Respiratory Diseases

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Upper Airway Diseases
- Laryngomalacia
- Obstructive Sleep Apnea
- Subglottic Stenosis
- Tracheomalacia
- Upper Respiratory Tract Infection (URI)

Lower Airway Diseases
- Asthma
- Bronchiolitis
- Cystic Fibrosis
- Meconium Aspiration Syndrome

Respiratory diseases represent the most common systemic illnesses in children, and are likely to influence anesthetic management. This chapter reviews the most common important upper and lower airway diseases in children.

**Upper Airway Diseases**

Laryngomalacia
Laryngomalacia is the most common laryngeal disorder of the newborn. It is a congenital abnormality of the epiglottis and aryepiglottic folds that allows their inward collapse into the airway during inspiration. This inward collapse results in nearly complete upper airway obstruction that is manifested by audible inspiratory stridor, usually in the few several months of life. The stridor is usually more prominent when the infant is lying supine, crying, or feeding. In most cases it is benign, and will be outgrown during the first year of life. Laryngomalacia is occasionally associated with gastroesophageal reflux and, in rare cases, causes hypoxemia or hypoventilation, and interferes with normal feeding and subsequent growth. Infants in this latter group require definitive diagnosis by direct laryngoscopy under general anesthesia. Rigid bronchoscopy is performed at the same time to rule out subglottic causes of airway obstruction. Severe laryngomalacia is treated by performing a supraglottoplasty, in which a CO2 laser is used to trim the length of the epiglottis and partially sever the aryepiglottic folds to prevent the epiglottis from infolding into the glottic opening during inspiration.

During induction of general anesthesia, infants with laryngomalacia commonly exhibit airway obstruction that is not relieved by placement of an oral airway device. Deepening the anesthetic will often relieve the obstruction because of progressive weakening of the diaphragm and decreasing the strength of inspiration. However, during upper airway obstruction, speed of inhalational induction is slowed. Positive-pressure ventilation is usually easily accomplished in these infants, especially after the onset of neuromuscular blockade.

Obstructive Sleep Apnea
Obstructive sleep apnea (OSA) in children is the result of adenotonsillar hypertrophy, combined with an abnormally small retropharyngeal space, and altered neuromuscular control of upper airway patency during sleep. It mainly occurs in children between the ages of 2 and 4 years, and is especially prevalent in children with obesity and trisomy 21. The clinical manifestations include partial or complete upper airway obstruction during sleep, restless sleep, morning headaches, behavioral disturbances, and daytime somnolence. Severe cases of untreated longstanding OSA can result in chronic hypoxemia, polycythemia, and cor pulmonale. Children with electrocardiographic or radiographic cardiac abnormalities should be referred to a pediatric cardiologist for further evaluation and management.

The most common therapy for pediatric OSA is adenotonsillectomy (see Chapter 29), which alleviates symptoms in most children. Some pediatric anesthesiologists prefer to reduce the dose of the preoperative...
sedative in children with OSA, for fear of causing life-threatening upper airway obstruction in an unmonitored environment. However, it has been this author’s experience that a routine dose of oral midazolam in children with OSA does not cause significant upper airway obstruction.

During induction of general anesthesia, virtually all children with untreated OSA will exhibit partial or complete upper airway obstruction. Insertion of an artificial oral airway device after loss of consciousness will bypass the obstruction and allow easy bag-mask ventilation. In the immediate postoperative period following adenotonsillectomy, the incidence of airway obstruction is higher in children with OSA when compared with those who undergo adenotonsillectomy for recurrent infections. Therefore, children with significant OSA should be hospitalized overnight following the procedure. Even some time after adenotonsillectomy has been performed, a predisposition toward upper airway obstruction during sleep or sedation may persist throughout childhood. Children with OSA are more likely to develop adult-type OSA.

### Subglottic Stenosis

Subglottic stenosis is an abnormal narrowing of the extrathoracic trachea below the level of the vocal cords. It may be present at birth (webs, strictures, etc.) or, more commonly, is acquired secondary to chronic inflammation and scarring from the presence of an endotracheal tube. Congenital subglottic stenosis is more common in children with multiple congenital anomalies and in children with trisomy 21.

Acquired subglottic stenosis is the most common acquired anomaly of the larynx in children and the most common abnormality requiring tracheotomy in children younger than 12 months. The chronic presence of an endotracheal tube causes inflammation and scarring, particularly at the level of the cricoid ring, and a restrictive scar is formed. The clinical manifestations of subglottic stenosis include inspiratory stridor during crying or at the time of an upper respiratory tract infection, during which tracheal narrowing increases secondary to edema.

Subglottic stenosis is diagnosed using rigid bronchoscopy under general anesthesia. Positive-pressure ventilation via bag and mask can be difficult when the narrowing is severe. An additional anesthetic implication is the need for an endotracheal tube that is markedly smaller than that predicted for age. Severe cases require treatment with an anterior cricoid split procedure or a more complete tracheal reconstruction (laryngotracheoplasty), and some children require tracheostomy. Following tracheal reconstruction, these children will remain paralyzed and mechanically ventilated for several days while the tracheal tissue heals over the endotracheal tube.

### Tracheomalacia

Tracheomalacia is defined as a softening of the tracheal cartilage, which then becomes susceptible to collapse when the intraluminal tracheal pressure is less than the extraluminal tracheal pressure. Thus, airway collapse can occur during forceful coughing or exhalation. Congenital tracheomalacia occurs in infants with a tracheoesophageal fistula and some genetic disorders such as trisomy 21 and the mucopolysaccharidoses. Acquired tracheomalacia occurs in children who required long-term mechanical ventilation during early infancy, and in children with tracheal compression lesions such as a vascular ring.

Clinical manifestations of tracheomalacia include noisy breathing, “barky” cough, wheezing, and respiratory distress (e.g., dyspnea). These symptoms are often exacerbated during a URI (upper respiratory infection). Many children with tracheomalacia are initially thought to be asthmatic until properly diagnosed.

Anesthetic implications for children with tracheomalacia are similar to those for laryngomalacia. Positive-pressure ventilation, especially after administration of a neuromuscular blocker, will characteristically result in the ability to easily open the softened trachea and establish adequate ventilation. Coughing and partial upper airway obstruction will exacerbate tracheal collapse and rapidly lead to hypoxemia. This is particularly difficult to manage during emergence from general anesthesia and after tracheal extubation. Children with severe tracheomalacia may require a “deep extubation” to avoid these complications.

### Upper Respiratory Tract Infection (URI)

Viral upper respiratory tract infections (URIs) are frequent in children, especially during the winter months. Typical symptoms include rhinorrhea, congestion, cough, fever, and malaise. Subclinical manifestations may include upper and lower airway edema, increased respiratory tract secretions, pneumonia, and bronchial irritability.

Intraoperative airway complications during general anesthesia seem to be more common in children with a URI. These include coughing, laryngospasm, bronchospasm, and hypoxemia. Infants under 12 months of age tend to have more intraoperative complications than older children, and use of an endotracheal tube as compared with a facemask or laryngeal mask airway (LMA) increases the risk of these complications. Passive exposure to cigarette smoke is an additional risk factor. Apneic oxygenation is less effective; thus oxyhemoglobin desaturation may occur when, during rapid sequence induction, the child is not receiving positive-pressure ventilation.
Use of thiopental for induction of general anesthesia is associated with more airway complications than when propofol is used.

Transient postoperative hypoxemia, postintubation croup, and postoperative pneumonia are more likely to occur in children with a URI. Long-term complications and true outcomes are difficult to define and quantify and may not differ between normal children and those with a current or recent URI.

With these possible complications in mind, when a child presents with a URI, it is intuitive that an elective procedure requiring general anesthesia should be canceled. But, because so many children have a concurrent URI at the time of their scheduled surgery, and long-term negative outcomes have not been demonstrated, this decision process is complex. How, then, should the anesthesiologist decide when to cancel an elective procedure in a child with a URI? First, one should assess the severity of the child’s illness. The child with a runny nose without additional findings may be suffering from vascular or allergic rhinitis (Box 4-1), which is usually not associated with perioperative airway complications. If it is clear that the illness is viral, one must then identify the factors that are likely to increase perioperative complications (Box 4-2). If any of these risk factors are present, it may be prudent to perform the procedure at a later date when the child is in better health. On the other hand, there are a variety of additional factors that may influence the anesthesiologist’s decision to proceed with surgery or cancel the case. The most common reason for proceeding with a case even though risk factors are present is the continuous presence of a URI that will likely continue without surgical intervention. This occurs when children require adenoidectomy or myringotomy to relieve chronic middle ear fluid collections. Nonmedical factors that might sway the anesthesiologist in favor of proceeding with the case are logistical family concerns, such as the parents taking a day off from work, difficulty finding day care, traveling a long distance at a great inconvenience to the family, etc. Since outcomes are not proven to be worse after surgery in children with a URI, these factors may play a role in the decision of whether or not to proceed. Most children who present with a URI have neither extremely mild symptoms nor severe symptoms. In these children we must use our judgment to determine the proper course of action based on what we believe is best for the child.

To minimize airway irritability, sevoflurane should be chosen for an inhalational induction and propofol for an intravenous induction. Neuromuscular blockade should be administered as rapidly as possible to prevent laryngospasm. Some authors suggest administration of an anticholinergic agent, such as atropine or glycopyrrolate, to attenuate vagally mediated airway complications; however, this remains untested. When feasible, facemask or LMA anesthesia is preferred over endotracheal intubation.

There is no consensus when to schedule elective surgery following an acute URI between (and even within!) children’s hospitals. In a 1979 publication that described the development of lower respiratory symptoms during general anesthesia in children with a URI, McGill and colleagues from DC Children’s Hospital wrote: “the optimal period of recovery from the URI that should be allowed prior to considering the patient a candidate for an elective surgical procedure has not been defined.” More than 20 years later, this is still true. Subclinical pathology, such

<table>
<thead>
<tr>
<th>Box 4-1 Distinguishing a Viral URI from Allergic Rhinitis</th>
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<tbody>
<tr>
<td><strong>Viral URI</strong></td>
</tr>
<tr>
<td>Purulent rhinorrhea</td>
</tr>
<tr>
<td>Presence of fever</td>
</tr>
<tr>
<td>Productive cough</td>
</tr>
<tr>
<td>Other family members ill</td>
</tr>
<tr>
<td>Lower respiratory tract signs (e.g., wheeze, rales, bronchospasm)</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Box 4-2 Preoperative Factors Suggesting Cancellation of an Elective Procedure in a Child with a URI</th>
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<tbody>
<tr>
<td>Coexisting medical disease (especially cardiac, pulmonary, or severe neuromuscular disease)</td>
</tr>
<tr>
<td>History of prematurity</td>
</tr>
<tr>
<td>Lower respiratory tract signs (e.g., wheezing, rales)</td>
</tr>
<tr>
<td>High fever (&gt;102°F)</td>
</tr>
<tr>
<td>Productive cough</td>
</tr>
<tr>
<td>Major airway, abdominal, or thoracic surgery</td>
</tr>
<tr>
<td>Parent is worried about proceeding</td>
</tr>
<tr>
<td>Surgeon is worried about proceeding (Ha!)</td>
</tr>
</tbody>
</table>

Many studies have attempted to elucidate risk factors associated with perioperative events in children with URIs who undergo general anesthesia. Most of these are limited by the inconsistent definition of a URI, and the retrospective nature of the data collection. Dr Tait and his colleagues performed a prospective study of children with mild URIs presenting for general anesthesia to determine the incidence of and independent risk factors for perioperative complications.

They enrolled 1078 children between the ages of 1 month and 18 years. The children were divided into three cohorts: active URI (n = 407), URI within 4 weeks (n = 335), and 336 controls. They defined a URI as a minimum of two of the following symptoms: rhinorrhea, sore or scratchy throat, sneezing, nasal congestion, malaise, cough, and fever <38°C, together with confirmation from a parent. Occurrence and severity of respiratory complications were collected prospectively (Table 4-1).

Table 4-1 Scoring System for Each of Six Respiratory Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Severity Scores</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>( \text{SpO}_2 ) (%)</td>
<td>95–100</td>
</tr>
<tr>
<td>Cough (n)</td>
<td>None</td>
</tr>
<tr>
<td>Breath-holding (s)</td>
<td>None</td>
</tr>
<tr>
<td>Laryngospasm</td>
<td>None</td>
</tr>
<tr>
<td>Bronchospasm</td>
<td>None</td>
</tr>
<tr>
<td>Secretions</td>
<td>None</td>
</tr>
</tbody>
</table>

Table 4-2 Incidence of Perioperative Adverse Respiratory Events by URI Status (n (%))

<table>
<thead>
<tr>
<th>URI Status</th>
<th>Breath-holding</th>
<th>Laryngospasm</th>
<th>Bronchospasm</th>
<th>Severe Cough</th>
<th>( \text{SpO}_2 &lt;90% )</th>
<th>Adverse Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active URI (n = 407)</td>
<td>124 (30.5)%b</td>
<td>8 (2.0)%f</td>
<td>9 (2.2)%d</td>
<td>25 (5.7)</td>
<td>40 (9.8)%b</td>
<td>64 (15.7)%e</td>
</tr>
<tr>
<td>Recent URI (n = 335)</td>
<td>78 (23.3)</td>
<td>9 (2.7)%f</td>
<td>5 (1.5)%d</td>
<td>9 (2.7)</td>
<td>19 (5.7)</td>
<td>49 (14.7)%e</td>
</tr>
<tr>
<td>No URI (n = 336)</td>
<td>60 (17.9)</td>
<td>8 (2.4)%f</td>
<td>5 (1.5)%d</td>
<td>11 (3.3)</td>
<td>14 (4.2)</td>
<td>26 (7.8)</td>
</tr>
</tbody>
</table>

\( a p < 0.05 \) versus no URI.
\( b p < 0.05 \) versus recent URI.
\( c \) Laryngospasm requiring positive airway pressure.
\( d \) Laryngospasm requiring succinylcholine.

The findings in this study confirm that children with an active URI had a higher risk of major arterial desaturation, severe coughing, and overall adverse respiratory events than controls without an active or recent URI (Table 4-2). Children who had airway management with an endotracheal tube were also more likely to demonstrate airway complications than those managed with an LMA or facemask. There were no differences in the incidences of laryngospasm or bronchospasm between the three groups. As would be expected, children who underwent airway procedures (e.g., adenotonsillectomy) were more likely to have airway complications.

Independent risk factors for respiratory complications in children with active URIs included: copious secretions, presence of an endotracheal tube when the child was below 5 years of age, prematurity (<37 weeks), nasal congestion, paternal smoking, reactive airway disease, and airway surgery. One child with a recent URI required hospitalization for stridor, and two children with active URIs were hospitalized with pneumonia.

The findings in this study confirm that children with an active URI are at increased risk for respiratory complications, especially when intubated, and during airway surgery. These findings also extend to the child with a recent URI within 4 weeks of the surgical procedure. Knowledge of some of the independent risk factors can assist anesthesiologists who are confronted with the often difficult decision of whether or not to cancel the case in the immediate preoperative period.
as airway edema, atelectasis, and bronchial reactivity may remain for up to several weeks after the acute URI have resolved. Three to four weeks seems to be a reasonable waiting time, but for many children this merely represents the period between successive illnesses.

**LOWER AIRWAY DISEASES**

The “lower airway” is traditionally thought of as that portion of the respiratory system that is contained within the thoracic cavity. Therefore, lower airway diseases are those that primarily involve the lungs and bronchial system.

**Asthma**

Asthma is defined as a chronic disease of reversible airway obstruction, and is characterized by bronchial hyperreactivity, inflammation, and mucous secretion. Clinical manifestations of asthma include wheezing, persistent dry cough, and dyspnea on exertion. During an acute exacerbation, marked respiratory distress occurs, which may include chest wall retractions and a prolonged expiratory phase secondary to bronchial obstruction. Recent studies suggest that chronic airway inflammation rather than smooth-muscle contraction is the primary underlying pathophysiologic mechanism, and thus, maintenance treatment regimens have changed accordingly.

### Case 1

A 13-month-old male is scheduled for bilateral myringotomy and tube insertions. He has a history of wheezing with colds, for which he takes nebulized albuterol as needed. His last episode of wheezing with a cold was 3 weeks ago.

**Is there anything else you would like to know before proceeding with general anesthesia?**

I’d like to know more about his respiratory history. Specifically, I’m interested to know whether he ever required an emergency room visit or hospitalization for his asthma. This will give me a better idea of the severity of his illness. I want to know about his recent health, with regard to viral illnesses, and I will ask the parents if he is exposed to cigarette smoke at home. Children exposed to second-hand smoke tend to exhibit more airway complications during general anesthesia.

On physical exam, I’ll pay careful attention to the respiratory system. I’ll try to detect the presence of wheezing on auscultation of the lungs, and I will examine his chest to detect use of accessory muscles of respiration. Respiratory rate and pulse oximetry values should be normal.

**How will you induce and maintain general anesthesia in this child? Is it any different from a child without asthma?**

This child will receive premedication with oral midazolam 0.5 mg/kg, and oral acetaminophen 15 mg/kg. He will then undergo induction and maintenance of general anesthesia with sevoflurane by facemask throughout the entire procedure, which should last no longer than 10 minutes. I will administer 20 µg/kg of intranasal fentanyl to provide postoperative analgesia. As long as this child does not demonstrate wheezing, I will not do anything differently from I would for a child without asthma. For example, prophylactic inhaled albuterol will not be administered, and no intravenous line is necessary.

**During the procedure you detect wheezing through the precordial stethoscope. What will you do?**

Wheezing is a sign of bronchospasm but can also be caused by other entities. Initially, I will rule out light anesthesia and upper airway obstruction by deepening the general anesthetic while I reposition the head and neck, and suction out the oropharynx to clear any secretions. Simultaneously, I will examine the chest, feel the ventilation bag and observe the capnographic tracing, all of which can give me clues about efficacy of air entry and expiratory time. Again, I’m trying to differentiate upper from lower airway obstruction. These maneuvers, in combination with deepening the anesthetic using positive-pressure ventilation, will extinguish wheezing in almost all cases without requiring bronchodilator therapy.

**How will your treatment differ if the patient is tachypneic and is wheezing in the post-anesthesia care unit (PACU)?**

Wheezing in the PACU requires a different treatment strategy from the intraoperative setting. Oxygen supplementation will be administered if the oxyhemoglobin saturation is below 96% on room air. Treatment will consist of nebulized albuterol, 2.5 mg diluted in 3–4 mL of normal saline. In the majority of cases, one treatment is all that is needed for the wheezing to abate, and the child can then be observed and discharged to home if otherwise well. Reasons for hospital admission will include continuing bronchospasm that is not responding to one or two bronchodilator treatments, and a persistent oxygen requirement. Intravenous access will be required for administration of methylprednisolone 2.5 mg/kg. If the child appears to be in pain, I will administer oral oxycodone 0.1 mg/kg.
Case 2

A 4-year-old boy with asthma requires general endotracheal anesthesia for umbilical hernia repair. He is maintained on inhaled steroids, inhaled cromolyn, an orally administered leukotriene antagonist, and occasionally requires nebulized albuterol for acute episodes of wheezing. Two weeks prior to the surgery, he required one week of oral prednisone for an asthma exacerbation that was worse than usual.

Does the recent exacerbation and oral steroid requirement change your approach to the anesthetic management?

There are two ways the history of a recent asthma exacerbation may change my anesthetic management approach. First, I will make sure the child is now in excellent health, and without any wheezing or URI. The procedure is purely elective and should not be performed if the child is still having symptoms of his illness. Second, if his illness has completely abated this child may be a candidate for prophylactic oral steroid therapy for several days prior to the procedure. I will make this determination by speaking with the boy’s parents several days prior to the procedure. If he has required regular hospitalization for his asthma, or frequent systemic steroid use in the past, it indicates that his disease is prone to flare-ups. I will ask his pediatrician to see him prior to the scheduled surgery and prescribe oral steroids for several days. This usually consists of prednisone, up to 1 mg/kg daily.

If this child has had frequent asthma recurrences, I will alter my intraoperative management approach by avoiding endotracheal intubation. Most surgeons who perform umbilical hernia repair prefer intraoperative paralysis and there is no reason I can’t use a LMA with controlled ventilation during the procedure. I will avoid administration of medications that are associated with histamine release, such as morphine and mivacurium, and I will remind the surgeon to administer local anesthetic into the wound, up to 1 mL/kg of 0.25% bupivacaine or 0.2% ropivacaine.

With a prevalence of approximately 10% (and continually increasing in most urban areas) asthma has become the most common chronic illness in children in the United States. Ninety percent of children with asthma present before the age of 6 years. An exacerbation of asthma may be caused by allergic, environmental, infectious, or emotional stimuli, among others, and can last up to several hours. Some resolve spontaneously, whereas others require aggressive medical therapy.

Anesthesiologists will most commonly encounter children with asthma prior to elective surgery. The majority of these children will have not had a recent exacerbation of wheezing, and may be taking maintenance therapy. Preoperatively, the anesthesiologist should assess the severity and current status of the child’s illness by focusing on several aspects related to the disease. Important details of the medical history include the number of emergency room visits during the previous year, number of hospitalizations for asthma exacerbations, previous occurrences of pneumothorax or respiratory arrest, and the current and recent medication history. The parents and child (if old enough) will usually be able to provide a relative estimate of the current severity of their condition.

The physical examination of the child is focused on the respiratory system, looking for clues of ongoing bronchospasm. These include audible wheezes on expiration, a prolonged expiratory time, and use of accessory muscles of respiration. Pulse oximetry measurement should be obtained to determine the child’s baseline oxyhemoglobin saturation. A reading less than 96% in room air is a cause for concern and further evaluation.

Based on the history and physical exam findings, the anesthesiologist should estimate whether the child is optimized for elective surgery and whether or not to proceed with an elective anesthetic. For example, mild wheezing may be serious in a child who never wheezes between acute exacerbations, as opposed to the child who continually has a baseline wheeze, who may be considered to be optimized at the time of surgery.

The treatment of asthma consists mainly of bronchodilators and inhaled corticosteroids. Nebulized β₂-agonists (e.g., albuterol, levalbuterol) produce bronchodilatation via stimulation of β₂-receptors on airway smooth muscle. They are administered as daily maintenance agents or on an as-needed basis. Administration of steroids is associated with decreased airway inflammation, decreased mucus secretion, and decreased release of proinflammatory cytokines. Aerosolized steroids (e.g., budesonide) are breathed directly into the lungs and are not associated with systemic side-effects, but are generally not useful during acute exacerbations. Intravenous steroids will begin to decrease airway inflammation within several hours of administration and are an appropriate treatment during an acute exacerbation.

Additional preventative therapies include orally administered leukotriene receptor antagonists (leukotrienes are lipid mediators generated from the metabolism of arachidonic acid, and have been shown to play an important role in the pathogenesis of asthmatic inflammation), and inhaled or oral cromolyn, which prevents episodes of bronchospasm by stabilizing the mast cell membrane and preventing release of inflammatory
of action is smooth-muscle relaxation secondary to inhibition of calcium uptake. The current dose recommendation of intravenous magnesium for treating asthma is 25–75 mg/kg over 20 minutes.

The anesthetic management of children with asthma is aimed at preventing an exacerbation of the disease.

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**Case 3**

A 10-year-old female is diagnosed with acute appendicitis and is scheduled for an emergency laparoscopic appendectomy. She has a history of asthma for which she takes maintenance therapy with inhaled steroids, inhaled cromolyn, and a leukotriene antagonist. Three days ago she was treated in the emergency room for an acute asthma attack. She received inhaled albuterol and intravenous methylprednisolone. Some residual wheeze remains, and she states she is not back to her usual state of good health.

**How will you approach the anesthetic management of this child?**

Since this procedure is urgent, I don’t have much time to further optimize this child’s asthmatic condition prior to appendectomy. She should receive a nebulized albuterol treatment, either in the emergency room or upon arrival to the OR holding area, and one intravenous dose of methylprednisolone. I will also administer intravenous midazolam as a preoperative anxiolytic. Preoperative intravenous hydration is also important in this child – she has probably had limited oral intake recently, and I want to minimize thickening of her bronchial secretions.

Rapid sequence induction of general anesthesia is indicated in this patient owing to the nature of her abdominal process. It should be tailored so as to minimize the chances of bronchial reactivity following endotracheal intubation. Following an adequate interval of preoxygenation, I will administer glycopyrrolate 0.01 mg/kg, fentanyl 2 μg/kg, lidocaine 1.5 mg/kg, propofol 5 mg/kg, and rocuronium 1.2 mg/kg while an assistant holds cricoid pressure. This combination of medications should provide reliable intubating conditions within 60 seconds. For maintenance of general anesthesia I can use any of the inhalational agents (except for desflurane because of its airway irritating properties), and continue administration of fentanyl as needed.

**How will the presence of asthma change your ventilator settings?**

Minute ventilation settings should be appropriate for this child’s age and weight. However, asthmatic patients with a significant degree of airway obstruction will require a longer than usual expiratory time, and a slower ventilatory rate to allow for complete alveolar emptying. In the worse-case scenario, asthmatic patients can develop air trapping, which can lead to tension pneumothorax. However, this rarely occurs in patients who do not exhibit severe airway obstruction at the time of institution of mechanical ventilation. I would choose a pressure ventilation mode over a volume ventilation mode to minimize abrupt increases in peak inspiratory pressures should bronchospasm occur. It is primarily a matter of personal preference and whether one desires to trigger a ventilator alarm if the peak inspiratory pressure is above a predefined setting, or if the delivered tidal volume is below a predefined limit.

**During the procedure, you detect wheezing by auscultation, the capnograph changes to an up-sloping shape, and the delivered tidal volume decreases, all of which indicate the onset of bronchospasm. What will you do?**

The likelihood of asthmatic-related bronchospasm in this patient is high, but I will initially rule out other obvious causes such as right main stem bronchial intubation (which often happens when a patient is placed in the Trendelenburg position), and excess secretions in the endotracheal tube. I will increase the concentration of the inhalational agent (within hemodynamic limits), and reconfirm adequate neuromuscular blockade using a twitch monitor. The inhaled oxygen concentration will be increased if necessary. If none of these rapidly reverse the wheeze, I will administer inhaled albuterol through the endotracheal tube. The most practical way of doing this intraoperatively is by using a metered-dose inhaler that is connected to the anesthesiа breathing circuit between the inspiratory limb and patient Y-piece. This can be performed by inserting the bronchodilator canister into a 60-mL syringe barrel and using the plunger to actuate the medication (Fig. 4-1), or by directly inserting the canister into the breathing circuit using a specialized adapter (Fig. 4-2). Access into the circuit is attained through a removable cap, through which the spray is actuated just prior to a positive-pressure breath. In practice, however, a very low percentage of the bronchodilator actually reaches the lungs because it adheres to the circuit and endotracheal tube. The smaller the diameter of the endotracheal tube, the less actuated medication will actually reach the lungs. Therefore, multiple administrations of albuterol are delivered (usually between 10 and 20) until bronchospasm is relieved, or until the patient develops tachycardia from absorption of the adrenergic agonist.
The most common intraoperative cause of bronchospasm in asthmatic children is tracheal stimulation during insertion of an endotracheal tube. Tracheal intubation should be avoided if at all possible in favor of facemask or LMA anesthesia. If tracheal intubation is required, airway reflexes should be suppressed by attaining a sufficiently deep level of general anesthesia prior to endotracheal tube insertion. All inhaled anesthetic agents will accomplish this goal as well as providing some degree of direct bronchodilation, although most pediatric anesthesiologists would not include desflurane in this category because of its irritative effects on the upper and lower airways. Adult studies demonstrate that intravenous induction of general anesthesia with propofol is associated with less bronchospasm than thiopental or etomidate. Ketamine is frequently used in asthmatic patients because of its ability to cause bronchodilation by releasing endogenous adrenergic agonists, but there appears to be no advantage over propofol. The use of an opioid or a neuromuscular blocker that causes histamine release (e.g., morphine, mivacurium) is generally avoided; however, there are no data to substantiate this practice. Another theoretical practice is the use of edrophonium instead of neostigmine, which may possess greater tendency to cause bronchoconstriction.

Regional anesthesia is encouraged in patients with asthma. Blunting of the sympathetic response as a result of central regional blockade is not likely to initiate or exacerbate bronchospasm in an asthmatic child since there is no direct adrenergic innervation to human airway smooth muscle.

Bronchiolitis

Bronchiolitis is an acute viral infection of the lower airways that primarily affects children below the age of 2 years. The most common etiologic agent is respiratory syncytial virus (RSV), although most respiratory viruses have been associated with the clinical syndrome of bronchiolitis. Clinical manifestations include wheezing during or after a URI prodrome and varying degrees of respiratory distress. Some infants will exhibit hypoxemia and require oxygen supplementation, bronchodilator therapy, and hospital admission. Children with preexisting bronchopulmonary dysplasia (BPD) or cyanotic congenital heart disease are particularly prone to respiratory failure during an episode of bronchiolitis.

Treatment of bronchiolitis is mainly supportive; endotracheal intubation and mechanical ventilation may be required in children with respiratory failure. Ribavirin is an inhaled antiviral agent, but has equivocal efficacy, and is reserved for children with serious coexisting medical diseases. A history of bronchiolitis during infancy is associated with a higher risk of asthma or wheezing in older children during a URI.

Cystic Fibrosis

Cystic fibrosis (CF) is an autosomal recessive disease that affects approximately 1 in 3000 Caucasian children, and is much less frequent in other racial populations. The basic defect in CF is altered electrolyte secretion and distribution across epithelial membranes. Its major clinical consequences include progressive chronic lung disease, pancreatic destruction with intestinal malabsorption, and progressive liver damage later in life. The lung disease often begins in early childhood and is characterized by increased volume and viscosity of secretions that result in small airway blockage, atelectasis, bronchospasm, pneumothoraces, and frequent
Table 4-3 Classification of Severity of Meconium Aspiration Syndrome (MAS)

<table>
<thead>
<tr>
<th>Type of MAS</th>
<th>Therapy Required</th>
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<tbody>
<tr>
<td>Mild</td>
<td>&lt;40% oxygen therapy for &lt;48 hours</td>
</tr>
<tr>
<td>Moderate</td>
<td>&gt;40% oxygen therapy for &gt;48 hours</td>
</tr>
<tr>
<td>Severe</td>
<td>Requirement for mechanical ventilation</td>
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</tbody>
</table>

antibiotic-resistant bacterial infections. Nasal polyp formation and sinus infections are common. Bronchiectasis develops later in life: occasional bouts of hemoptysis may lead to significant anemia.

Over the past several decades, medical management of this disease has improved significantly, and patients often live well into adulthood. Treatment strategies include chest physical therapy, exercise, and frequent coughing to mobilize secretions. Bronchodilators and anti-inflammatory medications decrease airway reactivity. Bacterial pneumonia requires aggressive antibiotic therapy. Nebulized dornase (Pulmozyme) can be administered to break down thick DNA complexes that are present in mucus due to cell destruction and bacterial infection. Normal growth can often be achieved with pancreatic enzyme replacement, fat-soluble vitamin supplements, and high-calorie high-protein diets.

Common reasons that children with CF require surgery include meconium ileus in the newborn period, nasal polypectomy, and endoscopic sinus surgery. Older or more severely ill children may require anesthesia for placement of indwelling central line access, or gastrostomy tube insertion. Preoperative evaluation of pulmonary function is essential; possible studies include chest radiography, pulmonary function tests, and arterial blood gas analysis. Optimization of infection control and physiotherapy for secretion clearance are priorities, and are coordinated with the child’s pulmonologist.

The anesthetic technique of choice for children with CF is controversial. Some advocate use of ketamine because of its minimal effects on ventilatory function; however, others cite ketamine’s ability to increase airway secretions, which may worsen respiratory function in patients with CF. Fluid management is also controversial - some pediatric anesthesiologists prefer a liberal fluid strategy to decrease viscosity of bronchial secretions while others advocate minimization of fluids to decrease airway secretions at the expense of increased viscosity. It seems that avoidance of either overhydration or dehydration is the most prudent course of action.

In children with significant pulmonary disease and poor nutritional status, placement of an endotracheal tube and application of mechanical ventilation often entails postoperative transfer to the ICU and the difficult decision-making process concerning the timing and appropriateness of tracheal extubation. Postoperative management should be proactively planned in conjunction with the intensive care physicians, and with the input of the patient and family.

Meconium Aspiration Syndrome

Fetal hypoxia triggers the passage of meconium into the amniotic fluid, which is then swallowed into the oropharynx and aspirated into the trachea and lungs prior to or at the time of birth. Passage of thin meconium in a vigorous, otherwise well neonate can result in mild meconium aspiration syndrome (MAS; Table 4-3). The passage of thick meconium in an asphyxiated newborn can result in moderate or severe MAS. Moderate or severe MAS occurs when aspirated meconium causes bronchial obstruction and pneumonitis, which leads to ventilation/perfusion mismatch and hypoxemia. The presence of meconium in the amniotic fluid warrants aggressive suctioning of the fetal mouth and pharynx prior to delivery, and attempted tracheal suctioning prior to the newborn taking its first breaths. However, when a substantial amount of thick meconium has been aspirated by an asphyxiated infant, peripartum suctioning does not prevent severe MAS.

Hypoxemia and acidosis increase pulmonary vascular resistance and lead to persistent pulmonary hypertension of the newborn (PPHN) (see Chapter 1). Treatment includes optimization of mechanical ventilation and possible institution of extracorporeal membrane oxygenation (ECMO) until lung function returns to normal and PPHN is resolved.

ADDITIONAL ARTICLES TO KNOW


