Introduction

Acute infections of the respiratory tract are common in pediatric patients. Respiratory disease represents the leading cause of hospitalization in children less than four years of age and is responsible for many physicians’ office and emergency department visits. The severity of upper respiratory tract infection ranges from mild, self-limited disease, to potentially life-threatening airway obstruction. The prepared clinician can often make a diagnosis based solely on the history and physical examination, using radiographs and laboratory exams to aid in diagnosis when the clinical picture is unclear. At times, airway collapse is imminent and the clinician must proceed directly to endoscopy for definitive diagnosis and airway protection. This discussion will include the pathogenesis, clinical presentation and management of epiglottitis, croup and tracheitis in the pediatric population.

Basic Science

Stridor is a common finding in patients with upper respiratory disease. It is not a diagnosis, but a sign of airway obstruction. Airflow in the upper respiratory tract normally approximates laminar flow. As inflammation occurs in the airway, it is narrowed. As described by the Venturi effect, the rate of flow is increased in this narrowed segment. In normal circumstances, the moving column of air exerts a slight negative pressure on the wall of the airway. The Bernoulli principle describes a decrease (or increased negativity) in this pressure as the velocity of flow increases. This increase in intraluminal negative pressure serves to promote airway collapse. These laws governing a flowing air column serve to cause an increase in turbulence within the moving column. This is appreciated on physical examination as stridor.

Airway compromise at the glottic level may present with inspiratory stridor early in the disease process or biphasic stridor due to the fixed nature of the obstruction occurring within the cartilaginous laryngeal framework as the compromise progresses. Narrowing above the glottic level characteristically produces inspiratory stridor due to collapse of the unsupported soft tissues of the hypopharynx and supraglottis upon the creation of negative pressure within the airway. Narrowing of the distal airways is increased with the positive intrathoracic pressure generated during exhalation, thus producing expiratory wheezing.

Anatomic differences between the pediatric and adult airway render children more susceptible to acute airway compromise from infectious disease. The subglottis is the narrowest segment of the pediatric airway, while the adult airway is smallest at the glottic level. The subglottis is encircled by the rigid cricoid cartilage and has a loosely attached mucosa that allows the formation of submucosal edema. Any inflammation at the subglottic level greatly reduces the airway diameter. The magnitude of airway compromise can be calculated remembering the cross-sectional area of a cylinder is proportional to the
square of the radius \( (\pi r^2) \). Thus, \( \pi r_{\text{narrowed}}^2 / \pi r_{\text{normal}}^2 \times 100 \) equals the percentage of remaining airway as compared to normal. Using this formula and assuming that the normal newborn subglottis has a diameter of approximately 5 mm, it can be calculated that 1 mm of edema in the subglottis reduces the airway to 36% of its original cross-sectional area \( (2^2/2.5^2 \times 100) \). The drastic effect of swelling is even more significant when congenital airway narrowing such as subglottic stenosis (subglottis less than 4 mm) is exacerbated by acute inflammation within the airway.

**Epiglottitis (Supraglottitis)**

First described in 1878 by Michel and labeled “angina epiglottidea anterior”, epiglottitis, or more correctly supraglottitis, represents a true airway emergency. It is a bacterial cellulitis of the supraglottic structures, most notably the lingual surface of the epiglottis, but also affecting the aryepiglottic folds. As the supraglottic edema increases, the epiglottis is forced posteriorly causing progressive airway obstruction. Supraglottitis tends to occur in patients aged 2 to 7 years old, but cases in patients under 1 year have been reported. *Haemophilus influenzae* type B (HIB) is the most commonly implicated organism, but group A, β-hemolytic streptococcus, staphylococcus, pneumococcus, klebsiella, candida and viruses have been isolated as well. The introduction of HIB vaccination in the mid 1980’s has greatly decreased the incidence of the disease. A recent study by Senior et al. examining the features of supraglottitis before and after the introduction of the HIB vaccine, demonstrates a dramatic decrease in the incidence of the disease and indicates that organisms other than HIB may account for a greater percentage of supraglottitis in immunized populations.

Children with acute supraglottitis present with severe throat pain, fever, irritability and respiratory distress. The symptoms are usually rapidly progressive (within hours). Characteristically, the child is toxic appearing, and assumes an upright sitting position with the chin up and mouth open, often bracing themselves on their hands. This classic position is known as the “tripod position”. Patients often exhibit difficulty in handling their secretions due to severe odynophagia. Speech is limited due to pain and the voice may sound muffled. Stridor is a late finding and signals near complete airway obstruction. The white blood cell count is usually elevated. Secondary sites of infection are present 50% of the time, including meningitis, otitis media, pneumonia and cellulitis.

The diagnosis of supraglottitis is made by direct inspection of the supraglottic structures, best performed in the operative suite. If the diagnosis is suspected by history and physical examination, the child should be monitored at all times by a physician capable of controlling the airway. Any anxiety-provoking maneuvers should be avoided, including intraoral examination or phlebotomy. When the diagnosis is in question and the child has no symptoms of airway compromise, radiologic examination can confirm the diagnosis and rule out foreign body, retropharyngeal abscess or croup, all of which are included in the differential diagnosis. The lateral soft tissue neck film is the single most useful study. Patients with supraglottitis will exhibit thickening and rounding of the epiglottis (the “thumb” sign), with loss of the vallecular air space. The aryepiglottic folds are thickened and the hypopharynx is distended. Anteroposterior views of the neck reveal a normal subglottis in contrast to the narrowed subglottis characteristic of croup. Chest radiographs may show cardiac enlargement and pulmonary edema as a result of the upper airway obstruction.

Once the diagnosis of supraglottitis is made, arrangements for endoscopy should be made as expeditiously as possible. As stated previously, the child should be attended at all times by someone capable of attaining an airway, and any anxiety-provoking maneuvers avoided. Good communication between the endoscopist and anesthesiologist is imperative. It is preferable to maintain spontaneous ventilation until an airway has been established. Once the patient is anesthetized, the supraglottic structures are visualized and the patient is orotracheally intubated; this is changed to a nasotracheal tube before the conclusion of the procedure. A rigid telescope with an endotracheal tube threaded over it and rigid bronchoscopes (age appropriate size and one size smaller) should be available, as should supplies for tracheotomy. Blood may be drawn at this time for complete blood count and cultures. The typical examination reveals erythema and edema of the supraglottis, including the epiglottis, aryepiglottic folds and arytenoids. An abscess is sometimes present on the lingual surface of the epiglottis and landmarks are frequently obscured. Cultures should be obtained from the epiglottis and sent for identification and sensitivity. Historically, patients underwent tracheotomy when diagnosed with supraglottitis. This is now rarely necessary and nasotracheal intubation is preferred.
With the airway secured, the patient is transferred to the intensive care unit after antibiotic therapy is instituted in the operative suit. Antibiotic therapy of choice has traditionally been chloramphenicol and ampicillin. Now, however, ceftriaxone, cefuroxime or ampicillin/sulbactam are all appropriate alternatives. Adjustments in antibiotic coverage are made as necessary for culture and sensitivity results. The patient may be extubated when an air leak is present with positive pressure, or when repeat endoscopic examination reveals resolution of the supraglottic swelling. Extubation usually can be performed within 48 hours as response to antibiotics is typically rapid.

**Croup (Laryngotracheobronchitis)**

The word *croup* is derived from the ancient Scottish language and refers to the barking cough that is invariably present with infectious narrowing of the glottis and subglottis, but may be present with many congenital and infectious airway lesions. Many terms have been applied to infection of the glottic and subglottic regions, but it is most appropriately termed laryngotracheobronchitis (LTB). The entity is a common disease of childhood, affecting children primarily between the ages of 6 months and 3 years. The disease is relatively rare in children under 1 year old, and should prompt an investigation for underlying airway pathology when present in this age group. LTB has been noted to cause as much as 90% of infectious airway obstructions. Three to 5% of children have one episode, 5% of these have recurrent episodes. The need for hospitalization is rare (1.5% to 15%) and airway compromise to the point that intubation is required infrequent (1% to 5%). The most common etiologic organisms are the Parainfluenza viruses types 1 and 2, but influenza A and B, respiratory syncitial virus, herpes simplex type I, measles, adenovirus and varicella have all been reported.

Patients with LTB typically present with a several day history of upper respiratory-type symptoms progressing to the characteristic barking cough, hoarseness and stridor. The stridor is most commonly inspiratory, with biphasic stridor indicating severe airway compromise. Low-grade fever is common, while leukocytosis is inconsistent. The presence of biphasic stridor, retractions, severe tachypnea or oxygen desaturations should alert the physician to impending airway collapse. Several scoring systems for LTB have been proposed, with that by Westley *et al.* being the most commonly used. It is based on the level of consciousness, cyanosis, stridor, air entry and retractions. While such scoring systems are useful for research purposes, the clinical picture should always govern the level of intervention.

The high fever, severe odynophagia and rapid progression characteristic of supraglottitis usually lead to little confusion with the symptoms of LTB. Radiography can be quite helpful in establishing the diagnosis of LTB. The anteroposterior (AP) soft tissue neck film classically shows narrowing of the subglottic area, or “steeple sign”. Lateral soft tissue neck films may demonstrate haziness within the subglottis, with normal supraglottic structures in contrast to the findings present with supraglottitis. It may be noted that the subglottic narrowing seen in LTB is dynamic, being more prominent on inspiration secondary to the intraluminal negative pressure, and less severe upon expiration. This is in contrast to the subglottic narrowing seen in congenital subglottic stenosis or subglottic hemangioma, both of which are static in relation to the respiratory cycle. Radiographic findings may be absent in as many as 50% of patients with LTB, and frequently the diagnosis is made on history and physical examination alone. Radiography may show an unsuspected foreign body. Flexible fiberoptic airway examination may reveal edema of the glottis and subglottic region, but is to be discouraged in patients with severe respiratory distress. When severe respiratory compromise is present, direct laryngoscopy and intubation best make the diagnosis.

Laryngotracheobronchitis is most frequently self-limited, and in many instances supportive care is all that is required. Historically, patients have been treated with humidified air, either from a humidifier or by instructing the child’s parents to sit in the bathroom with a warm shower. The presumed effect is to soothe the inflamed mucosa of the subglottis and liquefy secretions to allow expectoration. There has been no scientific evidence that humidified air has any effect on the subglottic mucosa however, and patients treated with mist tent showed no difference in clinical course than those without. Despite the lack of objective benefit, strong anecdotal evidence supports the use of humidification. Mist tents have the potential to provoke anxiety due to separation from the parents and may lessen the ability to effectively monitor the patient secondary to thick mist; blow-by humidification is thus preferred.
Racemic epinephrine has been available in the United States since 1971 and shown to be highly effective in reducing airway edema as a result of its $\alpha$-adrenergic effect on mucosal vasculature. Initially administered by intermittent positive pressure, nebulization of 0.5 ml of a 2.25% solution diluted in 3 cc of normal saline has been shown to be highly effective and better tolerated by children. Racemic epinephrine is a 1:1 mixture of the left ($l$-) and right ($d$-) optical isomers of epinephrine. The $l$-isomer is more widely available, is less expensive, and has been shown to be as efficacious as racemic epinephrine with no increased side effects. Rapid clinical improvement can be expected within 10 to 30 minutes. The response typically wanes within 2 hours, with some patients experiencing rebound edema. In the past, it had been recommended that any child treated with epinephrine be hospitalized for observation due to this potential for worsening of the airway obstruction. More recent reports suggest that these patients may be safely discharged from the emergency department after an observation period of no less than 3 hours if reliable monitoring by the parents or guardians and the ability to easily return to the emergency department are available. The potential for significant cardiovascular side effects with the use of epinephrine dictates that its use be reserved for severely ill patients who do not respond to more conservative intervention, and used with extreme caution in patients with tachycardia or cardiac abnormalities such as Tetralogy of Fallot or idiopathic hypertrophic subaortic stenosis.

Steroids have been used for the management of LTB since the 1960’s and have been the source of much controversy. Recent studies by Johnson et al. and Klassen et al. have shown clear improvement in children with severe croup treated with steroids. Both studies examined the effectiveness of nebulized budesonide and intramuscular (Johnson) or oral (Klassen) dexamethasone in the treatment of severe croup in an outpatient setting. All modes of administration showed benefit, with similar results between nebulized budesonide and dexamethasone. Johnson et al. demonstrated a decreased hospitalization rate in those patients treated with steroids as compared to those treated with placebo. Budesonide is currently unavailable in the United States, however, and is somewhat less desirable as it is cost-prohibitive compared to dexamethasone with no clear advantages. Dexamethasone may be administered as a single dose of 0.6 mg/kg either orally, intramuscularly or intravenously.

The exact mechanism of action of corticosteroids is unclear, but they have been shown to decrease the permeability of capillary endothelium and stabilize lysosomal membranes. These actions have the effect of reducing submucosal edema and decreasing the inflammatory reaction. In general, the results of steroid administration will not be appreciated for at least 3 hours, thus steroids are usually administered with epinephrine. Steroids should be reserved for patients with severe symptoms and any patient in whom epinephrine is used should be considered for steroid therapy. The use of steroids for severe LTB may avoid the need for intubation, and as stated previously, may lower the number of hospital admissions due to LTB. Side effects with the use of steroids as described have been rare, but patients should be observed for the possibility of candidal overgrowth or the promotion of the development of a bacterial tracheitis.

Heliox, a mixture of helium and oxygen, has shown to be of benefit in the management of severe croup. It serves to decrease the work of breathing by promoting laminar flow through the partially obstructed airway. The mixture may be used as an adjunct to medical therapy with humidification, epinephrine and steroids.

Rarely, LTB does not respond to the administration of humidified air, epinephrine and steroids. In such instances, intubation may become necessary. This is best performed in the operative suite with the patient breathing spontaneously. Thorough endoscopy at that time can rule out tracheitis or foreign body. Nasotracheal intubation is preferred and a tube smaller than that expected for the patient’s age should be used to avoid excessive subglottic trauma with the attendant risk of subglottic stenosis. Extubation is possible when an air leak is detected, usually within several days. Endoscopy is also indicated for patients who fail to develop an air leak after 5-7 days of intubation or those with recurrent or atypical LTB. It is ideal in such cases to allow 3-4 weeks for resolution of the acute inflammatory changes so that anatomic abnormalities such as congenital subglottic stenosis may be appreciated. As in supraglottitis, the endoscopic examination may be enhanced with the use of rigid endoscopes.
Spasmodic Croup

Spasmodic croup presents in a manner similar to LTB. Patients typically have barking cough with stridor, but lack a viral prodrome and fever. The stridor is usually of sudden onset, most commonly at night. Episodes are frequently recurrent and resolve within hours, either spontaneously or with cool humidified air. The pathogenesis is unknown.

Bacterial Tracheitis

Bacterial tracheitis is a disease which has many synonymous names including bacterial laryngotracheobronchitis, membranous laryngotracheobronchitis and pseudomembranous croup. Although described by Chevalier Jackson as early as 1945, the detailed description of the disease is generally accredited to Jones et al. in 1979. It is a rare disease, but should be kept in the differential diagnosis of any child with respiratory distress as it is potentially life threatening. The peak incidence is in the fall and winter, affecting children from a wide age range, from 6 months to 8 years with an average of 5 years. It is accepted that the bacterial infection of the tracheal mucosa represents a complication of viral LTB. Historically, the causative organisms have been *Staphylococcus aureus*, *Haemophilus influenzae*, α-hemolytic *Streptococcus*, and group A *Streptococcus*. A recent study by Bernstein et al. found *Moraxella catarrhalis* to be the most frequently implicated pathogen in a study of 47 patients, with *S. aureus* remaining the second most common organism isolated. Rarely, gram-negative enteric organisms are found.

The clinical presentation in children with bacterial tracheitis is often described as intermediate between the presentations of supraglottitis and LTB. Patients frequently have a several day history of viral upper respiratory symptoms with fever, cough and stridor, similar to LTB. They may then have a rapid onset of high fever, respiratory distress and toxic appearance. Odynophagia and drooling are absent. Marked leukocytosis is often noted. Patients frequently have concurrent sites of infection, pneumonia being most common.

The patient in severe respiratory distress is best diagnosed and treated in the operative suite with endoscopy and airway control. Patients without signs of impending respiratory collapse may be evaluated with radiography. Anteroposterior radiographs of the upper airway frequently show the “steeple sign” noted in viral LTB. The lateral airway films are more useful. The tracheal air column may appear diffusely hazy with multiple luminal soft tissue irregularities indicative of pseudomembrane detachment. No one clinical or radiographic feature is capable of firmly making the diagnosis of bacterial tracheitis, and when seriously considered, endoscopy is the diagnostic method of choice.

Endoscopy may not only make the diagnosis accurately and promptly, but may also be therapeutic. As with supraglottitis and LTB, anesthesia with spontaneous ventilation is preferred. The larynx, subglottic trachea and bronchi should be systematically examined. The typical findings on endoscopy include edema of the subglottis with ulceration and pseudomembrane formation in the trachea. A thick inflammatory exudate with sloughed mucosa frequently obstructs the lumen of the trachea and main bronchi. This thick material should be removed with suction and foreign body forceps as necessary. Specimens for Gram’s stain, culture and sensitivities should be obtained. It is sometimes necessary to perform repeat endoscopy to remove reaccumulated material. Most patients will require intubation and ventilatory support, but this decision should be made on a case-by-case basis by the endoscopist in consultation with the pediatric intensivist. The aforementioned study by Bernstein et al. had a 57% rate of intubation, but indicates that previous series have required intubation in over 80% of patients. Intubation is usually required for 3-7 days, with the decision for extubation being guided by clinical improvement as evidenced by decreased secretions, defervescence and air leak. Broad spectrum antibiotic therapy should be instituted immediately. Appropriate regimens include a semi-synthetic penicillin such as nafcillin with a third-generation cephalosporin (Ceftriaxone, Cefotaxime) for coverage of Gram-negative organisms. Cefuroxime and Ampicillin/Sulbactam (Unasyn) have been used for initial therapy as well. Ultimately, antibiotic coverage should be dictated by the Gram’s stain, culture and sensitivity results. Length of therapy is 10 to 14 days total.
Case Study

A 6-year-old male presented to the emergency department with fever, respiratory distress and inspiratory stridor. The patient’s mother stated that he had been mildly ill for past 3-4 days with rhinorrhea, hoarseness, cough and low grade fever. Earlier the evening of presentation he began to develop high fever to 103°F, with gradually increasing respiratory distress. Initial evaluation revealed the child to be in moderate distress with tachypnea greater than 30 breaths per minute and fever of 102.7°F. Oxygen saturations were 95-97% on room air. Subternal retractions were noted and the patient had a harsh barking cough. Lung sounds were decreased in the right lower lobe with fine crackles.

The Otolaryngology service was consulted. After evaluation in the emergency department, arrangements were made for urgent endoscopy with a tentative diagnosis of bacterial tracheitis. He was transferred directly to the operating suite. After inhalational anesthesia was induced, the patient was orotracheally intubated by the anesthesiologist with a 5.0-mm inner diameter endotracheal tube. Blood was then collected for complete blood count and cultures. Direct laryngoscopy, tracheoscopy and bronchoscopy were then performed. The examination revealed edema of the true vocal folds. The trachea was coated with purulent secretions. The mucosa was ulcerated with sloughing into the tracheal lumen. Copious purulent secretions were encountered in the right lower bronchus. Specimens were sent for culture and sensitivity. The orotracheal tube was changed to a nasotracheal tube and the patient transferred to the pediatric intensive care unit. He was empirically started on IV Cefuroxime.

The culture revealed *S. aureus*, sensitive to Cefuroxime, from both the trachea and right lower bronchus. Subsequent chest x-rays revealed a right lower lobe infiltrate consistent with pneumonitis. The CBC revealed a WBC count of 19,000/mm³. Blood cultures were negative. He showed rapid clinical improvement with decreased fever and secretions over the next 72 hours. In the morning of the fourth day after intubation, an air leak was noted with positive pressure ventilation. He was extubated in the PICU later that day without difficulty. The next day he was transferred to the floor and showed continued improvement. He was discharged 7 days after admission on oral antibiotics for a total course of 14 days.

Controversies and Future Directions

As a result of the widespread use of immunizations against *Haemophilus influenzae* type B, the incidence of supraglottitis in children is greatly decreased. Bailey reports a decrease from an incidence of 3.47 cases per 100,000 in 1980 to 0.63 cases per 100,000 in 1990. While the incidence in children is decreasing, the incidence in adults appears to be stable. As indicated in the study from Senior et al., other organisms may become more common causes. These post-immunization trends bear close monitoring and frequent re-evaluation.

Historically, airway control in patients with supraglottitis was attained by tracheotomy at the time of diagnosis. This is now rarely necessary and nasotracheal intubation is widely accepted. There has been some debate as to the safety of monitoring in the intensive care setting without airway protection for patients with mild supraglottitis. Further investigation is warranted before this is recommended in the pediatric population, as the disease may progress rapidly to airway collapse.

The treatment of viral laryngotracheobronchitis has been the source of much controversy. The introduction of inhaled epinephrine has allowed rapid treatment of many children with moderate to severe LTB and has most assuredly avoided intubation in many patients. There is still debate as to the appropriate disposition of children treated in the emergency department with nebulized epinephrine. In the past, it was advocated that all patients be admitted as rebound mucosal edema could worsen airway obstruction. It now appears that patients may be discharged after an appropriate observation period. This question is made even more complex with the use of steroids in the management of LTB. Dexamethasone is widely accepted as effective and appropriate therapy for viral LTB in outpatients as well as inpatients. This was affirmed by Johnson et al., who demonstrated that children treated with glucocorticoids were less likely to require hospital admission than children treated with placebo. While currently not available in the United States, nebulized budesonide may offer another option in the route of delivery, but as shown by Klassen et al. offered no clear benefit over oral dexamethasone while being more costly. Furthermore, there are no clear-
cut indicators as to which patients should receive what therapy. These issues make the management of viral LTB variable and subject to the preference of the clinician. The decision as to whether hospital admission is necessary must often be made on the basis of mitigating circumstances, such as the distance from the patient’s home to the hospital and reliability of supervision.

Conclusion

Infectious diseases of the upper respiratory tract are common in the pediatric population. These infections have the potential to be life threatening and may progress rapidly. The otolaryngologist must be able to make a prompt diagnosis, often based on the history and general appearance alone. Management decisions must be made quickly with accurate diagnosis and the assurance of an adequate airway being the foremost goals.

References


