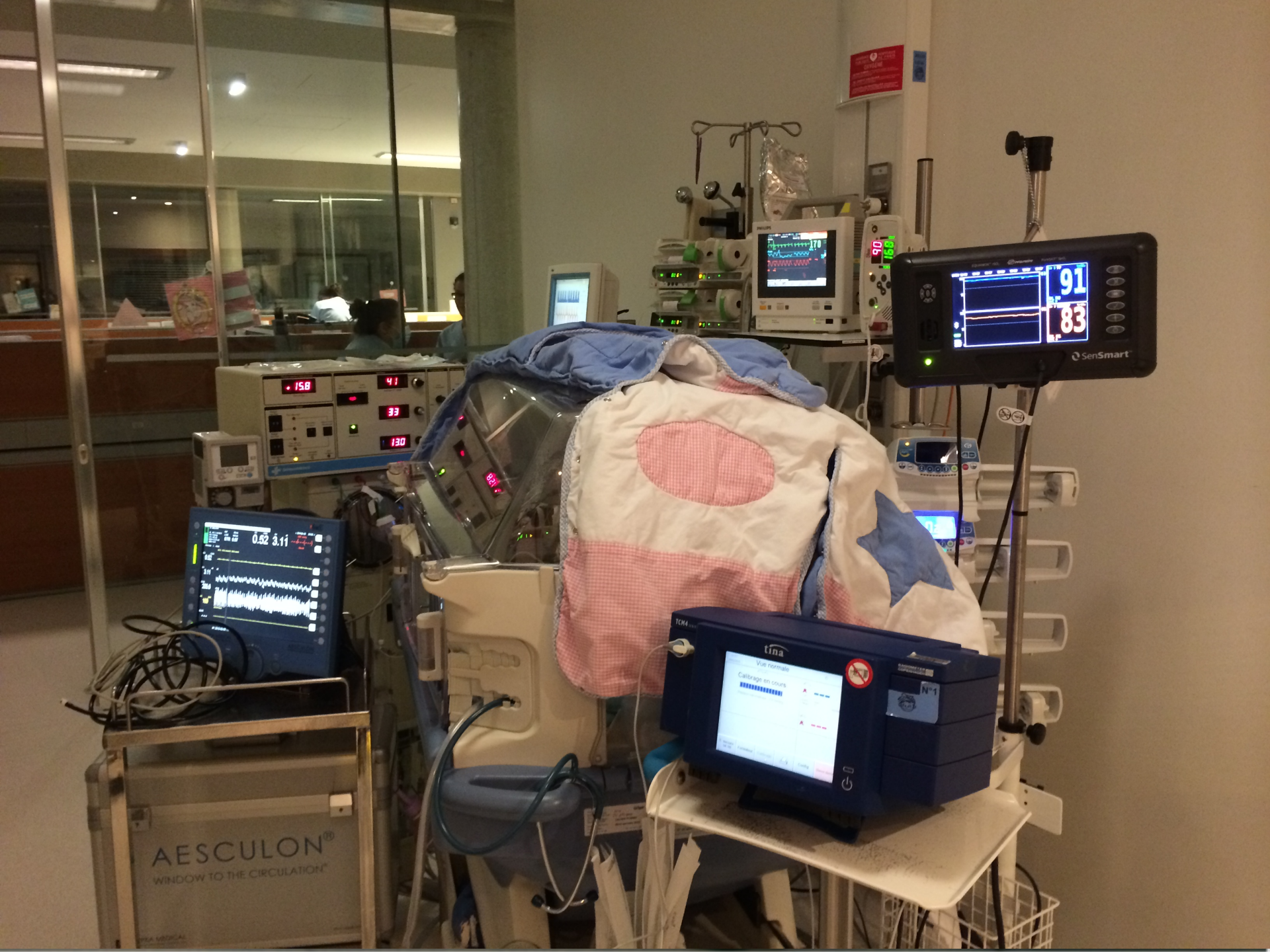
Variable	Retinopathy		
	Moderate or severe (N = 15)	Mild (N = 37)	None (N = 49)
	no. of hours		
Mean ±SD	33.9±19.4	18.6±11.3	9.8±9.9
Median	35.6	16.5	6.3
Range	2–61	1–54	1–50
	no. (%) of infants		
Duration (hr)			
≥12	13 (25)	26 (50)	13 (25)
<12	2 (4)	11 (22)	36 (73)

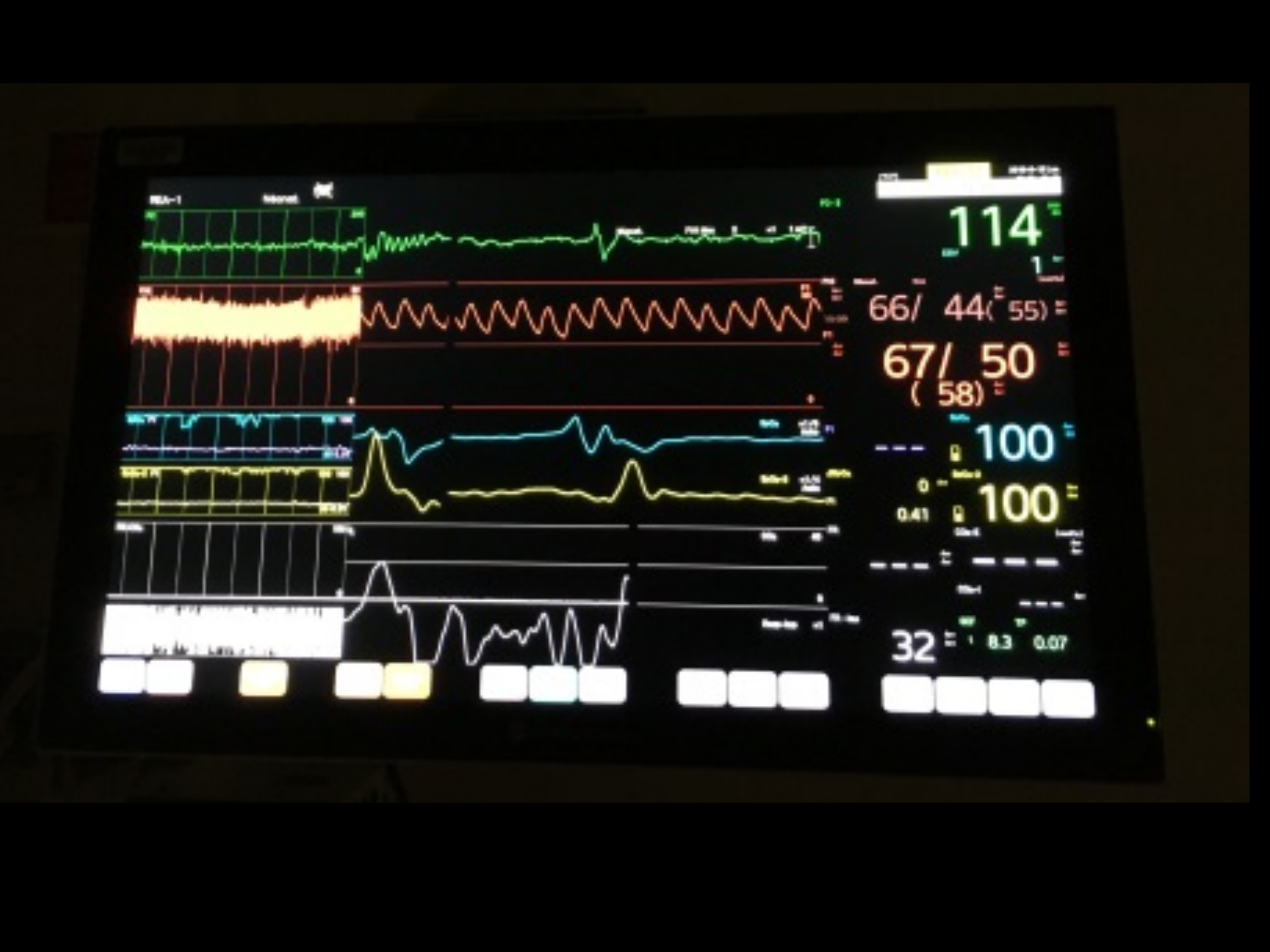
Table 4. Unadjusted and Adjusted Odds Ratios and 95 Percent Confidence Intervals in the Ordinal Logistic-Regression Model for the 101 Infants Studied.*

Variable	Unadjusted	Adjusted
	odds ratio (95% CI)	
$tcPO_2$ ≥80 mm Hg (per 12-hr period)	3.0 (2.0–4.5)	1.9 (1.2–3.0)
Birth weight (per 100-g decrement)	2.4 (1.8–3.2)	2.3 (1.6–3.4)
5-Minute Apgar score (≤7 vs. >7)	5.3 (2.3–12.2)	7.2 (2.5–21)
Supplemental oxygen (FiO_2 ≥0.4) during entire hospitalization (per 72-hr period)	1.4 (1.1–1.8)	1.0 (0.97–1.05)

*The adjusted odds ratios were adjusted for the other variables shown. CI denotes confidence interval, and FiO_2 fraction of inspired oxygen.

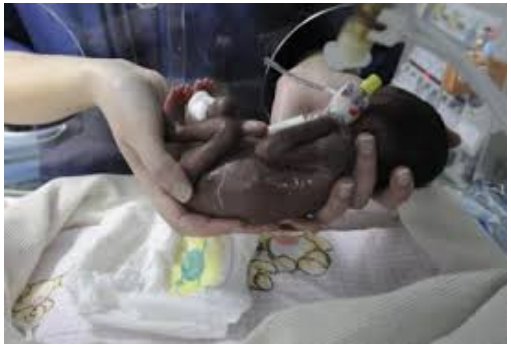
Flynn TJ et al, NEJM 1992


AESCULON
WINDOW TO THE CIRCULATION
tina
SenSmart
91
83


114
66/ 44(55)
67/ 50
(58)
100
100
0.41
32
8.3
0.07

44°C
NICU admission
(max 15-20 min)

44°C
When required
(relevant vent changes, iNO etc)
(max 15-20 min)



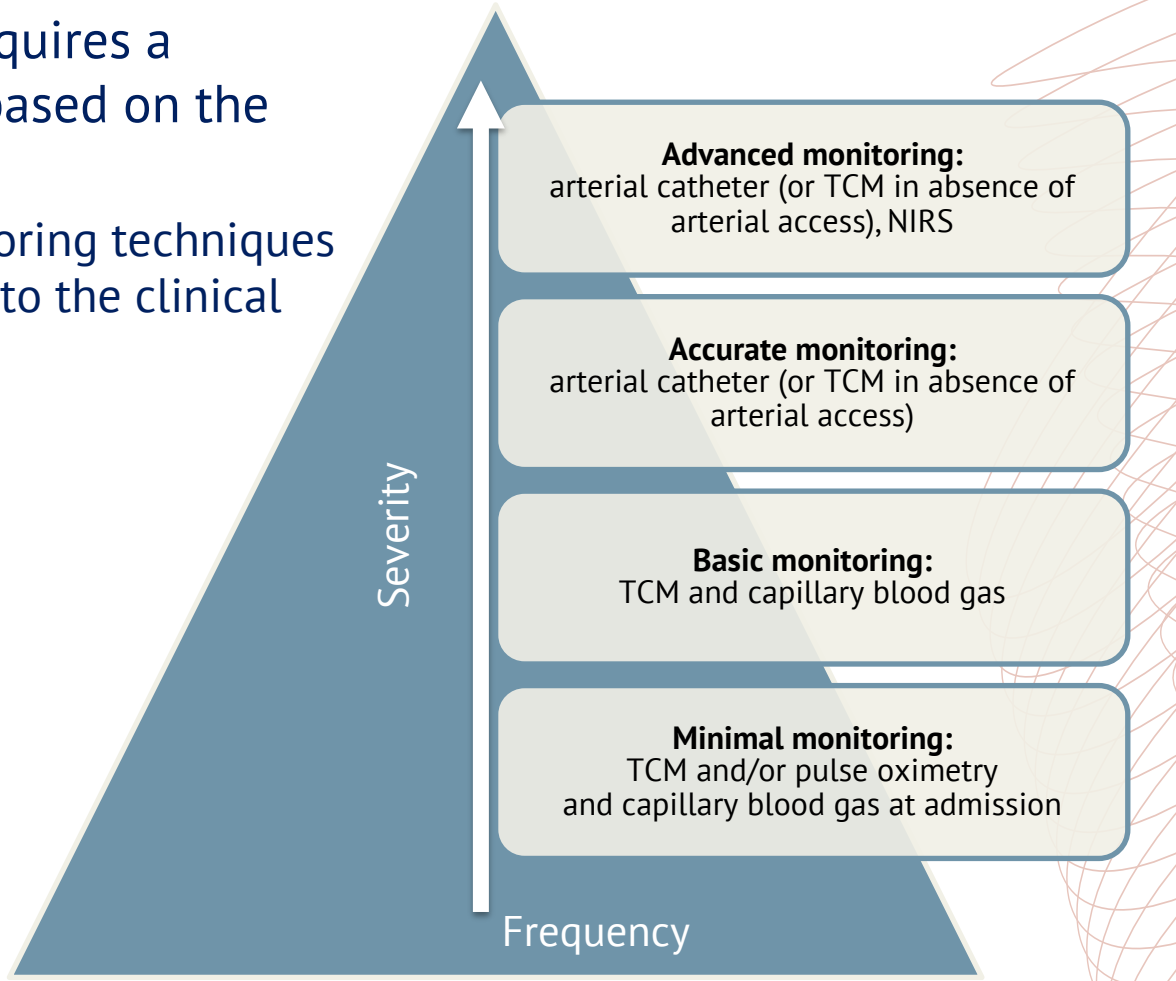
41.5/42°C
Routine monitoring

CONCLUSION

COR2ED
THE HEART OF MEDICAL EDUCATION

Blood gas monitoring requires a **personalised approach**, based on the severity of the situation

- The different monitoring techniques are complementary to the clinical picture



Modified with permission from: De Luca D, et al. J Pédiatrie Puériculture. 2015;28:276-300.
NIRS, near-infrared spectroscopy; TCM, transcutaneous monitoring

THANK YOU FOR YOUR ATTENTION

COR2ED
THE HEART OF MEDICAL EDUCATION

ANY QUESTIONS?

NADYA.YOUSEF@APHP.FR