Learning objectives

- Define and diagnose respiratory failure
- Describe traditional and novel treatment modalities including their benefits and risks
- Understand how and when to use non-invasive ventilation for respiratory failure in kids
- Brief tour of High Frequency Oscillatory Ventilation and ECMO
What is respiratory failure?
Pediatric Respiratory Failure

- Definitions: descriptive statistics or clinical or physiological?
- What are the etiologies?
- What H& P findings are significant?
- What are the therapeutic options?
Respiratory Failure or Distress is

- The primary diagnosis in almost 50% of admissions to pediatric intensive care
- A common cause of cardiopulmonary arrest in children
- The most common diagnosis in pediatric medical evacuation
- Somewhat seasonal, but occurs throughout the year
- Capable of striking fear in the hearts of non-peds medical providers
Definition of Respiratory Failure

- Physiologically based definition
  - \( \text{PaO}_2 < 60 \) with \( \text{FiO}_2 > 0.6 \)
  - \( \text{PaCO}_2 > 60 \)
  - \( \text{PaO}_2/\text{FiO}_2 \) ratio
  - A-a gradient
Derangements in pulmonary gas exchange in respiratory failure

- Hypoventilation
- Diffusion impairment
- Intrapulmonary shunting
- Ventilation-perfusion or V/Q mismatch
- Further classify these by anatomic lesion, abnormalities of lung & chest wall mechanics, neuromuscular systems, and CNS control problems.
Classify Causes of Resp Failure By

- Age
- Anatomic lesions
- Abnormalities of lung and chest wall mechanics
- Neuromuscular systems
- Abnormalities of CNS control
Reasons to Manage an Airway
Indications for Airway Management

1. Hypoxemia
2. Hypercarbia
3. Neuromuscular disease
4. Impending airway obstruction
5. Therapies for other non-respiratory diseases
Hypoxemia

- Disorders associated with ventilation/perfusion (V/Q) mismatches
  - Ventilation and perfusion normally equal in alveoli
    - Areas well ventilated are well perfused; areas poorly ventilated are poorly perfused

- Abnormal compliance of lung

- Major diseases - pneumonia, sepsis, heart failure, bronchiolitis
Hypercarbia

- Better to be defined by pH rather than pCO2
  - Metabolic alkalosis can raise pCO2 without acidosis
- Also associated with V/Q abnormalities
- Disorders of airway resistance rather than compliance
- Can occur with many respiratory diseases, usually as patients get tired
- Classic example is asthma
Neuromuscular Disease

Two different categories

- Progressive muscular weakness doesn’t allow ventilation or oxygenation - respiratory pump failure
  - examples - Werdnig-Hoffman disease, Muscular dystrophy, spinal cord injury

- Absence of airway reflexes
  - Loss of cranial nerve function puts person at risk for aspiration, airway obstruction
  - examples - brain tumors, neuropathies, TBI
Let’s move this to the bedside...
The nose knows...

- Nose is responsible for 50% of total airway resistance at all ages.
- Infant: blockage of nose = respiratory distress or failure.

- So... *Sometimes, oral and nasal suctioning is all that is needed!!*
Anatomy : Tongue

- Large in proportion to rest of oral cavity
- Loss of tone with sleep, sedation, CNS dysfunction
- Frequent cause of upper airway obstruction
- So, **positioning with or without oral airway can be enough. And laryngoscopic stabilization of the tongue is more difficult.**
Physical Assessment

- Identify respiratory effort:
  - Increased: tachypnea and dyspnea suggest a heterogeneous group of mechanical problems within the lung or chest wall.
  - Decreased: bradypnea, apnea, Cheyne-Stokes suggest fatigue, neuromuscular disease, medications, etc.
What are you looking for?

- Degree of **TACHYPNEA** and tachycardia
- Adequacy of tidal volume (chest rise and abdominal excursion)
- Presence of **symmetric** air movement
- Nasal flaring
- Use of accessory muscles
  - Retractions
  - Head Bobbing
- **Grunting or stridor**
- Inability to lie down – position of comfort!
- Changes in I:E ratio
- Mental status: agitation or lethargy
Respiratory Assessment

Impending Respiratory Failure

- Severe work of breathing
- Reduced air entry
- Cyanosis despite $O_2$
- Irregular breathing / apnea
- Altered Consciousness
- Diaphoresis
Respiratory Assessment II

Status Asthmaticus/Obstructive Disease

- Tachypnea
- Nasal flaring
- Pale
- Expiratory wheezing

- Tachypnea
  - RR > 60
  - Retractions, grunting
  - Mottled
  - Insp/Exp wheezing

- Bradypnea
  - See saw respirations
  - Gray, cyanotic
  - No air movement
  - No wheezing
Respiratory Assessment III

Upper Airway Obstruction

- Tachypnea
- Pale
- Stridor
- Sonorous respirations i.e., snoring

- Tachypnea
- Inspiratory retractions
- Mottled
- Head bobbing

- Bradypnea
- See saw respirations
- Gray, cyanotic
- No air movement despite effort!
Goal #4 - When should you worry?

- People who ask for help, think they are going to die
- Can’t talk in full sentences
- When you stop hearing breath sounds, not when you hear wheezes
- Increasing tiredness
- Progression of neurological symptoms
Noninvasive Ventilation (NIV)

- Provision of ventilatory support without the need for an invasive artificial airway.
- Using a mask or cannula, gas is conducted from a positive pressure source into the nose or mouth.
- The expiratory phase is passive.
NIV: Avoiding Complications of Endotracheal Intubation

- Insertion of endotracheal tube
  * aspiration of gastric contents
  * esophageal intubation
  * patient discomfort
  * vocal cord injury
  * subglottic injury

- Risks with sedatives/paralytics
Limitations of NIV

- Requires patient cooperation
- CPAP/BiPAP require tight seal
- Loss of ability to suction airway
- Upper airway must be patent and intact
- May add to workload for staff
Complications of NIV

- Pneumothorax
- Hypotension
- Aspiration
  * pneumonia
  * airway edema
- Over or under sedation
- Nasal congestion
- Sinusitis
- Nasal/oral dryness
- Gastric distention
- Mask discomfort
- Skin breakdown
NIV: How does it help?

- Improves respiratory muscle function
- Increases lung volume
- Oxygenation and compliance
- Reduces vascular resistance
- Reduces left ventricular afterload
- Rests muscles of respiration
- Helps maintain airway patency
- Improves sleep quality
Using NIV: CPAP

- Continuous pressure support ventilation throughout inspiration and expiration
- Optimal patient is neonate or young infant
- Settings:
  - Pressure 4-10cm H2O
  - FiO2 max depends on TV times RR
- Alarms: loss of pressure
NIV: Nasal CPAP

- Increases pulmonary compliance
- Prevents alveolar collapse
- Increases spontaneous tidal volume and reduces respiratory effort
NIV: CPAP

- Decrease in alveolar-arterial oxygen pressure gradient
- Increases airway diameter
- Conserves surfactant
- Splints the airway
- Splints the diaphragm
- Reduces mechanical obstruction
NIV: BiPAP

- Bi-level portable pressure support ventilation that cycles between higher inspiratory and lower expiratory pressures
- Adjustable triggering mechanisms
- Adjustable inspiratory times
BiPAP Face Mask
High Flow Nasal Cannula

- High flow up to 8LPM in infants
- Almost 100% humidity at body temp
- No need for tight fitting mask
- Patient comfort is a big bonus: a happy baby has positive effects on everyone’s health.
- This can be positive pressure ventilation, with it’s many benefits AND risks
Cannula looks exactly like a regular nasal cannula, but just below the chin, it is connected to a heated water tubing that surrounds the heated and humidified gas. The water tubing cocoon keeps the humidity in suspension and decreases rainout. Because the patient can tolerate much higher flows without the complications of with a traditional cannula, we deliver FiO2 close to 1.0. Since the generation of flow through a regular nasal cannula can result in inadvertent continuous positive airway pressure (CPAP), this may be delivered with a HFNC as well.
High Flow Nasal Cannula

- Some positive published data in kids
- Good success at ANMC
- May avoid more invasive airway management
- Debate about feeding on HFNC
Indications for NIV in intensive care

- Primary support mode for moderate to severe respiratory failure
- Stabilization before endotracheal intubation
- Difficult intubation
- End of life status
Acute Respiratory Conditions Appropriate for Trial of NIV in Kids

- Hypoxemic respiratory failure
- Small and large airway obstruction
  * Status Asthmaticus
  * Bronchiolitis and Pneumonia
  * Exacerbation of BPD or CLD
  * Cystic Fibrosis
Contraindications to NIV

- Uncooperative patient
- Absent airway reflexes
- Full stomach/gastric distention?
- Glasgow coma scale <12-13
- Inadequate staffing or training: each type of NIV requires critical care training for RT and RN and MD staff.
Heliox

- Helium is a biologically inert gas of low molecular weight
- Mixture of helium and oxygen has been successful in treating:
  * reactive airway disease
  * post-extubation upper airway obs.
  * airway swelling post radiation tx
  * patients with BPD/COPD
Heliox and Grahm’s Law

- The flow of gas through an orifice is inversely proportional to the square root of its density.

- Thus, heliox is useful in overcoming airway resistance and obstruction.

- Heliox reduces turbulent flow and allows laminar flow at higher rates.

- Concomitant decrease in the work of breathing.
Heliox in RSV Bronchiolitis:

- Compared with conventional management of fluids, oxygen, and nebulized epinephrine, patients given Heliox MAY have improvement in clinical respiratory scores, heart rate, respiratory rate, and length of Pediatric ICU stay.

- However, pediatric studies are few.
Advantages of Heliox:

- MAY avoid endotracheal intubation and mechanical ventilation
- Less use of sedatives/paralytics
- Can be used with CPAP and BIPAP
- Patient benefits from more frequent visits with respiratory therapists
Heliox: How low can you go?

- Ideally, patient should receive an 80:20 ratio of helium to oxygen—maximizes the laminar flow and decreases turbulence. Published peds studies are few, but have used 70:30 and 80/20.

- **DANGER:** oxygen monitoring equipment can give inaccurate readings, thus hypoxemia is a risk.
Downside of Heliox:

- Price: helium is expensive
- Costs: respiratory therapists are mandatory for set-up and monitoring
- High risk for hypothermia: helium has high thermal conductivity
- High risk for hypoxemia because of the high FiO2 needs of many patients
- Wean slowly
- Does it really work in bronchiolitis?
Nitric Oxide

- Pulmonary vasodilator useful in PPHN and reactive pulmonary hypertension
- Can be given via NIV or ETT
- Well studied in pediatrics, especially in neonatology
- May combine with CPAP/BIPAP as alternative to intubation
Nitric Oxide: Downside

- Free radical - forms methemoglobin which must be monitored
- As a free radical, may have additional unknown risks
- Requires a special “scavenging” mechanism
- Must be weaned slowly
- Expensive?
When NIV Fails: step it up

- Conventional endotracheal intubation and conventional mandatory ventilation (CMV)
- High Frequency Oscillatory Ventilation (HFOV)
- Dual Lung Ventilation with CMV or a combination of HFOV and CMV.
  Example: management of a high output bronchopleural fistula
- Extracorporeal Membrane Oxygenation (ECMO)
Decision to Intubate

- Ask the 4 questions for intubation
- Complications of intubation
- Know the signs of a difficult intubation
- Know medical conditions that would indicate intubation
- Understand the decision tree to intubate (see appendix)
**Airway Control/Airway Protection**

- 4 questions
  1. Is there failure of airway protection?
  2. Is there failure to ventilate?
  3. Is there a failure to oxygenate?
  4. What is the anticipated clinical course?
INDICATIONS for INTUBATION

- Failed Non-Invasive Ventilation
- Lower airway and parenchymal disorders resulting in hypoxemia and/or hypercarbia
- Upper airway obstruction, actual or imminent
- Hemodynamic instability or anticipated instability
- CNS dysfunction (loss of protective reflexes, altered LOC, neuromuscular weakness)
- Therapeutic hyperventilation (pulmonary hypertension, metabolic acidosis)
- Management of pulmonary secretions
- Emergency drug administration
High Frequency Ventilation:

- **WHEN:** usually, hypoxemia despite conventional intubation/ventilation
- **HOW:** Improves gas exchange by continuous alveolar recruitment with the use of increased mean airway pressures (MAP)
- **WHO:** Works well on neonates and smaller pediatric patients; less data in big kids and adults
MAP provides a constant distending pressure equivalent to CPAP. This inflates the lung to a constant and optimal lung volume maximizing the area for gas exchange and preventing alveolar collapse in the expiratory phase.

Ventilation is dependent on amplitude and to lesser degree frequency. Thus when using HOFV CO2 elimination and oxygenation are relatively independent.
High-frequency oscillatory ventilation (HFOV) may be a more ideal method of ventilation to minimize ventilator-associated lung injury.

- HFOV avoids high peak inspiratory pressures, prevents end-inspiratory overdistension.
- Avoids repetitive recruitment and de-recruitment of unstable lung alveoli, prevents end-expiratory collapse.
HFOV

- **Frequency**: High frequency ventilation rate (Hz, cycles per second)
- **MAP**: Mean airway pressure (cmH2O)
- **Amplitude**: delta P or power is the variation around the MAP
- **Oxygenation** is dependent on MAP and FiO2
PICU-HFOV Initial Management

- Mean airway pressure (MAP) 2-10 cmH2O > MAP of CMV
- Frequency (Hz) per body size, 2-12 kg = 10 Hz, 13-20 = 8 Hz, 21-34 kg = 7 Hz, >35 kg = 6 Hz OR per the disease process
- Power set at 4.0 or to achieve a chest “wiggle” (from shoulders to groin)
- FiO2 at 1.0
Hazards of the OSCILLATOR:

- Barotrauma
- Decreased venous return and cardiac output
- Hypotension, PPHN
- Compromised secretion management, usually don’t suction ETT in peds
HFOV Graduate
Life Support: The Outer Limits
Bypass the lungs: ECMO

- Also known as extracorporeal life support (ECLS)
- A modified form of cardiopulmonary bypass to provide prolonged tissue oxygen delivery in patients with respiratory and/or cardiac failure.
- Overall survival is 60-70% in pediatrics and neonatal patients.
ECMO: Patient Selection

- Accepted modality for neonates and children who have failed conventional therapy and in whom cardiac and/or respiratory insufficiency is potentially reversible.

- Selection criteria: reversible disease, single organ failure, no contraindication for anticoagulation
Off to Wilford Hall Med Center on board a USAF C-130 on ECMO
A Few Months Post-ECMO
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Thanks for your attention!!