Pulse Oximetry in the Delivery Room:
Principles and Practice

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The speaker has signed a disclosure statement indicating that he has no significant financial interest or relationship with the companies or the manufacturer(s) of any commercial product and/or service that will be discussed as part of this presentation.

Session Summary
The use of pulse oximetry monitoring in the delivery room setting will be discussed, ranging from its initial introduction into newborn resuscitation techniques progressing to updates regarding pulse oximetry use in the Neonatal Resuscitation Program paradigm. The rationale for initial fraction of inspired oxygen (FiO2) selection and titration methods will be explained. Studies will be presented on the importance of avoiding excessive oxygen exposure in the delivery room.

Session Objectives
Upon completion of this presentation, the participant will be able to:
▪ state the rationale for use of oxygen saturation monitoring in the delivery room;
▪ convey the expected range of observed oxygen saturations during neonatal transition;
▪ delineate outcomes associated with excessive oxygen exposure in the delivery room.

References


Targeted Oxygen Saturation Monitoring in the Delivery Room

Florida Association for Neonatal Nurse Practitioners
Clinical Update and Review
October 17, 2017

Jonathan P. Mintzer, MD, FAAP

OVERVIEW

1) Recommendations
   o 2005 American Heart Association
   o 2010 International Consensus
   o 2015 International Consensus

2) Studies
   o Oximeter usage
   o Normative data
   o Oxygen titration

3) Conclusions

RECOMMENDATIONS


2005 AHA RECOMMENDATIONS

administration of supplementary oxygen. Evidence obtained with continuous oximetry, however, has shown that neonatal transition is a gradual process. Healthy infants born at term may take >10 minutes to achieve a predial oxygen saturation >95% and nearly 1 hour to achieve postdual saturation >95% (LOE 5).24–26 Cen-

Administration of a variable concentration of oxygen guided by pulse oximetry may improve the ability to achieve normoxia more quickly. Concerns about potential oxidant injury should caution the clinician about the use of excessive oxygen, especially in the premature infant.


2010 INTERNATIONAL CONSENSUS

- Progression to the next step following the initial evaluation is now defined by the simultaneous assessment of 2 vital characteristics: heart rate and respirations. Oximetry should be used for evaluation of oxygenation because assessment of color is unreliable.

- Administration of supplementary oxygen should be regulated by blending oxygen and air, and the concentration delivered should be guided by oximetry.

2010 INTERNATIONAL CONSENSUS

Treatment Recommendations
Heart rate should remain the primary vital sign by which to judge the need for and efficacy of resuscitation. Auscultation of the precordium should remain the primary means of assessing heart rate. There is a high likelihood of underestimating heart rate with palpation of the umbilical pulse, but this is preferable to other palpation locations.


2015 INTERNATIONAL CONSENSUS

• Use of pulse oximetry now well established

the initial oxygen concentration should be. Babies born at term should be started in air (21%), but there has been uncertainty as to whether the preterm baby should be started in a high concentration (50–100%) versus low concentration (21–30%) of oxygen while the pulse oximetry is being attached. This PICO question was intended to examine only the starting concentration of administered oxygen, not the targets.


Why Use Pulse Oximetry?

Subjective assessment of color
Vs.
Objective assessment of oxygenation

**O’DONNELL, 2007**

- HD video analysis of 20 deliveries
- \( n=27; \) NICU personnel
  - Neonatologist (7), Fellow (5), Nurse (14), Clerk (1)
- Report of “pink at beginning,” “became pink,” or “never pink”
- Results compared to \( \text{SpO}_2 \) monitoring

![Graph showing the proportion (%) of neonates who determined infants as “(2) videos not pink” according to the infants' highest oxygen saturation \( \text{SpO}_2 \) during the video clip.]


**Conclusion**

Color assessment alone is insufficient for assessing oxygenation status.


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**OXIMETER PROBLEMS**

**Difficulty with Pulse Oximeter Usage in Delivery Room?**

<table>
<thead>
<tr>
<th>Failure to obtain/maintain signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion artifact</td>
</tr>
<tr>
<td>Acrocyanosis</td>
</tr>
<tr>
<td>Presence of vernix</td>
</tr>
<tr>
<td>Cracked/wrinkled skin</td>
</tr>
<tr>
<td>Low perfusion</td>
</tr>
<tr>
<td>Tissue edema</td>
</tr>
<tr>
<td>High ambient light</td>
</tr>
<tr>
<td>Large infants</td>
</tr>
</tbody>
</table>

Dawson JA & Morley CJ. Seminars in Fetal & Neonatal Medicine, 2010.
Obtaining a Pulse Oximetry Signal

Does technique of probe placement affect time to first SpO2 measure?

O’DONNELL, 2005

• Probe placement study
• n=40; stable NICU babies
  – Masimo Radical; preductal only
  – 3 probe application techniques
• Outcome: time to data collection (displayed heart rate)

Probe placement techniques:
1) Sensor connected to cable, then infant
2) Sensor connected to cable, then investigator’s finger, then infant
3) Sensor applied to infant, then connected to cable

O’DONNELL, 2005

Table 1: Time taken to apply the sensor and display data for each method of application

<table>
<thead>
<tr>
<th>Method</th>
<th>Time to apply sensor (s)</th>
<th>Time to display accurate HR (s)</th>
<th>Total time to display accurate HR data (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1</td>
<td>9 (2)</td>
<td>23 (20)</td>
<td>32 (21)</td>
</tr>
<tr>
<td>Method 2</td>
<td>10 (2)</td>
<td>18 (17)</td>
<td>28 (17)</td>
</tr>
<tr>
<td>Method 3</td>
<td>12 (3)</td>
<td>13 (4)</td>
<td>25 (7)</td>
</tr>
</tbody>
</table>

Values are mean (SD). Method 1, sensor connected to oximeter, then to neonate; method 2, sensor connected to oximeter, applied to investigator’s finger, then to neonate; method 3, sensor applied to neonate, then connected to oximeter. HR: Heart rate.
Conclusions

- Probe placement technique affects time to first measure.
- First apply sensor to infant, then attach to cable.


Interpretation of Pulse Oximetry?

- Normative study
- n=468 newborns
  - No resuscitation, no O2 usage
- Immediate preductal oximetry
- Creation of normative curves


What’s NORMAL for a newborn?

Change over time?
Preterm vs. Term?
Vaginal vs. Cesarean?


<table>
<thead>
<tr>
<th>TABLE 1 Infant Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kamin</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>n (%)</td>
</tr>
<tr>
<td>Gestational age, mean (SD), wk</td>
</tr>
<tr>
<td>Preterm (&lt;32 wk), n (%)</td>
</tr>
<tr>
<td>Preterm (32-36 wk), n (%)</td>
</tr>
<tr>
<td>Term (37-41 wk), n (%)</td>
</tr>
<tr>
<td>Birth weight, mean ± SD, g</td>
</tr>
<tr>
<td>Labor remained, n (%)</td>
</tr>
<tr>
<td>Neonatal hypopproteinemia, n (%)</td>
</tr>
<tr>
<td>General anesthetic, n (%)</td>
</tr>
<tr>
<td>Vaginal birth, n (%)</td>
</tr>
<tr>
<td>Apgar score at 1 min, median (IQR)</td>
</tr>
<tr>
<td>Apgar score at 5 min, median (IQR)</td>
</tr>
<tr>
<td>Time from birth to first data, median (IQR)</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>TABLE 2 Comparison of SpO2 Values at 1 to 10 Minutes After Birth for Preterm and Term Births</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time after birth</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>1 min</td>
</tr>
<tr>
<td>2 min</td>
</tr>
<tr>
<td>3 min</td>
</tr>
<tr>
<td>4 min</td>
</tr>
<tr>
<td>5 min</td>
</tr>
<tr>
<td>6 min</td>
</tr>
<tr>
<td>7 min</td>
</tr>
<tr>
<td>8 min</td>
</tr>
<tr>
<td>9 min</td>
</tr>
<tr>
<td>10 min</td>
</tr>
</tbody>
</table>


- Lower SpO2 for preterm infants at all time points
- Longer transition to achieve SpO2 >90%
**Time to Reach Targets**

- Longer transition for preterm than term infants
- Not statistically significant at any target SpO₂

**Vaginal versus Cesarean**

- Lower SpO₂ at earliest measure for Cesarean
- Similar rate of rise, though lagging
**Conclusions**

- 5-10 min to achieve SpO₂ >90% is **NORMAL!**
- Full-term faster than premature
- Vaginal delivery faster than Cesarean

**Why is this Important?**

**How Much O₂ Does a Newborn Require?**

**MONITORING OXIMETRY**

- Expected 5-10 min transition
  - Less O₂ administration?
- Initiation of critical care in the delivery room setting
  - Eg. pulse oximetry, O₂ blending
- Personalization of care

**Titration of Oxygen**

**Excess O₂ = HARM**

**OXYGEN AT DELIVERY**

- High O₂
  - **Pro:** Rapid oxygenation
  - **Con:** Oxidative stress
- Low O₂ (room air)
  - **Pro:** Decreased reactive O₂ species
  - **Con:** Increased transition time?

**Oxygen Usage in the Delivery Room**

**Does Oxygen Exposure in the Delivery Room Affect Outcomes?**

• Prospective, randomized trial
• n=42; <28wk; immediate oximetry
  o $\text{FiO}_2$ 30% (n=19) vs. 90% (n=23)
  o Target $\text{SpO}_2$ 85% at 10min
  o Stepwise 10% $\text{O}_2$ adjustments
  o Response to HR<80 or $\text{SpO}_2$

• Outcomes – achievement of $\text{SpO}_2$
target; $\text{O}_2$ delivered; RA ventilation

VENTO, 2009

- Prospective, randomized trial
- n=78; 24-28wk; immediate oximetry
  - FiO₂ 30% (n=37) vs. 90% (n=41)
  - Target SpO₂: 75% (5min), 85% (10min)
  - Stepwise 10% titrations
- Outcomes
  - 1) Neonatal death or BPD (O₂ at 36wk)
  - 2) Oxidative stress/inflammatory markers


VENTO, 2009

Study Groups

<table>
<thead>
<tr>
<th>Low O₂</th>
<th>High O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>75%</td>
<td>90%</td>
</tr>
<tr>
<td>LWT</td>
<td>24.6 ± 2.6</td>
</tr>
<tr>
<td>BW</td>
<td>1,004 ± 187</td>
</tr>
<tr>
<td>Gender</td>
<td>Male: 16, Female: 22</td>
</tr>
<tr>
<td>Gestational age</td>
<td>33.07 ± 4.22</td>
</tr>
<tr>
<td>IBW</td>
<td>700 ± 160</td>
</tr>
<tr>
<td>Apgar</td>
<td>7 (5min), 9 (10min)</td>
</tr>
<tr>
<td>SIV</td>
<td>50 ± 10</td>
</tr>
<tr>
<td>NICU</td>
<td>12%</td>
</tr>
<tr>
<td>Mortality</td>
<td>3%</td>
</tr>
</tbody>
</table>

VENTO, 2009

Oxidative Stress

<table>
<thead>
<tr>
<th>Oxidized Glutathione</th>
<th>Reduced Glutathione</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>0.7</td>
<td>0.4</td>
</tr>
</tbody>
</table>

VENTO, 2009

Long-Term Outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low O₂</th>
<th>High O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of O₂ treatment</td>
<td>20.5 ± 5.2</td>
<td>15.2 ± 4.8</td>
</tr>
<tr>
<td>Duration of mech. ventilation &amp; CPAP</td>
<td>18.0 ± 5.0</td>
<td>13.0 ± 4.0</td>
</tr>
<tr>
<td>Rate of BPD (13% vs. 6%)</td>
<td>13%</td>
<td>6%</td>
</tr>
</tbody>
</table>

KAPADIA, 2013

- Prospective, randomized trial
- n=88; 24-34wk, immediate oximetry
  - FiO2 21% (n=44) vs. 100% (n=44)
  - Titration based on 2010 guidelines
- Outcomes
  - 1) Oxidative stress markers
  - 2) Clinical measures/outcomes

KAPADIA, 2013

Study Groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>IID 0.1 x 10^6</th>
<th>IID 0.5 x 10^6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism</td>
<td>28 (1-84)</td>
<td>28 (1-84)</td>
</tr>
<tr>
<td>Arterial</td>
<td>24 (3-53)</td>
<td>24 (3-53)</td>
</tr>
<tr>
<td>Baseline</td>
<td>17 (1-40)</td>
<td>17 (1-40)</td>
</tr>
<tr>
<td>Age, weeks</td>
<td>37 (27-44)</td>
<td>37 (27-44)</td>
</tr>
<tr>
<td>Birthweight</td>
<td>1116 (830-1450)</td>
<td>1116 (830-1450)</td>
</tr>
<tr>
<td>Gestation</td>
<td>33 (28-38)</td>
<td>33 (28-38)</td>
</tr>
<tr>
<td>Apgar score</td>
<td>6.1 (1.6-11.8)</td>
<td>6.1 (1.6-11.8)</td>
</tr>
<tr>
<td>Duration</td>
<td>2.4 (1-4.5)</td>
<td>2.4 (1-4.5)</td>
</tr>
<tr>
<td>Admission systolic</td>
<td>110 (70-170)</td>
<td>110 (70-170)</td>
</tr>
<tr>
<td>Admission diastolic</td>
<td>70 (50-100)</td>
<td>70 (50-100)</td>
</tr>
<tr>
<td>Neonatal death</td>
<td>0 (0-0)</td>
<td>0 (0-0)</td>
</tr>
</tbody>
</table>

KAPADIA, 2013

Resuscitation

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>SpO2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>80 (60-90)</td>
</tr>
<tr>
<td>1</td>
<td>85 (70-95)</td>
</tr>
<tr>
<td>3</td>
<td>90 (80-100)</td>
</tr>
</tbody>
</table>

KAPADIA, 2013

Resuscitation

FiO2

SpO2

KAPADIA, 2013

Resuscitation

FiO2

SpO2

KAPADIA, 2013

Table 1: Oxidative stress markers

<table>
<thead>
<tr>
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<th>IID 0.1 x 10^6</th>
<th>IID 0.5 x 10^6</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNF-α</td>
<td>28.5 (1-84)</td>
<td>28.5 (1-84)</td>
</tr>
<tr>
<td>IL-8</td>
<td>24 (3-53)</td>
<td>24 (3-53)</td>
</tr>
<tr>
<td>Baseline</td>
<td>17 (1-40)</td>
<td>17 (1-40)</td>
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<tr>
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<td>0 (0-0)</td>
</tr>
</tbody>
</table>
**Resuscitation**

SpO₂ > 94%

SpO₂ < 10%ile

**Oxidative Stress**

Total hydroperoxides

Biological antioxidant potential

Oxidative balance ratio

**SAUGSTAD, 2014**

- Systematic review; metaanalysis
  - 10 randomized studies
- ≤ 32wk GA
  - Low FiO₂ (21-30%); n=321
  - High FiO₂ (60-100%); n=356
  - Varied titration; generally based on 2005 guidelines
- Clinical outcomes

**SAUGSTAD, 2014**

Mortality

**Table 1** Basic characteristics of the included and excluded randomized studies according to the initial respiratory fraction of oxygen (FiO₂) employed for resuscitation in the delivery room

<table>
<thead>
<tr>
<th>Study</th>
<th>Modeled</th>
<th>GA weeks</th>
<th>Low FiO₂</th>
<th>High FiO₂</th>
<th>Mortality definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lord et al. (2013)</td>
<td>Yes</td>
<td>24-32</td>
<td>0.21</td>
<td>0.30</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Wang (2013)</td>
<td>Yes</td>
<td>24-32</td>
<td>0.21</td>
<td>1.0</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Kamat (2013)</td>
<td>Yes</td>
<td>23-32</td>
<td>0.21</td>
<td>1.0</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Kibibi et al. (2013)</td>
<td>Yes</td>
<td>28-34</td>
<td>0.50</td>
<td>0.05</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Different (2013)</td>
<td>Yes</td>
<td>29-34</td>
<td>0.50</td>
<td>0.05</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Hackett (2013)</td>
<td>Yes</td>
<td>29-34</td>
<td>0.50</td>
<td>0.05</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Reyes (2013)</td>
<td>Yes</td>
<td>29-34</td>
<td>0.50</td>
<td>0.05</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Kapadia (2013)</td>
<td>Yes</td>
<td>29-34</td>
<td>0.50</td>
<td>0.05</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Excluded studies</td>
<td>No</td>
<td>Unknown</td>
<td>1.0</td>
<td>0.0</td>
<td>30 day before discharge</td>
</tr>
<tr>
<td>Kibibi et al. (2013)</td>
<td>Yes</td>
<td>23-32</td>
<td>0.21</td>
<td>1.0</td>
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</tr>
<tr>
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<td>Yes</td>
<td>23-32</td>
<td>0.21</td>
<td>1.0</td>
<td>30 day before discharge</td>
</tr>
</tbody>
</table>

See study characteristics for a complete description of the randomization and inclusions and exclusions criteria in each study.

**SAUGSTAD, 2014**

**Mortality**

Relative risk meta-analysis plot (random effects)
SAUGSTAD, 2014

Bronchopulmonary Dysplasia


Intraventricular Hemorrhage


TATARANNO, 2015

- Randomized trial; 2 NICUs (Australia)
- TO2RPIDO study; subset analysis
- n=119; < 32wk GA
  - FiO2 100% (n=60) vs. 21% (n=59)
  - Titration based on 2005 guidelines
- Oxidative stress markers


Study Groups


Resuscitation


Oxidative Stress Markers

**TATARANNO, 2015**

**Changes in Oxidative Stress Markers**

- Advanced oxidative protein products
- Isoprostanes

(Changes between 2 and 12 hours after birth)


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**Oxygen Usage in the Delivery Room**

**Putting Theory Into Practice**

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**GANDHI, 2013**

- Transitional Oxygen Targeting System (TOTS)
  - Real-time graphical display of SpO₂ target achievement

- Prospective cohort study
- Comparison to SpO₂ alone


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**GANDHI, 2013**

- n=40; ≤36wk requiring O₂
- FiO₂ 40%; titration in 10% increments
- Goal (TOTS) = 10-50th percentiles from normative curves (32-36wk GA)
- Goal (Control) = SpO₂ 70% (3min) and SpO₂ 80% (5min)
- Outcome: time in target range

CONCLUSIONS - 1

• Color is an unreliable indicator of oxygenation status

• Immediate preductal pulse oximetry is now recommended for all delivery room resuscitations

CONCLUSIONS - 2

• For fastest SpO2 signal:
  o 1) Oximeter on; awaiting signal
  o 2) Apply probe to neonate
  o 3) Attach probe to oximeter cable

• SpO2 normative data now available

CONCLUSIONS - 3

• Titration of O2 in the delivery room affects short- and long-term outcomes

• Delivery room resuscitation strategies remain an area of ongoing investigation

FUTURE DIRECTIONS

• Closed-loop inspired oxygen (CLIO2)
• Feedback loop between pulse oximeter and FiO2 control
• “Automated FiO2 adjustment”
• COMING SOON…
TAKE-HOME MESSAGE

Use me!

QUESTIONS?