Respiratory Management of the Neonate: Methods & Strategies

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Objectives:
- Define mechanisms of lung injury
- Review strategies to prevent or minimize lung injury
- Discuss respiratory interventions & methods of ventilation
- List nursing care for infants receiving respiratory support

Goals of treatment:
- Ultimate Goal is Normal Survival
- Decrease morbidity: Minimize CLD, PVL, IVH, ROP, and Sepsis
- Decrease ventilator days: Decrease hospital stay and cost

Causes of CLD or BPD
- Prematurity and Surfactant deficiency
- Volutrauma and/or Atelectrauma
- Oxygen free radicals via high inspired O₂ concentrations
- Pre-existing lung damage and/or inflammation by sepsis and chemical pneumonitis with resulting inflammation

Mortality is now predominantly from complications of extreme prematurity. Such as infection, necrotizing entercolitis (NEC), & intracranial hemorrhage.

Our focus has changed from reducing mortality to reducing the incidence of chronic lung disease (CLD), which has improved the survival of ELBW infants.

Acute Lung Injury
Acute Lung Injury

Chronic Lung Injury

CLD/BPD

Also known as bronchopulmonary dysplasia (BPD)

Defined as...
- Infants born less than 32 weeks gestation require O2 at 36 weeks gestation or at discharge
- Infants born greater than 32 weeks and require O2 at 28 days or discharge

What is Chronic Lung Disease?

Identify Infants at Risk for Lung Injury

- ELBW infants (< 28 weeks gestation). This group is at the greatest risk due to lack of alveolar structure and surfactant deficiency
- Meconium Aspiration (MAS): injured and chemically inflamed lungs
- Infants with sepsis or pulmonary hypertension (PPHN). They require high support to maintain oxygenation
- Infants with lung hypoplasia due to Congenital diaphragmatic hernia (CHD), abdominal defects, & oligohydramnios.

Signs and Symptoms of CLD

- Babies with RDS generally begin to show signs of improvement at days 3-4 of life, however infants with CLD do not improve
- The infant's oxygen demands do not decrease as they should – they can even increase
- Tachypnea Tachycardia
- Continued grunting, flaring and retracting
- Poor weight gain or stunted growth – this is due to the increased demand for energy for breathing. Energy is used to breathe rather than for growth
- Coarse crackles may be heard in the chest
- PIE-Pulmonary Interstitial Emphysema on CXR
Surfactant

Volutrauma and Atelectrauma

- Volutrauma: the over distention of alveoli and airways
- Atelectrauma: the repeated alveolar collapse and reopening

Oxygen: Is O2 toxic?

- Too much O2 results in the over production of oxygen free radicals
  - Pulmonary inflammation
  - ROP
- Oxygen toxicity is the most severe side effect of oxygen therapy in newborns. The lungs take the brunt of the damage, which can result in inflammation, hemorrhaging and swelling
- O2 free radicals initiate lung injury sequence that can cause alveolar damage, and progressive pulmonary dysfunction
- However, PaO2 too low
  - PVL
  - Decreased growth
  - CP
  - Cor Pulmonale
  - Increased mortality

Strategies to Prevent or Minimize Lung Injury

- Surfactant administration
- Minimize the use of inspired O2
- Minimize the use of mechanical ventilation
- Minimize inflation pressures
- Ensure optimal heat/humidity to inspired gases
- Reduce sepsis risk and airway injury
- Use optimal PEEP or Continuous Positive Airway Pressure (CPAP)

Surfactant Therapy: Prophylactic Treatment of the ELBW

- Egberts (Peds 1993:92:768) Showed prophylactic surfactant especially beneficial in male neonates < 28 weeks or < 1000grams.
- Take surfactant to delivery room, administer before 15” of life if intubation is completed
Surfactant Therapy: Rescue

- Infants with HMD diagnosis should get surfactant within 1st hour of life.
- Not all premature infants need exogenous surfactant, particularly those who have received antenatal corticosteroids
- Repeated doses may be given for PaO2 < 80 with FIO2 > 30%
- Variety of surfactant types

FIO2: Titration to SpO2 in the DR

<table>
<thead>
<tr>
<th>Time</th>
<th>SpO2 (pre-ductal)</th>
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<tbody>
<tr>
<td>1 minute</td>
<td>60-65%</td>
</tr>
<tr>
<td>2 minutes</td>
<td>65-70%</td>
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<tr>
<td>3 minutes</td>
<td>70-75%</td>
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<tr>
<td>4 minutes</td>
<td>75-80%</td>
</tr>
<tr>
<td>5 minutes</td>
<td>80-85%</td>
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<tr>
<td>5-10 minutes</td>
<td>85-95%</td>
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Admissions maintain SpO2 88-97% (target 90-95%)

Strategies to Minimize Lung Injury: Gentle Ventilation to Decrease VILI

- “Just a few cycles can trigger an inflammatory reaction”
  - Excessive tidal volume (VT), not pressure, is chiefly responsible for lung injury. (Volutrauma)
  - Gentle ventilation is of fundamental importance to reducing the incidence of these injuries

Minimizing VILI

- Use lung protective ventilation modes
- Conventional Ventilation vs. High Frequency Ventilation

Minimize VILI: Conventional Ventilation (CMV)

- Current ventilators have microprocessor controls that allow ELBW infants to trigger the ventilator, allowing for synchronization.
- Volumes are calculated or measured through pneumotachometers

Minimize VILI: CMV

- Optimal choice of VT is 4-6 ml/kg
- Use minimal inflation pressures. Only enough to achieve optimal VT
- PEEP 4-6 cm H2O to maintain FRC
- Inspiratory Time (Ti): 0.3-0.4 seconds
Minimize VILI: HFOV

• In theory, the benefit of HFOV is the reduction of iatrogenic ventilator injury while maintaining adequate gas exchange using similar Mean Airway Pressures (MAPs), but lower peak inspiratory pressure associated with continuous mechanical ventilation (CMV)

HFOV

• Cochrane Data Base did not find evidence of great advantages of HFOV over CMV in the ELBW infants. Thus, there are two theories to the use of HFOV.
  • Prophylactic treatment of the ELBW infant. It is recommended in experienced centers.
  • Rescue Treatment: Severe respiratory failure refractory to CMV or in newborns with significant CO2 retention. Standard of care for infants with PPHN, Congenital Diaphragmatic Hernia (CDH), active air leak, Meconium Aspiration

Strategy: Minimize use of Mechanical Ventilation

• Attempt early extubation with NCPAP support (Nasal Continuous Positive Airway Pressure)
  • Studies show that employing NCPAP reduces the duration and need for intubation, which reduces the risk of BPD
  • Continuous pressure is applied during the entire respiratory cycle to prevent the alveoli from collapsing and thus permit a more normal breathing pattern

Strategy: Minimal Use of Mechanical Ventilation: NCPAP

• Stabilizes the upper airway
• Improves lung function by restoring FRC
• Promotes normal breathing and reduces apnea
• Allows development of small airways
• Facilitates utilization of natural surfactant
• Non-invasive, thus no risk for sepsis from Ventilator Acquired Pneumonia (VAP)

Strategy: Optimal Humidification

• Ensure optimal heating of gas to ~37°C, for all inspired gases to provide optimal humidification of airways.
  • Mechanical ventilation
  • NCPAP
  • SIPAP
  • Hi Flow NC
  • Hood Therapy

Respiratory Interventions & Modes of ventilation:

• NCPAP: Conventional vs. Variable Flow
• Vapotherm/Hi Flow NC
• CMV: Draeger Baby Log, Maquet Servo I & 300A
• HFOV: Sensormedic 3100A
NCPAP

**Disadvantages:**
- Fixation and application can be difficult to maintain
- It is a challenge to maintain a constant stable positive pressure
- Some systems have increased expiratory resistance leading to increased work of breathing (WOB) and respiratory fatigue
- Increased abdominal distention and increased production of secretions

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**NCPAP: Conventional vs. Variable Flow**

- **Conventional:** maintains CPAP via a mechanical ventilator or “Bubble CPAP” uses continuous flow and expiratory valve to produce ambient expiratory pressure (PEEP)
  - During expiratory phase of respiratory cycle infant has to exhale against the oncoming gas flow which can lead to added WOB.
- **Variable Flow CPAP:** Infant Flow uses Fluidic Flip action/Airlift uses Vortex
  - No valves or moving parts are needed
  - CPAP is created in the generator to provide constant stable positive airway pressure
  - This allows a constant and stable CPAP that supports the infant's efforts and ensures that FRC is maintained
  - Decreased WOB

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**NCPAP Equipment Fit**

- Correct application of Silicone Prongs & masks
  - Prongs too small= leak
  - Prongs too large = may misshape nares or pop out
  - Masks too small= collapse of nasal structure & obstruction
  - Mask too large= leak
  - Correct cap size and placement
NCPAP Care Considerations

- **Nursing Care:**
  - prong position with hourly vitals
  - Skin condition and color
  - Chest wall stability & retractions (WOB)
  - Blood Gases, SpO2, TcCO2
  - Signs of irritability
  - Suctioning: Gently with multi-purpose device, lower pressures. Watch for thick oral secretions that can occlude airway.
  - Enteral feeds - via orogastric route only
  - NG tubes impede fixation and increase risk for nasal erosion

- **Skin Integrity Assessment Tool**
  
<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
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<tbody>
<tr>
<td>Stage 0</td>
<td>No discoloration or indent. No intervention</td>
</tr>
<tr>
<td>Stage I</td>
<td>Mild redness and indent noted. Color and indent improves with brief rest period. No other interventions required</td>
</tr>
<tr>
<td>Stage II</td>
<td>Redness or bruising that does not improve with brief rest. Infant may require increased breaks off CPAP or change in appliance (alteration of prong/mask). Check prong size to ensure that the largest the nare can accommodate are used (lessens amount of pressure required on appliance). Consider barrier to halt progression to stage III</td>
</tr>
<tr>
<td>Stage III</td>
<td>Nares excoriated and weepy. May or may not have bleeding. Prongs should not be used if epistomal damage noted. Mask should not be used for upper lip damage. Consider frequent breaks. Notify MD or ARNP of findings</td>
</tr>
<tr>
<td>Stage IV</td>
<td>Nares necrotic with severe tissue damage. Consider removal of NCPAP; intubation may be required</td>
</tr>
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- **SiPAP**
  - Delivers CPAP and inspiratory pressure (up to 10 cmH2O)
  - Infant Flow SiPAP is a device which enables the Biphasic continuous positive end-expiratory pressure (Biphasic) by addition of an intermittent “Sigh, SiPAP pressure” to the nasal CPAP
  - Potential benefits
    - Recruit lung volume
    - Off-load respiratory work (VT-3-6 ml/kg)
    - Stimulate respiratory center

NCPAP Hands On

- Nasal Care done with hands on at least Q 3-4 hours
- Skin should be kept clean and dry
- Perform skin integrity assessment
- Any changes to skin condition needs to be documented and evaluated

NCPAP

- Parameters for CPAP should be set according to the needs of each infant.
  - PEEP 4-6 cm H2O (many use aggressive levels of 6-8 cm H2O)
  - PaCO2 tolerated at 45-65 mmHg
    - (Permissive Hypercapnia) with pH > 7.2
  - O2 to maintain PaO2 50-70 mmHg
  - Adequate heated & humidified gases
  - Primary reason for failure is apnea
  - Methylxanthines or Caffeine

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SiPAP

Hi Flow Nasal Cannula

Hi Flow NC

Modes of Ventilation: Drager

Drager

- Volume Guarantee: (volume targeting 4-6ml/kg)
- Can be used with SIMV, AC and PSV (Pressure support ventilation)
- Requires flow sensor-air leak sensitive
- Set Target VT, Max PIP, Rate, PEEP, Ti, flow

Special cannula’s for each device.

Modes of Ventilation: Maquet Servo i

Versatile modes of ventilation:
PRVC (pressure regulated volume control)
PRVC SIMV
PC (pressure control)
Volume support & automode
NIV: NAVA
Maquet Servo i: PRVC

- Delivers targeted VT (4-6ml/kg) at the lowest pressure possible/responds to changes in compliance.
- Set Vt, peep, rate, iT
- Flow is variable
- Volumes are measured at ventilator, unless “Y sensor software and flow sensor are added.
- Y sensor allows volume and pressure measurement at ETT.

Management of CMV

- Volume Control or Volume Targeting:
  *manipulation of the pH & pCO2 is by adjusting the minute ventilation.
  \[ Ve = \text{rate} \times \text{volume} \]
  *Control of PO2 is adjustments of the FIO2, PEEP, & indirectly adjusting the PIP to increase VT or increasing the VT.
- Pressure Control Ventilation:
  *manipulation of pH & pCO2 adjust Ve, by adjusting rate and ∆P (PIP-PEEP)
  *Control pO2 by adjustments to the FIO2 & PEEP

Modes of Ventilation: Sensormedics 3100A

iNO

- NO is administered in gaseous form through the inspiratory limb of the ventilator circuitry between the ventilator and the humidifier
- Expiratory gas is scavenged from the expiratory block of the ventilator to the wall suction
- Babies receiving iNO therapy have a bagging circuit complete with scavenging device fitted, so that in the event of ventilator failure or resuscitation, iNO may continue to be administered

iNO What is It?

- Nitric oxide is an endogenous free radical, synthesized in endothelial cells, that causes vascular smooth muscle relaxation → vasodilation.
- Inhaled nitric oxide (iNO) selectively targets pulmonary vessels, causing a potent and sustained vasodilatation → increased pulmonary blood flow
- iNO is a treatment for pulmonary hypertension
- iNO efficacy is improved by prior optimization of an infant’s clinical condition (pulmonary disease and ventilation, cardiac performance and systemic hemodynamics and physiology) and should only be considered as part of an overall clinical strategy

Who

- Term or near term infants with pulmonary hypertension evidenced by poor oxygenation and, if possible, confirmed by echocardiography
  - Primary pulmonary hypertension
  - Secondary pulmonary hypertension resulting from:
    - Infection
    - Parenchymal disease such as meconium aspiration syndrome, pneumonia or RDS
    - Pulmonary hypoplasia: idiopathic or secondary to congenital diaphragmatic hernia or anhydramnios/oligohydramnios
    - Severe peripartum hypoxia
    - Congenital lung malformations such as alveolar capillary dysplasia or congenital cystadenomatoid malformation (CCAM)
    - Congenital heart disease
HFOV:

- Oxygenation = MAP (Mean Airway Pressure)
- Lung volume is maintained by a continuous pressure holding the lung open at an optimal level
- Lung recruitment:
  - Chest X-ray should show 8-9 ribs
  - If air leak or CLD 7-8 ribs

HFOV: Optimal Inflation

- No inflation
- Over inflation
- Proper inflation

HFOV

- Ventilation is controlled by adjustments to the Amplitude of each cycle “Power”
- The Frequency is the time allowed for each cycle
  - 1 Hertz = 60 cycles
- Recommended Hertz in neonates 12-15
  - Term infants = 10 Hz
  - MEC Aspiration = 8 Hz
- Recommended Amplitude titrate to “Chest Wiggle”

HFOV Strategy for Diffuse Alveolar Disease-RDS

- Set MAP 1-2 cm H2O > CV (this opens and stabilizes the lung volume)
- Frequency 12-15 Hz (720-900 cycles)
- Amplitude set to give adequate chest wiggle or shake
- Adjust with blood gases to keep PaCO2 in high 40’s
- Wean FIO2 to < ~40%, then wean MAP

Nursing Care with the ELBW Infant on Respiratory Support

- Prone, supine or side lying
- Positioners & containment
- Chin ideally in the midline
- Watch Endotracheal Tube

Nursing Care: Positioning
Nursing Care: Positioning

Positioning:

Positioning: Supine with head support

Positioning on NCPAP

Positioning on NCPAP

Kangaroo Care on Ventilator
Nursing Care: Suctioning

- **Goal:** Minimize injury that could be caused by suctioning by ensuring proper suctioning catheter placement and using sterile technique
- The ETT is suctioned to prevent a build up of secretions and therefore blockage of the airway
- **Indications for suctioning**
  - Use of Saline
  - Frequency of Suctioning
- **Variable methods of technique:**
  - Shallow vs. deep suctioning
  - Closed vs. open suctioning

Oral Care

- To minimize tenacious secretion collection in the mouth
- To maintain mucosal integrity
- Minimize VAP
- Use of colostrum and breast milk to prevent VAP is a feasible method

Special Considerations with HFOV
HFOV considerations

- Prevent inadvertent extubation:
  - Set brakes on Oscillator
  - Avoid pulling on ETT, keep in straight alignment
  - Suctioning & Turns: DO NOT DISCONNECT. This will cause alveolar collapse and loss of lung volume
  - Stop oscillations with advancement of catheter, maintain MAP, resume oscillations after removal of catheter from ETT
- Weighing:
  - Make sure infants are placed on a bed with in bed scales
- X-Rays
  - Keep on mechanical ventilation
  - Hold head midline

Nursing Care: Minimize Use of Inflation/Ambu Bags

- If using inflation bags, ensure that excessive inflation pressures are avoided
  - Flow inflating bags with manometer
  - Self inflating bags with pop-off
  - Neopuff (recommended)

Review

- Chronic lung disease is a chronic pulmonary syndrome affecting infants after exposure to mechanical ventilation and supplemental O2 and characterized by the need for supplemental O2 beyond 36 weeks postmenstrual age

Conclusion

- Prevention of lung injury in extremely premature infants requires that the multiple variables contributing to their development be minimized while factors that facilitate the normal development of the lungs are maximized
  - Avoid premature delivery
  - Antenatal steroids/MgSO4 for neuroprotection/treat suspected chorio
  - Early surfactant
  - Gentle mechanical ventilation techniques
  - Minimal stimulation protocol/Developmentally appropriate support
  - Early extubation, with use of NCPAP
  - Avoid hyperoxia & hypoxia, hypo & hyper carbia
  - Other: Management of PDA, postnatal steroids (inhaled), antioxidants & nutritional support
References

18. Tomohiko Nakamura, New Infant Flow System; BiPhasic CPAP (SiPAP), Neonatal Care. 23(5), 2010, 457-60.
20. Airwater Inc, Infant Flow SiPAP operators’ manual
21. Inhaled nitric oxide iNO therapy for the term or near term neonate