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61 Croup in Children (Acute Laryngotracheobronchitis)

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SHORT VIEW SUMMARY

Definition
- Croup is an acute viral infection of the upper airway presenting as stridor and a brassy cough.
- Most children develop croup only once, but a few children develop recurrent episodes called spasmodic croup.

Epidemiology
- Croup can be sporadic but usually occurs in epidemics in the fall that in temperate climates recently have been worse in odd-numbered years.

Etiology and Microbiology
- Parainfluenza type 1 virus infection is the most common cause of viral croup.
- The other parainfluenza viruses, respiratory syncytial virus (RSV), adenovirus, and measles are a few of the other agents associated with viral croup.
- Bacterial infections of the airway, including epiglottitis (*Haemophilus influenzae* type b) and tracheitis *(Staphylococcus aureus, Streptococcus),* represent medical emergencies and should be rapidly discriminated from viral croup.
- Diphtheria should be considered in the developing world and in nonimmunized populations.

Diagnosis
- Diagnosis is clinical, although radiographs of the upper airway may be helpful.
- Children with epiglottitis and bacterial tracheitis are typically toxic and have difficulty swallowing and usually lack the brassy cough and harsh stridor.
- Recurrent (spasmodic) croup may be more common in children with atopy or gastroesophageal reflux.

Therapy
- Home remedies including mist and cold air have not been proven to be effective.
- A single dose of a systemic corticosteroid decreases the severity and length of croup.

… the sharp stridulous voice which I can resemble to nothing more nearly than the crowing of a cock … is the true diagnostic sign of the disease.

Francis Home, 1765[1]

Croup is an age-specific viral infection of the upper and lower respiratory tracts that produces inflammation in the subglottic area and results in a striking picture of dyspnea accompanied on inspiration by the characteristic stridulous notes of croup. Croup demonstrates the piquant interaction of host and microorganism. Age, gender, an undefined predisposition of the child, and the specific virus all seem to influence whether a child's respiratory tract infection manifests as croup and how severe it is.

HISTORY

Home first introduced the word "croup" in his treatise, "An Inquiry into the Nature, Causes and Cure of the Croup," in which he described 12 patients with croup.[1] The term *croup* is descended from an Anglo-Saxon word *kropan*[2] or the old Scottish term *roup,* which meant "to cry out in a shrill voice." For the next century, the term *croup* was applied to numerous probably viral and bacterial diseases, which included diphtheria and "cynache trachealis," which was often called "membranous" or "true" croup, as opposed to "spasmodic" or "false" croup. Differentiation awaited Klebs' discovery of *Corynebacterium diphtheriae* in 1883. In 1948, Rabe[3] classified the forms of infectious croup according to etiology—bacterial or nonbacterial—and suggested that the latter, larger group was viral in origin. He was able to identify a pathogen—*C. diphtheriae* or *Haemophilus influenzae* type b—in only 15% of his 347 patients.

NOMENCLATURE

The term *croup* now generally refers to an acute respiratory tract illness characterized by a distinctive barking cough, hoarseness, and inspiratory stridor in a young child, usually between 6 months and 3 years old. This syndrome results from inflammation of varying levels of the upper respiratory tract, which sometimes spreads to the lower respiratory tract, producing concomitant lower respiratory tract findings. Croup is primarily laryngotracheitis and encompasses a spectrum of infections from laryngitis to laryngotracheobronchitis and sometimes laryngotracheobronchopneumonitis.

Most common among the clinical argot of croup are recurrent, allergic, and spasmodic croup. Most children develop croup only once or twice despite multiple infections with the viruses that are prime etiologic agents. Some children have recurrent episodes of croup, however, which is often referred to as "spasmodic croup." Spasmodic croup and "allergic croup" also have been applied to cases that tend to be sudden in onset, often at night, with minimal coryza and fever, and that occur among children with a family history of croup or atopy.[4] Spasmodic croup generally cannot be differentiated from a single episode of the usual type of croup, however, in its clinical manifestations or in its etiology, which is usually viral.

INCIDENCE

Croup is a common illness among outpatients, but few cases require hospitalization.[4-7] Croup occurs in 2% to 6% of young children each year. About 10% to 16% of all children experience at least one attack of croup, and 5% have recurrent croup, consisting of three or more episodes. The peak occurrence is in the second year of life, with most cases occurring between 3 months and 3 years of age. In a Seattle prepaid group practice, the annual incidence of croup was 7 per 1000 for all children younger than 6 years, and the peak incidence in the second year of life was 14.9 per 1000 children.[7] Among children younger than 2 years of age presenting to emergency departments in Alberta, Canada, for the period 1999 to 2005, the rates of croup ranged from 30.9 to 49.6 per 1000 emergency department visits.[8]

Hospital admissions have significantly declined in recent years in correlation with the use of effective outpatient therapy for croup. From 1979 to 1997, croup cases associated with parainfluenza viruses, estimated from the National Hospital Discharge Survey, showed that the number of admissions among children younger than 5 years decreased by approximately one third.[5] The average annual rates of hospitalizations for croup during 1972 to 1984 compared with 1994 to 1997 for children younger than 1 year decreased by 25% from 2.8 to 2.1 per 1000 children per year; and for children 1 to 4 years old, the annual

KEYWORDS

bacterial tracheitis; croup; dexamethasone; epiglottitis; laryngotracheobronchitis; nebulized epinephrine; parainfluenza virus; spasmodic croup; stridor; upper airway obstruction

rates decreased by 33% from 1.8 to 1.2. In Ontario, the estimated annual rates of hospitalization from 1988 to 2002 also showed a decline among children younger than 5 years, and the rates were lower among children 1 to 4 years old than among infants.[9] The decline did not begin until after the winter of 1993 to 1994, however, when the annual rate per 1000 children younger than 5 years was 2.67. In 2001 to 2002, the rate had declined by 86% to 0.37.

ETIOLOGY

Among children evaluated for croup in an emergency department, one or more viral agents were identified in 80% of specimens by reverse-transcriptase polymerase chain reaction (RT-PCR) assay; the parainfluenza viruses were detected most frequently.[10] No matter what means of detection were used, studies over decades have consistently shown that the parainfluenza viruses, especially type 1, are the most frequent cause of croup.[4-7,10-12] Only the parainfluenza viruses are associated with the major peaks of occurrence of croup cases (Fig. 61-1). Parainfluenza type 1 has been identified in approximately one fourth to one third of cases. Parainfluenza type 3 generally is the second most commonly associated virus, accounting for 6% to 10% of cases. A small proportion of all influenza illnesses among children is associated with croup, but among croup cases, influenza accounts for 1% to 10% of cases depending on the year and circulating strain. Similarly, although respiratory syncytial virus (RSV) infections are particularly prevalent among this age group, relatively few (about 5% of RSV infections) manifest as croup.

More recent studies using RT-PCR methods have suggested an etiologic role for viruses other than the parainfluenza viruses. Rhinoviruses, enteroviruses, adenoviruses, and bocavirus have been detected in 9% to 13% of specimens from children with croup.[10,12,13] Croup has also been observed in a small percentage of children younger than 5 years of age infected with metapneumovirus.[14] The human coronaviruses (hCoV) have been identified in up to 7% of young children with acute respiratory tract infections, with the NL63 strain most often associated with croup.[15] In Seoul, South Korea, hCoV NL63 was the second most commonly isolated virus from children presenting with croup.[16] The significance of these associations, however, is unclear because respiratory viruses often appear as coinfections and studies have been limited by small sample sizes. Larger studies are needed to confirm these findings.[17]

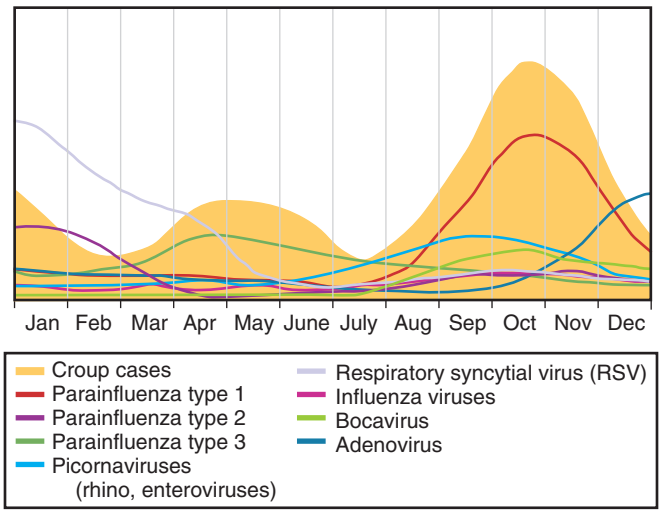

FIGURE 61-1 The seasonal occurrence of croup cases is shown in relation to the epidemiologic activity of the respiratory viruses associated with croup. The major seasons of croup cases in temperate climates occur in the fall to winter every other year when outbreaks of parainfluenza type 1 virus occur and in the spring to summer when parainfluenza type 3 is prominent. Influenza and respiratory syncytial virus are epidemic during the winter to spring but contribute small proportions of cases. The picornaviruses, adenovirus, coronaviruses, and bocavirus are present through many months of the year.

Outbreaks of measles in the United States and elsewhere serve as a reminder that rubeola in the prevaccine era often resulted in severe and complicated croup. During the 1989 to 1991 upsurge of measles cases in the United States, laryngotracheobronchitis complicated approximately 20% of the cases of measles among hospitalized patients in Los Angeles and Houston.[18,19] Children with croup as a complication of measles tended to be younger, they had a more severe course, and 17% to 22% required intubation. In some children, the outcome was fatal.

EPIDEMIOLOGY

The epidemiologic patterns of croup reflect mainly the seasonal predilection of the major agents (see Fig. 61-1). Parainfluenza virus type 1 predominantly occurs every other year in the fall, resulting in the major outbreaks of croup recognized biennially in odd-numbered years since 1993.[5,11] Other parainfluenza viruses have less distinctive seasonal patterns. Parainfluenza type 2 virus also contributes to the cases occurring in the fall and winter, but irregularly and at lower levels.[20] Parainfluenza type 3 virus appears yearly, and although it may be present throughout much of the year, parainfluenza type 3 virus predominantly occurs in the spring to fall and is the major cause of the swell of croup cases observed each spring. Influenza A and B viruses and RSV also contribute to the cases in the winter and spring. Rhinoviruses, enteroviruses, bocavirus, and coronaviruses are present through most of the year. In some areas, enteroviruses have an increased prevalence during the summer and fall and bocavirus is prevalent during the fall to spring (see Fig. 61-1).

PATHOPHYSIOLOGY

The shrill sonorous inspiration so characteristic of this complaint, marks very unequivocally its seat.... From some cause there is an unusual approximation of the sides of the glottis … the influence being very analogous to that produced by too strong compression of the reed against the mouthpiece of the clarinet by the lips of one who has made no great proficiency in that instrument, when a harsh, squeaking sound is produced abundantly discordant and grating to the ear.

Hugh Ley, 1836[21]

The virus initially infects the upper respiratory tract and usually produces congestion of the nasal passages and nasopharynx. Subsequently, especially during primary infection, the larynx, the trachea, and sometimes the bronchi become involved. The classic signs of croup—stridor, hoarseness, and cough—arise mostly from the inflammation of the larynx and trachea. The resulting obstruction is greatest at the subglottic level because this is the least distensible part of the airway because it is encircled by the cricoid cartilage, with the narrow anterior ring and the larger posterior quadrangular lamina forming a "signet ring." The impeded flow of air through this narrowed area produces the classic high-pitched vibratory sounds, or stridor. This is most apparent on inspiration because high linear velocity in the already narrowed airway creates a negative intraluminal pressure, narrowing the extrathoracic airway further, much as sucking on a partially occluded paper straw causes it to collapse inwardly. Airway collapse is enhanced in young children because of the increased compliance of their airway walls.[22]

Even minimal inflammation of the membranes lining the narrow passages of the larynx and glottis in a young child results in an appreciable degree of obstruction because resistance to airflow is inversely related to the fourth power of the radius of the airway. The mucous membrane is also looser and more vascular, and the cricoid cartilage is less rigid. Nasal obstruction and crying can aggravate the dynamic narrowing of the child's airway further.

With the subglottic obstruction, the child's tidal volume initially declines. This is compensated by an increase in the respiratory rate to maintain adequate alveolar ventilation (Fig. 61-2). If the degree of obstruction worsens, the work of breathing may increase such that the child tires and can no longer maintain an adequate respiratory effort. The tidal volume may decrease further, and, as the respiratory rate declines, hypercarbia and secondary hypoxemia ensue.

In addition to airway narrowing related to mucosal swelling and dynamic collapse, it is possible that upper airway inflammation leads

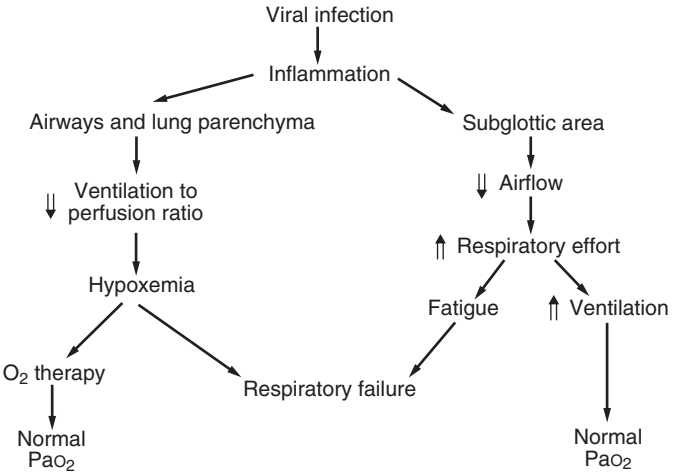

FIGURE 61-2 **Physiologic abnormalities in croup.**

to active constriction of the muscles of the upper trachea and larynx that might contribute to airway narrowing in some children with croup, particularly those with spasmodic croup. This might explain the association between recurrent croup and asthma or airway hyperreactivity.

CLINICAL MANIFESTATIONS

The disease generally comes on in the evening after the little patient has been exposed to the weather during the day and often after a slight catarrh of some days' standing. At first his voice is observed to be hoarse and pulling … he awakens with a most unusual cough, rough, and stridulous. And now his breathing is laborious, each inspiration being accompanied by a harsh, shrill noise.

John Cheyne, 1814[2]

Although abrupt onset of stridor at night may be the initial indication of illness, most children have a prodrome of mild upper respiratory tract signs of rhinorrhea, cough, and sometimes fever 12 to 48 hours before the onset of the distinctive "rough and stridulous" cough of croup. The deepening cough and hoarseness herald the onset of the respiratory stridor. The cough is not productive but has the striking deep brassy tone of a "seal's bark."* The respiratory stridor may be accompanied by retractions of the chest wall, which are usually most marked in the supraclavicular and suprasternal areas. Some children may progress to have inspiratory and expiratory stridor. The respiratory rate may be slightly elevated, but rates greater than 50 per minute are unusual in children with croup, in contrast to the marked tachypnea that is often evident with bronchiolitis.

The onset of stridor commonly occurs at night; in milder cases it may improve in the morning, only to worsen again at night. Children whose croup is characterized by abrupt nighttime onset with little prodrome of a respiratory tract infection, followed by daytime improvement, are often designated as having "spasmodic croup." These children tend to have repeated episodes over several days or separated by months. Generally, an episode of recurrent croup cannot be differentiated from the usual case of viral croup clinically or by viral etiology.[12] A viral etiology was identified by RT-PCR in 68% of the children, and the proportion with an identified viral infection was not significantly different between children with single and recurrent episodes of croup. A few children with recurrent croup have an underlying condition such as subglottic stenosis or gastroesophageal reflux.

For most children, the course of croup is less than 3 to 4 days. Although the cough may persist longer, the characteristic barking quality resolves within 2 days in most children.[23]

*The characteristic cough and stridor have also been described by Ley in 1836[21] as "the crowing of a cock, the yelping of a fox, the barking of a dog, the braying of an ass, or a ringing sound, as if the voice came from a brazen tube."

FIGURE 61-3 **Radiograph of the neck of a child with viral croup that shows the characteristic narrowing of the air shadow of the trachea in the subglottic area.**

DIAGNOSIS

The diagnosis of croup can almost always be made on the basis of the characteristic epidemiologic features, the clinical manifestations, and the history, especially in children 6 months through 3 years of age. Diagnostic procedures that upset the child may worsen the respiratory distress and should be avoided.[7] Laboratory analysis generally should be limited to tests necessary for management of a more severely ill child, such as tests used to assess dehydration and oxygenation. White blood cell counts and differentials are rarely helpful or distinctive in diagnosing croup. Identification of the specific viral agent also is usually unnecessary, and obtaining respiratory tract swabs and secretions is likely to augment the child's respiratory distress.

Viral identification may be warranted when specific antiviral therapy is being considered, such as for severely ill or high-risk children with influenza. In most instances, a rapid antigen assay, such as immunofluorescent and enzyme immunoassays, is used.[24] Rapid multiplex PCR assays for respiratory viruses provide an increasingly available alternative with improved sensitivity and relatively short turnaround times.

Radiographic Findings

Radiographic evaluation is usually unnecessary for the diagnosis of croup and, as noted earlier, should be undertaken with caution and careful monitoring of the child. Among atypical cases, however, the radiologic picture may be helpful in the differential diagnosis.

The characteristic manifestation of viral croup noted on an anteroposterior neck film is a 5- to 10-mm narrowed shadow of the trachea in the subglottic area. This is often described as the "hourglass" or "steeple" sign (Fig. 61-3). The lateral view of the neck may show an increased width of the airspace in the hypopharyngeal area. Dilation of the pharyngeal airway often is seen and is indicative of the child's increased respiratory effort. The diagnostic value of these radiographic findings is nevertheless questionable. They are not consistently observed in all cases of viral croup, and some studies have shown them to be of low specificity and sensitivity for confirming or ruling out viral croup.

Differential Diagnosis

For children presenting with atypical features or history, a broad range of diagnoses should be considered.[25] A case should be considered

atypical if the child does not have the most characteristic features of croup, especially the seal's bark cough and hoarseness.

The physician's most important clinical responsibility in evaluating a child with inspiratory upper airway obstruction is differentiating children with the common and usually benign viral croup from the few children who have life-threatening obstruction from bacterial epiglottitis or tracheitis. The history of a rapidly progressive course, high fever, a toxic appearance, and drooling are most characteristic of these bacterial processes, and the brassy cough of viral croup is characteristically absent. Children with these symptoms demand careful evaluation and management.

Acute bacterial epiglottitis is usually due to infection with *H. influenzae* type b and has become rare since the widespread use of vaccination.[25,26] The differentiating features of epiglottitis include the strikingly rapid onset and progression of the illness, high fever, and toxic appearance. The child is often sitting, leaning forward, and anxious and may have a muffled voice, marked dysphagia, and drooling. The history of an upper respiratory tract infection with rhinorrhea and laryngitis usually is not present. Epiglottitis is almost always an indication for prompt antibiotic therapy and securing the airway by intubation in a controlled environment.

Bacterial tracheitis has an acute onset and presentation similar to that of epiglottitis.[7,26-29] Its rapid and dramatic onset is characterized by high fever, stridor, and dyspnea with copious amounts of purulent sputum. The child may progress rapidly to complete airway obstruction. The course is unresponsive to therapy with nebulized epinephrine, and suspected cases should be managed as a medical emergency. Bacterial cellulitis and abscesses of the deep neck spaces, including peritonsillar and retropharyngeal abscesses, may also manifest with similar findings of high fever, dysphagia, and drooling.[30,31] The characteristic upper respiratory tract signs, hoarseness and barking cough, are usually not present. *C. diphtheriae,* although a major cause of stridor in the past, is now rarely seen in the United States and other developed countries but should still be considered in countries with low rates of immunization.[32] All of these diagnoses represent pediatric emergencies, and, as with epiglottitis, usually justify careful intubation.

Noninfectious causes of obstruction that mimic croup include aspiration of a foreign body, which is common in the same age group as that of viral croup; trauma to the upper airway, such as from toxic ingestions; and angioneurotic edema.[25] Anatomic abnormalities, such as vocal cord paralysis and anomalies that impinge on the laryngotracheal area, may cause stridor, especially when a respiratory tract infection augments the obstruction to airflow. These include tracheal stenosis, laryngeal webs, and papillomas. In most cases, the history and lack of acute signs of respiratory tract infection allow differentiation. In the older child, pulmonary function testing may be helpful. Occasionally, recurrent episodes of stridor may be related to gastrointestinal reflux.[33]

THERAPY

Appropriate therapy for croup is determined by the severity of the child's illness. Accurate assessment of the child's clinical status is essential. The natural fluctuations in the course of croup often confound this evaluation, however, as well as complicate assessment of the success of therapy.

Most children with mild croup may be cared for at home. Keeping a child with croup comfortable and avoiding disturbing procedures are particularly important, because anxiety and crying may enhance the respiratory distress. The child should be given adequate liquids and antipyretics if necessary.

Despite a plethora of home therapies for croup, none has proved consistently effective. Taking a child with croup outside to breathe cold air or into a shower to breathe warm mist are commonly recommended. Vaporizers and other means of producing mist in the home have long been advised. In the past century, steaming tea kettles were an integral and often primary mode of therapy. Nevertheless, the beneficial effects of mist have not been proved.[7,34-37]

Multiple scoring systems have been used to assess the severity of croup. The scoring system most frequently used is the Westley clinical score.[38] The major findings on physical examination used for this score are the degree of stridor, chest wall retractions, air entry, level of consciousness or fatigue, and presence of cyanosis. Guidelines for the management of croup generally have classified croup as mild, moderate, and severe, with patients with mild cases having corresponding Westley scores of 0 to 2, those with moderately severe cases having scores of 3 to 7, those with severe cases having scores of 8 to 11, and patients at risk for imminent respiratory failure having scores of 12 to 17 (Table 61-1).[4,7]

The therapy recommended varies according to the assessed level of severity, but the mainstay of therapy beyond supportive care is dexamethasone. One dose of dexamethasone orally or, if necessary, intramuscularly, administered to outpatients and in emergency departments has been shown to be effective in reducing the need for hospitalization.[7,39,40,41] Repeated doses are seldom necessary. Nebulized epinephrine, racemic epinephrine, or L-epinephrine may be added to the dexamethasone for children with severe croup.[38,42] Because improvement after nebulized epinephrine is transient, treatment may be repeated. A child treated with one of these aerosols should be observed for at least 2 hours (see Table 61-1) prior to discharge.

Administration of a mixture of helium and oxygen has long been used to improve gas exchange in various obstructive disorders of the upper and lower respiratory tract. Little evidence exists, however, that administering heliox to children with croup is beneficial.[43-45]

TABLE 61-1 Evaluation and Management of Children with Croup

	CROUP SEVERITY (WESTLEY SCORE)		
	Mild (≤2)	**Moderate (3-7)**	**Severe (≥8)**
	Barking cough, hoarseness; no stridor, no or minimal chest wall retractions *at rest*	Stridor and chest wall retractions *at rest; no agitation*	Stridor, sternal contractions *at rest, accompanied by agitation or fatigue*
Therapy			
Decongestants, cough suppressants, antibiotics	Not recommended	Not recommended	Not recommended
Humidification	Not proven beneficial	Not effective	Not effective
Corticosteroids	Dexamethasone (0.6 mg/kg, 1 dose PO)	Dexamethasone (0.6 mg/kg, 1 dose PO or IM)	Dexamethasone (0.6 mg/kg, 1 dose PO or IM)
Nebulized epinephrine	Not recommended	Not recommended	Nebulized racemic epinephrine (2.25%, 0.5 mL in 2.5 mL of saline or L-epinephrine (1:1000 dilution in 5 mL of saline)
Disposition	Discharge home	Discharge to home if no stridor and no retractions at rest. If no improvement in 4 hr, consider hospitalization.	Observe for 2 hr *Good response:* no recurrence, no stridor, no retractions at rest. Discharge to home possible. *Poor response:* stridor, retractions at rest after 2 epinephrine doses. Hospitalize.

IM, intramuscularly; PO, orally.

OUTCOME

Croup remains a common illness among young children. With the currently available modalities for management, most children may be cared for at home, and the illness usually resolves within 3 to 4 days.[23] Most have mild symptoms, and only about 5% of children discharged from the emergency department after corticosteroid therapy need to return because of worsening of symptoms.[46] If the child's symptoms are minimal at discharge, return within 24 hours is unlikely. In Canada, of all children with croup, about 4% have been estimated to require hospitalization and intubation was required for only 1 of the 170 hospitalized children or 1 in 4500 of all children with croup.[7,23]

ACKNOWLEDGMENT

Most of this chapter was written originally by Caroline Breese Hall, MD, 1939-2013.

Key References

The complete reference list is available online at Expert Consult.

8. Rosychu RJ, Klassen TP, Metes D, et al. Croup presentations to emergency departments in Alberta, Canada: a large population-based study. *Pediatr Pulmonol*. 2010;45:83-91.
11. Weinberg GA, Hall CB, Iwane MK, et al. Parainfluenza virus infection of young children: estimates of the population-based burden of hospitalization. *J Pediatr*. 2009;154:694-699.
13. Iwane MK, Prill MM, Miller EK, et al. Human rhinovirus species associated with hospitalizations for acute respiratory illness in young US children. *J Infect Dis*. 2011;204:1702-1710.
14. Prill MM, Iwane MK, Edwards KM, et al. Human coronavirus in young children hospitalized for acute respiratory illness and asymptomatic controls. *Pediatr Infect Dis J*. 2012;31:235-240.
15. Edwards KM, Zhu Y, Griffin MR, et al. Burden of human metapneumovirus infection in young children. *N Engl J Med*. 2013;368:633-643.
16. Sung JY, Lee HJ, Eun BW, et al. Role of human coronavirus NL63 in hospitalized children with croup. *Pediatr Infect Dis J*. 2010;29:822-826.
17. McIntosh K. Proving etiologic relationships to disease: the particular problem of human coronaviruses. *Pediatr Infect Dis J*. 2012;31:241-242.
40. Russell KF, Liang Y, O'Gorman K, et al. Glucocorticoids for croup. *Cochrane Database Syst Rev*. 2011;(1):CD001955.
42. Bjornson C, Russell KF, Vandermeer B, et al. Nebulized epinephrine for croup in children evidence-based child health. *Cochrane Database Syst Rev*. 2011;(2):CD006619.
45. Vorwerk C, Coats T. Heliox for croup in children. *Cochrane Database Syst Rev*. 2010;(2):CD006822.

References

1. Home F. *An Inquiry into the Nature, Causes and Cure of the Croup*. Edinburgh; 1765.
2. Cherry J. Croup. In: Kiple K, ed. *Cambridge History and Geography of Human Disease Project*. Bowling Green, OH: University of Cambridge Press; 1990:654-657.
3. Rabe E. Infectious croup, I. Etiology. *Pediatrics*. 1948;2: 255-265.
4. Cherry J. Clinical practice: croup. *N Engl J Med*. 2008;358: 384-391.
5. Counihan M, Shay D, Holman R, et al. Human parainfluenza virus–associated hospitalizations among children less than five years of age in the United States. *Pediatr Infect Dis J*. 2001;20:646-653.
6. Foy H, Cooney M, Maletzky A, et al. Incidence and etiology of pneumonia, croup, and bronchiolitis in preschool children belonging to a prepaid medical care group over a four-year period. *Am J Epidemiol*. 1973;97:80-92.
7. Alberta Clinical Practice Guideline Working Group. Guideline for the Diagnosis and Management of Croup, 2008. Available at http://www.topalbertadoctors.org/PDF/complete%20set/Croup/croup_guideline.pdf. Accessed November 10, 2008.
8. Rosychu RJ, Klassen TP, Metes D, et al. Croup presentations to emergency departments in Alberta, Canada: a large population-based study. *Pediatr Pulmonol*. 2010;45:83-91.
9. Segal A, Crighton E, Moineddin R, et al. Croup hospitalizations in Ontario: a 14-year time-series analysis. *Pediatrics*. 2005;116:51-55.
10. Rihkanen H, Ronkko E, Nieminen T, et al. Respiratory viruses in laryngeal croup of young children. *J Pediatr*. 2008;152:661-665.
11. Weinberg GA, Hall CB, Iwane MK, et al. Parainfluenza virus infection of young children: estimates of the population-based burden of hospitalization. *J Pediatr*. 2009;154:694-699.
12. Wall S, Wat D, Spiller B, et al. The viral aetiology of croup and recurrent croup. *Arch Dis Child*. 2009;94:359-360.
13. Iwane MK, Prill MM, Miller EK, et al. Human rhinovirus species associated with hospitalizations for acute respiratory illness in young US children. *J Infect Dis*. 2011;204: 1702-1710.
14. Prill MM, Iwane MK, Edwards KM, et al. Human coronavirus in young children hospitalized for acute respiratory illness and asymptomatic controls. *Pediatr Infect Dis J*. 2012; 31:235-240.
15. Edwards KM, Zhu Y, Griffin MR, et al. Burden of human metapneumovirus infection in young children. *N Engl J Med*. 2013;368:633-643.
16. Sung JY, Lee HJ, Eun BW, et al. Role of human coronavirus NL63 in hospitalized children with croup. *Pediatr Infect Dis J*. 2010;29:822-826.
17. McIntosh K. Proving etiologic relationships to disease: the particular problem of human coronaviruses. *Pediatr Infect Dis J*. 2012;31:241-242.
18. Ross L, Mason W, Lanson J, et al. Severe laryngotracheobronchitis as a complication of measles during an urban epidemic. *J Pediatr*. 1992;121:511-515.
19. Fortenberry J, Mariscalco M, Louis P, et al. Severe laryngotracheobronchitis complicating measles. *Am J Dis Child*. 1992;146:1040-1043.
20. Hall C. Respiratory syncytial virus and parainfluenza virus. *N Engl J Med*. 2001;344:1917-1928.
21. Ley H. *An Essay on the Laryngismus Stridulus or Croup-like Inspiration of Infants*. London: Churchill; 1836:6.
22. McBride J. Stridor in childhood. *J Fam Pract*. 1984;19: 782-790.
23. Johnson D, Williamson J. Croup: duration of symptoms and impact on family functioning. *Pediatr Res*. 2001;49:83A.
24. Henrickson K, Hall C. Diagnostic assays for respiratory syncytial virus disease. *Pediatr Infect Dis J*. 2007;26:S36-S40.
25. Sobol S, Zapata S. Epiglottitis and croup. *Otolaryngol Clin North Am*. 2008;41:551-566.
26. Shah S, Sharieff G. Pediatric respiratory infections. *Emerg Med Clin North Am*. 2007;25:961-979.
27. Donnelly B, McMillan J, Weiner L. Bacterial tracheitis: report of eight new cases and review. *Rev Infect Dis*. 1990; 12:729-735.
28. Hopkins A, Lahiri T, Salerno R, et al. Changing epidemiology of life-threatening upper airway infections: the reemergence of bacterial tracheitis. *Pediatrics*. 2006;118: 1418-1421.
29. Long S. Bacterial tracheitis. *Report on Pediatric Infectious Diseases*. 1992;2:29-31.
30. Page N, Bauer E, Lieu J. Clinical features and treatment of retropharyngeal abscess in children. *Otolaryngol Head Neck Surg*. 2008;138:300-306.
31. Johnson R, Stewart M. The contemporary approach to diagnosis and management of peritonsillar abscess. *Curr Opin Otolaryngol Head Neck Surg*. 2005;13:157-160.
32. Galazka A, Robertson S, Oblapenko G. Resurgence of diphtheria. *Eur J Epidemiol*. 1995;11:95-105.
33. Kwong K, Hoa M, Coticchia J. Recurrent croup presentation, diagnosis, and management. *Am J Otolaryngol*. 2007;28: 401-407.
34. Neto G, Kentab O, Klassen T, et al. A randomized controlled trial of mist in the acute treatment of moderate croup. *Acad Emerg Med*. 2002;9:873-879.
35. Scolnik D, Coates A, Stephens D, et al. Controlled delivery of high vs low humidity vs mist therapy for croup in emergency departments: a randomized controlled trial. *JAMA*. 2006;295:1274-1280.
36. Moore M, Little P. Humidified air inhalation for treating croup. *Cochrane Database Syst Rev*. 2006;(3):CD002870.
37. Lavine E, Scolnik D. Lack of efficacy of humidification in the treatment of croup: why do physicians persist in using an unproven modality? *Can J Emerg Med*. 2001;3:209-212.
38. Westley C, Cotton E, Brooks J. Nebulized racemic epinephrine by IPPB for the treatment of croup: a double-blind study. *Am J Dis Child*. 1978;132:484-487.
39. Bjornson C, Klassen T, Williamson J, et al. A randomized trial of a single dose of oral dexamethasone for mild croup. *N Engl J Med*. 2004;351:1306-1313.
40. Russell KF, Liang Y, O'Gorman K, et al. Glucocorticoids for croup. *Cochrane Database Syst Rev*. 2011;(1):CD001955.
41. Johnson D. Croup. *BMJ Clin Evid*. 2007;12:321.
42. Bjornson C, Russell KF, Vandermeer B, et al. Nebulized epinephrine for croup in children evidence-based child health. *Cochrane Database Syst Rev*. 2011;(2):CD006619.
43. Myers T. Use of heliox in children. *Respir Care*. 2006;51: 619-631.
44. Vorwerk C, Coats T. Use of helium-oxygen mixtures in the treatment of croup: a systematic review. *Emerg Med J*. 2008; 25:547-550.
45. Vorwerk C, Coats T. Heliox for croup in children. *Cochrane Database Syst Rev*. 2010;(2):CD006822.
46. Brown J. The management of croup. *Br Med Bull*. 2002;61: 189-202.