Respiratory Compromise in Pediatrics: Need for Rapid Identification and Assessment

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Objectives:
- Identify the anatomic differences between pediatric and adult patients that make infants and children more prone to respiratory failure
- Describe the signs and symptoms of respiratory compromise in the pediatric patient
- Review common causes of respiratory compromise in pediatric patients
- Discuss initial treatments of common respiratory illnesses

Kids are NOT small Adults
- Anatomy differs between ages even within the pediatric population
- Children older than 8 years, the airway tends to be more similar to adults.
- Physiological differences also exist between pediatric and adult populations
Head and Neck

- Prominent head, and large occiput
- Infants are obligate nasal breathers until age 3-6 months

Oral and Upper Airway:

- Large tongue
- Flap-like, omega-shaped epiglottis compared to firm and flat in adults
- Level of C2 or C3 in infants compared to C5 in adults
- More acute angle between glottic opening and base of tongue makes visualization of vocal cords during intubation harder
- Trachea is smaller, shorter, and more compliant
  - Leads to dynamic airway obstruction with negative pressure ventilation
- Resistance is length/radius^4 (smaller the radius the resistance is increased to the fourth power) - poiseuille's law
- Larynx is funnel-shaped versus column
- More prominent tonsils and adenoids
- Narrowest point of the trachea subglottic region, below the vocal cords. Increased risk of subglottic stenosis with ETT

Pediatric Airway Anatomy

<table>
<thead>
<tr>
<th>Children</th>
<th>Pediatric</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air entry</td>
<td>Nasal/buccal</td>
<td>nasal and oral</td>
</tr>
<tr>
<td>Nasal/Nostril</td>
<td>closed</td>
<td>closed</td>
</tr>
<tr>
<td>Larynx/Epiglottis</td>
<td>closed</td>
<td>closed</td>
</tr>
<tr>
<td>Epiglottis</td>
<td>Long, soft, omega-shaped</td>
<td>Short, soft, omega-shaped</td>
</tr>
<tr>
<td>Proportion of larynx to neck</td>
<td>large</td>
<td>equal or slightly larger</td>
</tr>
<tr>
<td>Nasal cavity</td>
<td>soft, malleable</td>
<td>fibrous, non-rigid</td>
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</tbody>
</table>
Thorax
- Rib cartilage more compliant
- Chest wall will retract more during distress, decreasing child's ability to maintain FRC (functional residual capacity) or increase needed tidal volume
- Different orientation of diaphragm muscles, oriented more horizontal vs oblique
- Diaphragm and intercostal muscles fatigue quicker in children
  - The diaphragm and intercostal muscles consist of two fiber types
    - Type I fibers are high oxidative and are considered resistant to fatigue and Type II fibers, considered standard muscle fibers, are readily fatigued.
    - The adult diaphragm is 50–55% type I fibers, whereas the term infant has 25% type I fibers and the premature infant has as low as 10%.
- Weaker intercostal muscles
  - In pediatrics, intercostal muscles only serve to stabilize chest wall, and not effective for ventilation

Physiological Differences
- Respiratory muscles have a significant oxygen and metabolite requirement in children. Up to 40% of cardiac output in stressful situations.
- Oxygen consumption higher in infants vs adults (6ml/kg/min vs 3ml/kg/min), and proportionally smaller FRC as compared to adults leads to desaturations more quickly in pediatric population.
Signs and Symptoms of respiratory Compromise

- Spectrum of signs and symptoms from respiratory distress to impending respiratory failure
- Signs/symptoms depend on etiology
- Tachypnea or bradypnea
- Use of accessory muscles
- Stridor
- Cyanosis
- Altered mental status
- Paradoxical breathing
- Agitation
- Gastroesophageal reflux
- Diaphoresis
- Cyanosis
- Tachycardia
- Grunting
- Change in voice
- Lethargy

Respiratory Failure

- Pulmonary system unable to meet the metabolic demand
- Three forms:
  - Hypoxic
  - Hypercapnia
  - Mixed (most common)
- Hypoxic: PaO₂ ≤ 60 mm Hg and abnormal PaO₂:FiO₂ ratio
- Hypercapnia: PaCO₂ > 35 mm Hg with pH < 7.35

OxyHemoglobin Dissociation Curve
Causes of Respiratory Compromise in Pediatrics
- Upper airway Disorders
- Lower airway Disorders

Common Causes of Respiratory Compromise in Pediatrics: Upper Airway
- Anatomical Disorders
- External/Internal Compression Disorders
- Infectious Disorders
- Miscellaneous Disorders

Anatomical Disorders
- Altered level of consciousness
- Tonsillar-Adenoidal hypertrophy
- Subglottic stenosis
- Macrognathia
- Macroglossia
- Vocal cord paralysis
- Choanal stenosis
Altered level of Consciousness

- Pediatric patients more prone to upper airway obstruction with LOC due to anatomy
  - Smaller chin and relatively large tongue
  - Smaller chin manifested by short mandibular rami and short distance from chin to hyoid cartilage
  - Creates smaller jaw space, one reason tongue is relatively larger for oral cavity

Treatment

- Re-position patient to relieve obstruction due to anatomical reasons
  - Optimal airway position is a patient straightened, and lying down: the external auditory canal should be just anterior to the shoulders
  - Use of head and shoulders is unnecessary or contraindicated
  - Head and shoulders to “sniffing position”
  - Be careful not to extend the neck excessively

- Use of oral or nasopharyngeal airways if available
  - Oral airways only used in unconscious patients – can illicit vomiting otherwise
  - Proper fitting for oral airways: the distance from the angle of the mouth to the tragus of the ear
  - Proper fitting of nasopharyngeal airways: length determined from the tip of the nose to the tragus of the ear

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Proper fitting of nasopharyngeal airways: length determined from the tip of the nose to the tragus of the ear
Tonsillar-Adenoidal Hypertrophy

- Hypertrophy combined with obesity is responsible for OSA and even acute upper airway obstruction.
  - Definitive treatment includes tonsillectomy and adenoidectomy.
- Can worsen respiratory distress during acute illnesses due to inflammation.
  - Inflammation
  - Increased airway edema
  - Use of oral airway
  - Positive pressure-CPAP/BIPAP

Choanal Stenosis/Atresia

- Obliteration or blockage of the posterior nasal aperture.
- Choanal atresia occurs in approximately one in 7000 live births.
- 2/3 of cases are unilateral.
  - Unilateral patients usually present late in life with unilateral nasal discharge or obstruction.
  - Bilateral patients present with upper airway obstruction, NOISEY BREATHING, and cyanosis that worsens with feeds.
- Symptoms of stenosis can be exacerbated during acute illness due to inflammation and increased mucus production/plugging.
- Diagnosis: CT of nose and nasopharynx.
- Treatment: surgery.

External/internal Compression Disorders

- Tumor
- Hemangioma
- Hematoma
- Cyst
- Papilloma
- Vascular rings/slings.
Vascular Rings

- Congenital anomalies of the aortic arch that result in compression of the tracheobronchial tree and/or esophagus, leading to respiratory and gastrointestinal symptoms
- Accounts for 1-3% of congenital heart disease
- Presentation varies widely from critical airway obstruction in neonates to incidental finding in adults
  - Symptoms:
    - Stridor, wheezing, cough, increased work of breathing, dysphagia, vomiting
- Diagnosis
  - Barium esophagogram
  - CT
  - MRA

Infectious Disorders

- Laryngotracheobronchitis (croup)
- Epiglottitis
- Bacterial tracheitis
- Retropharyngeal abscess
- Peritonsillar abscess
- Infectious mononucleosis
Signs/Symptoms similar in most upper airway disease processes

- Tripod position
- Inspiratory noises (stertor or stridor)
- Barky or seal-like cough

Mainstay treatments of upper airway disease processes

- Oxygen/ Heliox
  - Heliox is less dense than oxygen and less turbulent to enable better flow through areas of edema or obstruction
- Racemic Epinephrine
  - Causes topical vasoconstriction and smooth muscle relaxation
  - Used when stridor is heard
- Dexamethasone
  - Steroid that decreases inflammation
- Noninvasive positive pressure ventilation

Croup (Laryngotracheobronchitis)

- Respiratory illness caused by usually a virus that results in inflammation/edema of the larynx, subglottic airway, and sometimes extending into the bronchi
  - Primarily affecting children 6 months-4 years (peak 1-2 years)
  - Peak incidence in early fall and winter
- Most common virus: parainfluenza virus type 1
- Other viruses: RSV and adenovirus (although the laryngotracheal component is usually less severe than the lower airway component)
- The offending viral host causes inflammation due to increase in white blood cells along with mucosal edema and swelling
Croup (Laryngotracheobronchitis)

**Symptoms:**
- Barking cough
- Stridor
  - Usually just during inspiratory
  - Biphasic stridor may indicate airway edema that extends beyond the subglottic space in the intrathoracic trachea and bronchi
- Hoarseness
- Retractions

**Diagnosis:**
- Clinical diagnosis
- CXR: looking for the “steeple sign”
  - Narrowing of subglottic trachea coming to a point at the level of the vocal cords
- CBC
- Viral studies

**Treatments:**
- Oxygen and heliox
  - Heliox advantages: Low density so can flow through airway with less turbulence and resistance vs oxygen
- Mild croup:
  - Can be treated as an outpatient
  - Minimize situations that are distressing to patient which can worsening respiratory status by increasing inflammation
  - Hot steam (sit with patient in closed bathroom and fill with steam)
- Fever reductions
- Oral fluids

**Moderate/severe croup:**
- Administration of dexamethasone (0.6mg/kg) given oral/IV/inhaled
- Given once or scheduled Q6 hrs depending on severity
- Racemic epi (0.05ml/kg per dose) Q 2 hrs PRN
- Positive pressure ventilation
- IV fluids for hydration

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Epiglottis

- True emergency!
- Definition: Inflammation of the epiglottis and adjacent supraglottic structures. Without treatment, epiglottitis can progress to life-threatening airway obstruction.

- Etiology:
  - Historically most commonly caused by H. Influenza (More rare due to the widespread use of the H. Influenza type B vaccine)
  - Streptococcus pneumoniae and staphylococcus aureus are more common causes currently

- Symptoms:
  - Toxic appearing
  - Drooling
  - Dysphagia and dysphonia
  - Respiratory distress
  - Stridor (late in the course)
  - tripod or sniffing positions
  - High fevers

- Diagnosis:
  - Direct visualization of epiglottis

- Treatment:
  - Emergent interventions:
    - Place in most comfortable position for patient
    - Tripod position
    - Sniffing position
    - Keep patient calm and avoid noxious interventions to avoid worsening inflammation
    - Early administration of antibiotics
      - Broad spectrum effective against B-lactamase producing organisms
      - Second or third generation cephalosporins (ceftriaxone/ cefuroxime)

Mejia, Rodrigo MD. Pediatric Fundamental Critical Care Support, Society of Critical Medicine, 2008.
Miscellaneous Disorders
- Anaphylaxis
  - Serious allergic reaction with sudden onset

Anaphylaxis
- Treatment:
  - Remove the inciting agent if possible
  - Intramuscular Epinephrine
  - Management of airway:
    - Supplemental oxygen
    - Racemic epinephrine
    - IV steroids

Common Causes of Respiratory Compromise in Pediatrics: Lower Airway
- Asthma
- Bronchiolitis
- Pneumonia
Asthma

- Inflammatory disease of the lower airway that is characterized by a reversible airway obstruction due to bronchial smooth muscle contraction, increased mucus production, and airway edema.

- The obstruction and increased airway resistance due to bronchoconstriction and airway edema diminish airflow (seen mostly in expiration phase) causing air trapping, hyperinflation, and ventilation-perfusion mismatch.

**Signs and Symptoms**

- Wheezing (or lack of wheezing)
- Cough
- Shortness of breath
- Chest tightness
- Dyspnea
- Increased respiratory rate
- Use of accessory muscles, retractions
- Nasal flaring
- Grunting
- Anxiousness
- tripod position
- Prolonged expiratory phase
- Cyanosis and decreased mental status - late findings
Asthma

- Treatment:
  - Focuses on treatment of the triad
    - Bronchial smooth muscle contraction, increased mucus production, and airway edema.
  - Oxygen to maintain SpO2 > 93%
  - IV Fluids
  - Inhaled beta agonist - stimulate both B1 and B2 receptors. Beneficial effects from B2 stimulation on bronchial smooth muscle and mediate muscle relaxation
    - Short-acting
    - Examples: Albuterol, Levalbuterol
  - Nebulized vs metered dose inhalation

- Treatment continued:
  - Anticholinergic: Antagonizes acetylcholine receptors producing bronchodilation
    - Used as an adjunct therapy with inhaled beta agonists for ONLY 3 doses in children with moderate to severe exacerbations
    - Example: Ipratropium bromide (Atrovent), Albuterol-irratropium bromide (DuoNeb)
  - Steroids: Anti-inflammatory
    - Mandatory element of first line therapy for moderate to severe asthma
    - Example: Dexamethasone, Methylprednisolone

Bronchiolitis

- Lower respiratory tract infection that primarily affects the small airways (bronchioles).
- Typically caused by a viral infection. RSV being the most common viral agent, followed by rhinovirus.
- Viruses infect bronchial epithelial cells, and cause damage and inflammation in the small bronchi and bronchioles. This leads to edema, and excessive fluids causing obstruction of small airways and atelectasis.
**Bronchiolitis**

- **Signs/symptoms:**
  - Fever
  - Cough
  - Respiratory distress (increased respiratory rate, retractions)
  - Upper respiratory symptoms preceding: nasal congestion, rhinorrhea, conjunctivitis

**Treatment:**

- **SUPPORTIVE CARE!!**
  - Oxygen supplementation
  - Anti-pyretics
  - Beta-agonists and racemic epinephrine
    - Only if patient is responsive
  - Suction, Suction, Suction!

**Pneumonia**

- Inflammatory condition affecting the lungs, in particular the alveoli caused by either a viral or bacterial infection.
Pneumonia

Signs/symptoms:
- Cough
- Fever
- Secretions
- Nasal flaring or grunting
- Respiratory distress (use of accessory muscles, retractions, tachypnea)
- Referred pain ie. Abdominal pain
- Hypoxemia
- Crackles and decreased breath sounds on exam
- Malaise/lethargy

Treatment:
- Treatment depends on diagnosis of viral vs bacterial
- With either diagnosis of viral vs bacterial require basic supportive care:
  - Oxygen as needed (check pulse oximetry, saturations <90% require O2 administration)
  - Suction
  - Antipyretics
- Diagnosis of bacterial pneumonia requires treatment with antibiotics
  - Most common pathogen:
    - Streptococcus pneumoniae
  - Antibiotic of choice (first line):
    - Amoxicillin
  - Penicillin allergy: first or second generation cephalosporin (cefdinir)

Case Study #1

3 month old full-term male with no significant past medical history was referred to your ENT office with chief complaint of “noisy breathing”. Mother states that this is how he has always sounded since birth, but is worse when he is laying down. Also states he has frequent episodes of vomiting, and resultant poor weight gain. ROS revealed no fever, URI symptoms, cyanosis, or apnea.

What is your diagnosis?
Case Study #1

- Diagnosis: Vascular ring

- Clues to suggest this diagnosis:
  - Constant noisy breathing
  - Worse when lying down
  - Vomiting
  - No apnea or cyanosis

Case Study #2

- A 2 year old female with no significant past medical history presents to your ER with the chief complaint of “working harder to breathe”. Per mother, patient was in usual state of health until one week ago when she developed a runny nose, and cough but over the past day her cough has worsened. Now she is making this high pitch sound when she is breathing. This sound worsens when she is crying. ROS reveals + fever and + sick contacts.

  What is your diagnosis?

- Diagnosis: Croup

  On your initial assessment, patient is in obvious respiratory distress with moderate retractions, and tachypnea. + biphasic stridor present. Breath sounds are equal bilaterally. No wheezing or rales are heard.

  What’s your initial interventions?
Case Study #2

- Immediate interventions should include:
  - Placing patient in the most comfortable position
  - IV Decadron
  - Racemic epi nebulizer
  - Oxygen supplementation if patient is hypoxic on room air

Case Study #3

- You are a Family Practice Physician Assistant, and you just finished seeing your last patient of the day (2 year old male, no PMH). He just received his annual flu shot that was recommended. You are immediately called back into the room by the medical assistant because the patient has fainted.

What are your initial interventions to keep his airway patent?

- Remember pediatric patients are more prone to airway obstruction when they have LOC due to their anatomy.
  - Main anatomy differences:
    - Smaller chin and relatively large tongue
    - Large occiput
  - Optimal airway position in a patient obtunded, and lying down is the external auditory canal should lie just anterior to the shoulders
  - Use of oral airway if needed
References

- S. Kache, MD, Pediatric Airway & Respiratory physiology
- Walls, R Murphy, M. Manual of Emergency Airway Management 2005 © RnCeus Interactive, LLC