Intraoperative Respiratory Care of Premature Infants: Potential Risks and Anesthetic Considerations

Presented by Eileen Griffin CRNA, DNP
March 15, 2015

Conflict of Interest Disclosure

I have no conflicts of interest to disclose

Objectives

1. The learner will recognize potential complications associated with the respiratory care of premature infants including atelectrauma, volutrauma and barotrauma

2. The learner will demonstrate an understanding of the risks associated with increased FiO_2 delivery including retinopathy of prematurity and chronic lung disease

Objectives

3. The learner will become familiar with the clinical practice guidelines associated with the provision of optimal respiratory care to premature infants undergoing surgical intervention

So Many Questions…

Prematurity

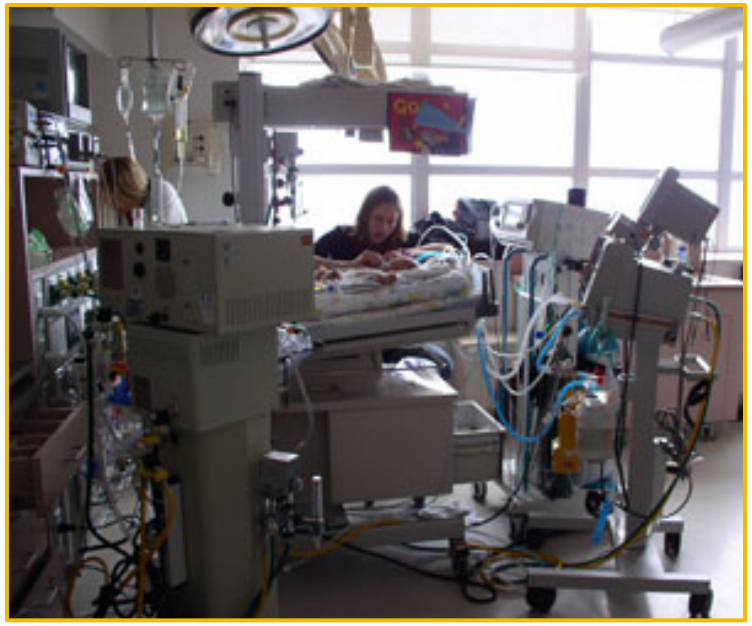
- **Prematurity** defined as birth less than 37 weeks completed gestation (IOM, 2007)
- **Early term** refers to infants born between 37 0/7 and 38 6/7 weeks (Fleischman et al., 2010)

Prematurity: Is there a problem?

- **Annual Statistics** (IOM, 2007; WHO, 2008)
  - **Prematurity** **12.5%**
  - **VLBW infants** **2%**
  - **Vanderbilt NICU surgeries** **340**
  - **Socioeconomic burden** **26.2 billion**

Neonatal Respiratory Dysfunction

- Premature infants are **susceptible** with **complex** respiratory physiology



Neonatal Respiratory Dysfunction

Respiratory Distress Syndrome (RDS)

- Immature lung with decreased ability to oxygenate and ventilate

Bronchopulmonary Dysplasia (BPD) and Chronic Lung Disease (CLD)

- Lung injury associated with mechanical ventilation

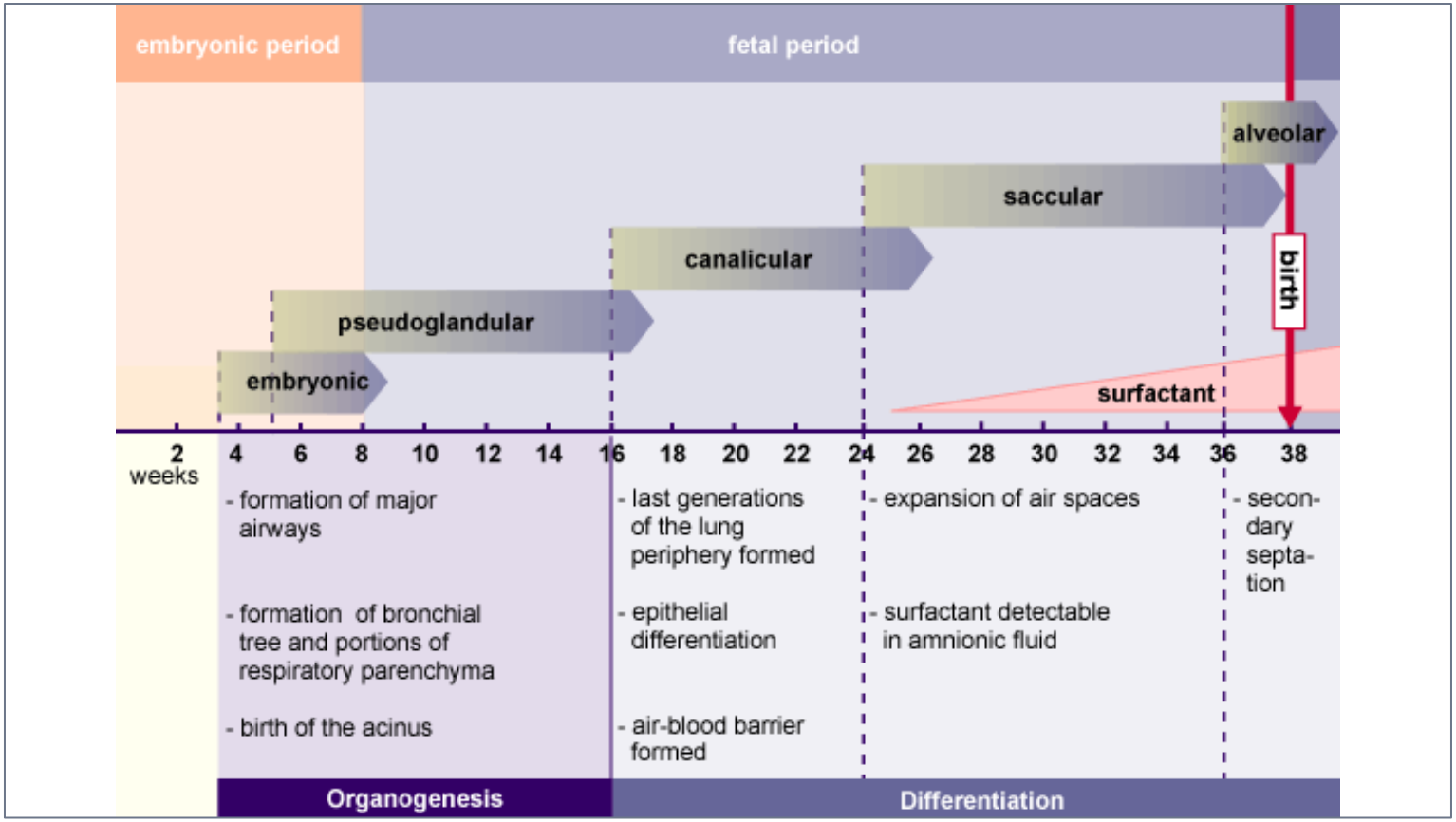
Neonatal Respiratory Dysfunction

Contributing Factors

- Differentiation of anatomic structures for gas exchange occurs late in gestation

- Development of gas exchange surfaces and the beginning of surfactant production occurs at 24 weeks gestation limiting fetal viability
  - Cote et al., 2009

Fetal Lung Development



http://www.embryology.ch/images/rrespiratory/01phasen/r1a_ueberblick_lunge_603.gif

Fetal Lung Development

Saccule/Alveolar Stage (24 weeks to term)

- **Alveolar ducts and sacs** continue to form
- **Surface area for gas-exchange** increases while thickness decreases
- Increased **surfactant** production
- Incidence of **RDS decreases** and is very low after 35-36 weeks

  - Coté et al., 2009

Balancing Oxygenation and Ventilation

Non-respiratory issues associated with variations in oxygenation and ventilation

- **Retinopathy of prematurity**
- **Hypoxic brain injury**
- **Intraventricular hemorrhage**
- **Periventricular leukomalacia**

Mechanisms of Ventilator Induced Lung Injury

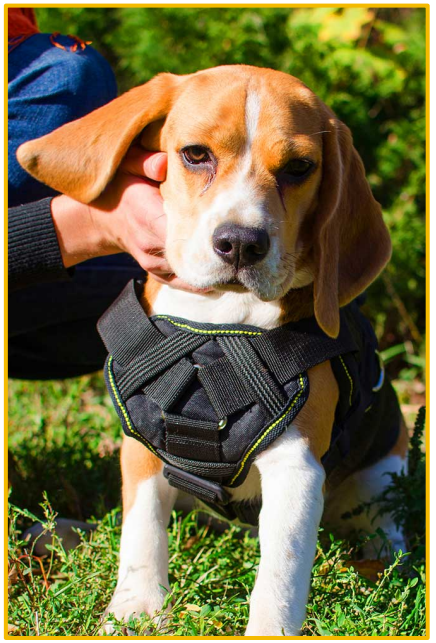
1. **Volutrauma** related to large gas volumes
2. **Atelectrauma** related to alveolar collapse and re-expansion
3. **Barotrauma** related to high airway pressure
4. **Biotrauma** related to increased inflammation

Ventilator Induced Lung Injury

- Mechanical lung injury previously attributed to high inspiratory pressures **(barotrauma)**

Ventilator Induced Lung Injury

- In animal studies, **markers of lung injury were consistently associated with a high tidal volume** regardless of airway pressure (Parker, et al., 1993)



Volutrauma

- **Most critical determinant of lung injury** appears to be **end-inspiratory lung volume**

- For these reasons, the **term 'volutrauma' has largely replaced 'barotrauma'.**

  - Thome & Ambalavan, 2009

Pressure vs. Volume

(Walsh, 2015)

Atelectrauma

- Additional lung injury is associated with **repeated collapse and re-opening of alveoli** during breathing cycle which may be alleviated by high positive end-expiratory pressure (PEEP)

- **Caution**: High PEEP settings increase end-expiratory volume

Ventilator Induced Lung Injury

- When a **moderately high tidal volume is added to high end-expiratory volume**, end-inspiratory over-distention and **increased volutrauma** may result.

Ventilator Induced Lung Injury

- Ventilatory strategy with **sufficient PEEP and low tidal volumes may be best choice** in parenchymal lung disease

Thome & Ambalavan, 2009

Carbon Dioxide Target Range

- **CAUTION:** $PaCO_2$ <35 mmHg may contribute to development of **bronchopulmonary dysplasia**
- **CAUTION:** Severe hypercapnia (>60 mmHg) may be associated with an increased risk of **intraventricular hemorrhage**
- **CAUTION:** Hypocapnia (<25 mmHg) may be associated with development of **periventricular leukomalacia, intracranial hemorrhage and cerebral palsy**

  - Thome and Ablvanan, 2009

CAUTION!

Permissive Hypercapnia

- Tolerating higher level of arterial partial pressure of carbon dioxide ($PaCO_2$) is considered **'permissive hypercapnia' ($PaCO_2$ > 40mmHg)**

- When combined **with use of low tidal volumes**, **permissive hypercapnia may reduce volutrauma** and lead to improved pulmonary outcomes

  - Thome & Ambalavanan, 2009

$PaCO_2$ Target Range

- **CONSIDER: Avoidance of large fluctuations in $PaCO_2$** values with target range approximately 35-45 mmHg (varies with baseline pulmonary function)

Thome & Ambalavanon, 2009

Oxygen Therapy

- **Goal of Oxygen Therapy**: Deliver sufficient oxygen to tissues while minimizing oxygen toxicity and oxidative stress
- Ideal arterial oxygen saturation value to maintain this balance remains uncertain

  - Schmidt et al., 2013 (COT)

Potential Risks of Oxygen Therapy

- Risks associated with supplemental oxygen therapy
  - **Retinopathy of Prematurity (ROP)**
  - **Bronchopulmonary Dysplasia (BPD)**
  - **Central nervous system damage**
    - Bancalari & Claure, 2013

SpO_2 Target Range: BOOST II

- **B**enefits **O**f **O**xygen **S**aturation **T**argeting Trial **(BOOST II)**
  - Randomized trial designed to compare SpO_2 targets of 85-89% vs. 91-95% in 2316 infants 24 0/7 weeks to 27 6.7 weeks gestation
  - **Primary outcome:** Survival without disability at 2 years adjusted gestational age (AGA)

SpO2 Target Range: SUPPORT

Surfactant, **P**ositive **P**ressure, and **O**xygenation **R**andomized **(SUPPORT)** Trial

- Randomized trial comparing the same SpO2 ranges among 1315 infants (Feb 2005-Feb 2009)
- Infants assigned to lower target range of 85-89% had lower risk of retinopathy of prematurity (ROP) than those in higher target group

SpO_2 Target Range: SUPPORT

However, they also had a lower survival rate to hospital discharge (mortality 19.9% vs. 16.2%)

BOOST II & SUPPORT Findings

- Among the 3631 infants from both BOOST II and SUPPORT trials, those randomly assigned to SpO2 91-95% had a higher survival rate at 36 weeks AGA than those assigned 85-89%

- Both trials closed recruitment after a joint safety analysis of the results following the institution of a revised SpO2 algorithm

Canadian Oxygen Trial (COT)

- Premature infants (1201) randomized to achieve oxygen saturation targets of 85-89% vs. 91-95% (Oct 2008-Aug 2012)
- **Primary outcomes**: Death, gross motor disability, cognitive or language delay, severe hearing loss, or bilateral blindness at 18 months AGA
- **Secondary outcomes:** Retinopathy of prematurity and brain injury

Canadian Oxygen Trial (COT)

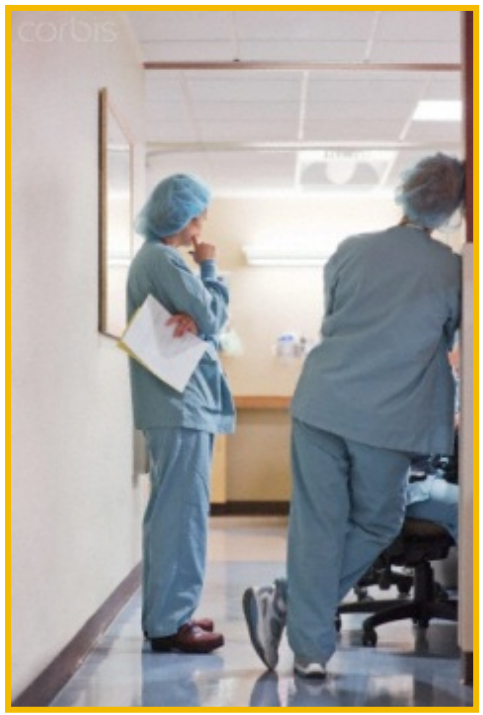
- **Conclusion:**
  - In extremely premature infants, targeting SpO2 85-89% compared to 91-95%, had no significant effects on rate of death or disability at 18 months of age
  - Targeting lower oxygen saturations reduced the AGA at last use of oxygen therapy

SpO2 Target Range Recommendation

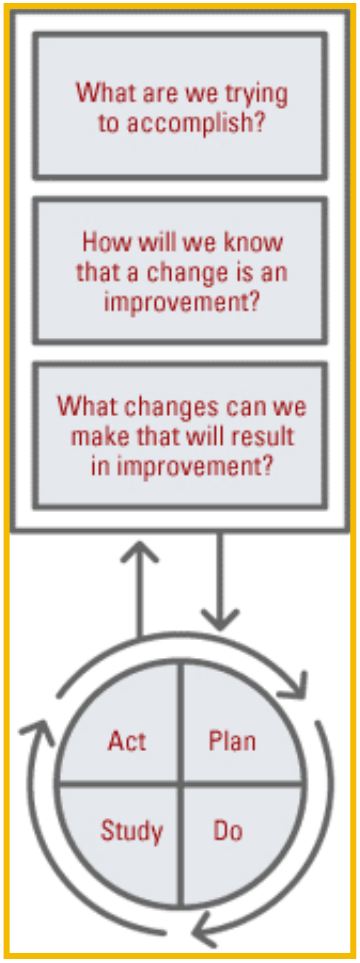
- Meta-analysis of all three trials planned in hopes of clarifying inconsistencies of results
- Current practice at Monroe Carell Jr. Children's Hospital at Vanderbilt targets an SpO2 range of 91-95% for infants less than 44 weeks AGA

Quality Improvement Initiative

- **Problem:** Observed lack of consistency related to intraoperative respiratory care of premature infants by both NICU and anesthesia staff



PDSA Study Design



Quality Improvement Initiative

- **Does a problem actually exist above and beyond anecdotal reports?**
  - Retrospective chart review conducted on infants born at less than 33 weeks gestational age and requiring surgical intervention within 30 days of life resulting in 18 qualified patients (cardiac surgery patients excluded)

Identified Areas of Inconsistency

- Mode of ventilation during transport
- Range of FiO_2 and associated SpO_2
- Use of specialized ventilators for infants $\leq$ 1000 gms
- Use of neuromuscular blocking agents
- Correct endotracheal tube placement postoperatively
- Postoperative disposition (NICU vs. PACU)

Quality Improvement Initiative

- **Purpose:** Develop evidence-based clinical practice guidelines (CPG's) for anesthesia providers to facilitate a consistent evidence-based practice

Clinical Practice Guidelines

Target Population: Premature infants born at less than 38 weeks gestational age requiring surgery before 44 weeks adjusted gestational age (AGA)

Clinical Practice Guidelines

I. **Complete/review preoperative evaluation. Systematically assess respiratory status.**
   - FiO_2 and correlating oxygen saturation
   - Mode of ventilation including PIP and correlating Vt
   - ETT size and depth

II. **Prepare for direct transport of patient to OR from NICU**
   - NICU ventilator for infants $\leq$ 1000 gms or requiring significant ventilatory support
   - Neonatal ventilator circuit
   - Intubation prior to transport of Vapotherm patients

Clinical Practice Guidelines

III. **Discuss intra- and postoperative respiratory care of patient with NICU staff attending or designated NICU fellow**
   - Extubation in OR vs. return to NICU intubated
   - Influence of pain management on extubation criteria

IV. **Transport intubated patients to OR using Neo-puff™**
   - Confirm
     - FiO_2
     - PIP
     - PEEP

Clinical Practice Guidelines

V. **Minimize ETT disconnection time when transferring from NICU isolette to OR table**
   - Avoid atelectrauma and fluctuations in FiO_2

VI. **Confirm ventilator settings established during preop preparation and planning**
   - Differences between anesthesia ventilator used in the OR and NICU ventilator
   - Pressure Control mode of ventilation preferred when using anesthesia ventilators
   - Variability of Vt and $ETCO_2$ readings

Clinical Practice Guidelines

VII. **Transport intubated patient to NICU postop using Neo-puff™**
- Verify full O2 and air tanks
- Contact Respiratory Therapy if necessary

VII. **Exchange monitors and complete patient hand-over process**
- Children's Hospital ICU transport guidelines
- Time-out
- SBAR report

Study Limitations

Limitations

- Small target population (n=18)
- Incomplete electronic data collection
- Retrospective

Quality Improvement Accountability: Will They Remember?

Recommendations

- Increase CPG awareness and access
- Multidisciplinary lecture series of issues associated with prematurity
- Follow-up PDSA cycle with evaluation of compliance with current guidelines
- Easy to remember mnemonic

NEO PRO Mnemonic

Neo **Puff** used for transport to and from NICU. NICU vent for neonates < 1000 grams

ETT **position**: High alert for main stem intubation with changes in head and neck position

O_2 delivery titrated for **target** **SpO_2 *91-95%***

Pre-oxygenate **with minimal FiO_2** (maintain target SpO2)

Restrict **ETT disconnects and FiO_2 fluctuation.** Note pre-op vent settings. Consider **Pressure Control** ventilation

O_2 related potential for retinopathy and chronic lung disease with SpO_2 > *97%*

Questions ?

Thank you!

References

Bachiller, P., McDonough, J. & Feldman, J. (2008). Do new anesthesia ventilators deliver small tidal volumes accurately during volume-controlled ventilation? *Pediatric Anesthesiology, 106(5)*, 1392-1400.

Bancalari, E. & Claure, N. (2013). Oxygen target outcomes in premature infants. *Journal of the American Medical Association, 309(20)*, 2161-2162.

Coté, C., Lerman, J., & Todres, D. (2009). *Practice of anesthesia for infants and children*. 4th Ed. Philadelphia, PA: Elsevier Saunders.

Fleischman, A., Oinuma, M., & Clark, S. (2010). Rethinking the definition of "term pregnancy". *Obstetrics and Gynocologists, 116(1)*, 136-139.

Habre, W. (2010). Neonatal ventilation. *Best practice & research clinical Anaesthesiology, 24*, 353-364. doi:10.1016/ j.bpa.2010.02.020

References

Parker, J., Hernandez, L., & Peevy, K. (1993). Mechanisms of ventilator-induced lung injury [Review]. *Critical Care Medicine, 21, 131*–143.

Schmidt, B., Whyte, R., Asztalos, E., Moddemann, D., Poets, C., Rabi, Y., … Roberts, R. (2013). Effects of targeting higher vs lower arterial oxygen saturations on death and disability in extremely preterm infants: A randomized clinical trial. *Journal of the American Medical Association, 309(20)*, 2111-2120.

Sweet, D., Carnielli, V., Greisen, G., Hallman, M., Ozek, E., Plavka, R., … Saugstad, O. (2010). European consensus guidelines on the management of neonatal respiratory distress syndrome in preterm infants – 2010 update. *Neonatology, 97*, 402-417. doi: 10.1159/000297773

Thome, U., & Ambalavanan, N. (2009). Permissive hypercapnia to decrease lung injury in ventilated preterm neonates. *Seminars in Fetal and Neonatal Medicine, 14*, 21-27.