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INFRAGLOTTIC AND BRONCHIAL INFECTIONS

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The Yankees are rapidly finding out the benefits of the telephone. A newly made grandmamma, we are told, was recently awakened by the bell at midnight, and told by her inexperienced daughter, "Baby has the croup. What shall I do with it?" Grandmamma replied she would call the family doctor, and would be there in a minute. Grandmamma woke the doctor, and told him the terrible news. He in turn asked to be put in telephone communication with the anxious mamma. "Lift the child to the telephone, and let me hear it cough," he commands. The child is lifted, and it coughs. "That's not the croup," he declares, and declines to leave his house on such small matters. He advises grandmamma also to stay in bed; and, all anxiety quieted, the trio settle down happy for the night.¹³⁸

Concerns over infraglottic and bronchial infections have been a source of anxiety and lost sleep for many children, parents, and physicians long before the advent of the telephone. The annual incidence of lower respiratory tract infections in children younger than 6 years old exceeds 5 million in the United States.⁸³ Despite the frequency of these infections, the often common and nonspecific clinical symptomatology, variable severity, and changing epidemiology over time all have contributed to our understanding and misunderstanding of these disorders. The anxiety of the relatives described in the opening passage is a poignant reminder that the diagnosis of diphtheritic croup at that time carried a mortality of around 25%.⁶²

By simple definition, laryngitis, tracheitis, bronchitis, and any combination of terms (e.g., laryngotracheitis, laryngotracheobronchitis [LTB], tracheobronchitis) represent inflammatory conditions of part or parts of the airway.^{42,155} In this basic form, no specific causes, infectious or noninfectious, are implied by these terms.

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PRIMARY CARE

ANATOMY AND HISTOLOGY

The respiratory tract from larynx to bronchus is composed of connective tissue, cartilage, muscle (intrinsic and extrinsic, striated and smooth), and mucosa, along with a vascular, lymphatic, and nervous supply.⁵⁵ The infraglottic respiratory tract includes those elements inferior to the vocal folds and adjacent apparatus from trachea to bronchi. The larynx is a complex structure composed of interacting elements of cartilage and muscle. Functions include phonation, air passage, and protection of the airway. The trachea is composed of a single complete cartilaginous ring (cricoid) and multiple incomplete rings along with loose connective tissue. The conducting portion of the airway undergoes multiple generations of arborization from trachea to terminal bronchioles, including primary (or main stem), lobar, segmental, and subsegmental bronchi and several generations of bronchioles. The remainder of the airway, or respiratory portion, includes additional divisions from respiratory bronchioles to alveoli. Variation in arborization secondary to asymmetric, dichotomous branching can result in a threefold difference in airway generations between basal and apical segments.^{22,167}

The epithelium lining the airway changes from stratified squamous to ciliated epithelium around the base of the epiglottis. Stratified squamous epithelium covers most of the epiglottis and vocal cords. Ciliated epithelium continues from the base of the epiglottis to the respiratory bronchioles. Mucous production is achieved by goblet cells and submucosal glands that are interspersed among the columnar cells. The movement of the cilia propels mucus and particulate matter (including dust and bacteria) toward the opening of the oropharynx. On descent into the respiratory tract, the amount of cartilage decreases, whereas the proportion of smooth muscle increases. The absence of cartilage and submucosal glands differentiates bronchioles from bronchi.²⁹

RESPIRATORY TRACT DEFENSES

As a structure open to the environment, the respiratory tract must be protected from a multitude of environmental insults. These exposures include changes in temperature and humidity as well as large and small particles (e.g., aspirated microorganisms and airborne toxins such as smoke and noxious gases). Defense of the respiratory tract is provided by a combination of physical forces and physiologic systems. Inhaled particles are deposited throughout the airway based on their size. Larger particles ($> 10 \mu\text{m}$) can be deposited by turbulence in the nasal passage, whereas smaller particles can be deposited further down on the mucous layer of the ciliated infraglottic airway.²² In addition to holding onto deposited particles, the mucous blanket provides a barrier for the epithelial lining of the airway against alterations in temperature and humidity. Cilia serve to propel mucus and trapped particles toward the oropharynx. Cough can result from the stimulation of irritant receptors located throughout the upper (URI) and lower respiratory tract. Cough is an important adjunct in clearing particles from the airway.²² Finally, cellular and humoral immunity are involved in respiratory tract defense. Immune cells (e.g., macrophages) circulate along the mucociliary blanket. These cells can remove small particles by phagocytosis, whereas immunoglobulins (especially IgA) can provide additional protection from infectious agents.

PATHOPHYSIOLOGY

Infection by a variety of microbiologic agents can produce similar pathophysiologic effects on the ciliated epithelium of the respiratory tract. These effects

include loss of ciliary function, release of inflammatory mediators, changes in mucous production and quality, edema, and cell death. All these changes, in varying degrees dependent on etiologic agents, can be responsible for the respiratory manifestations of infraglottic and bronchial infections. The specific clinical manifestations elicited may reflect the site of predominant inflammation. Although different agents may produce similar manifestations, a single agent acting in different hosts may be responsible for a range of disease states. Infection with influenza A virus may result in inflammation throughout the respiratory tract (URI infection, otitis media, croup, bronchiolitis, or pneumonia¹⁸⁰) and may produce signs and symptoms outside the respiratory tract. Studies in children have reported that only half of hospitalizations because of influenza are secondary to lower respiratory tract disease. Other organ systems, including central nervous and gastrointestinal, can show significant involvement in affected individuals.⁷⁵

CLASSIFICATION OF DISORDERS

A variety of systems of nomenclature have been used to classify infraglottic and bronchial infections. These systems may be based on etiologic (e.g., infectious, noninfectious), specific microbiologic (e.g., viral, bacterial, and so forth), anatomic (e.g., laryngeal, laryngotracheal, laryngotracheobronchial, tracheobronchial, bronchial, and so forth) and temporal (e.g., acute, chronic, recurrent) features. It must be understood, however, that these divisions often may appear arbitrary and indistinct when applied in the clinical setting. Anatomic classification may not take into account the spread of inflammation and infection among adjacent elements of the respiratory tract (i.e., does laryngitis exist separately from tracheitis, tracheitis from bronchitis, bronchitis from bronchiolitis, or bronchiolitis from pneumonitis or pneumonia?). It is often difficult clinically to predict the extent of involvement in the respiratory tract. Likewise, classification into a specific microbiologic category may be difficult to accomplish by history and clinical examination alone. Multiple infectious agents can result in similar signs and symptoms, whereas a single agent can cause a spectrum of illness. Viruses such as parainfluenza, influenza, and respiratory syncytial virus (RSV) can cause inflammation throughout the respiratory tract without consideration for any classification system.

For practical purposes, the following section focuses on acute infraglottic (specifically, viral croup and bacterial tracheitis) and acute bronchial infections.

INFRAGLOTTIC INFECTIONS

A generous supply of terms is the product of multiple attempts to categorize children with inflammatory upper airway obstruction.¹²⁹ Classifications of croup based on anatomy, pathology, microbiology, and even correctness have resulted in terms such as *croup syndrome*, *true croup*, *false-croup*, *pseudo croup*, *viral croup*, *spasmodic croup*, *recurrent croup*, *pseudomembranous croup*, *acute laryngitis*, *acute infective or infectious laryngitis*, *acute subglottic laryngitis*, *spasmodic laryngitis*, *catarrhal laryngitis*, *pseudomembranous laryngitis*, *laryngotracheitis*, *LTB*, *acute infective LTB*, *membranous tracheitis*, and *bacterial tracheitis* among others. This large mix of terms has contributed to the confusion that continues to exist in areas of infraglottic infections.²³ In some cases, multiple terms have been developed to describe what appear to be identical clinical conditions, whereas in other cases, a single term is used to encompass a spectrum of disease. A review of the history of infraglottic infections can help with our understanding of this area.

The term *croup* is derived from the Anglo-Saxon word *kropan*, meaning to cry

aloud.^{128,155} Croup or croup syndrome evolved from a descriptive term into a diagnosis encompassing several distinct disorders that share some degree of upper airway inflammation and obstruction. The croup syndrome recently has referred to viral croup, epiglottitis, and bacterial tracheitis.^{129,159}

Before the early 1900s, laryngeal diphtheria was the leading serious infection of the larynx and infraglottic airway. Croup or true croup had become synonymous with diphtheritic infections.²² During the early 1900s, the term *croup* expanded from diphtheria to include other infections of the larynx and infraglottic airway (i.e., supraglottitis/epiglottitis as well as subglottic infections). One hundred years after Blaud's initial description of nondiphtheritic croup (1823),^{129,91} nondiphtheritic infections had replaced diphtheritic causes of upper airway obstruction in children.⁶² Baum^{10,22} described acute bacterial LTB as a distinct clinical entity in 1928, and Sinclair^{22,148} provided one of the earliest descriptions of *Haemophilus influenzae* type B epiglottitis (supraglottitis) 13 years later.

Nonbacterial (i.e., viral) causes of croup were suspected in the first half of this century. This belief was based on the lack of an elevated white blood cell (WBC) count milder clinical course, and inability to isolate bacterial organisms in some patients with croup.¹³³ In this manner, Rabe^{141,142} classified the majority of croup cases (297/347) seen at New Haven Hospital as virus croup in 1948. Chanock^{19,159} is credited as the first to isolate a viral agent (a cytopathogenic myxovirus he referred to as the croup-associated virus) from patients with croup using tissue culture techniques in 1956. In the later half of this century, reports on viral agents became commonplace, and bacterial LTB seemed to disappear. The reasons behind this shift are unknown, although improved viral culture techniques and a reduction in the actual incidence of bacterial infraglottic infections (possibly caused by changes in organism virulence, host factors, antibiotic usage, and immunization) may be responsible. In recent years, the term *croup* has become synonymous with a generally self-limited, viral infection of the subglottic structures.¹¹⁷ *Stedman's Medical Dictionary*¹⁵⁵ defines croup as "laryngotracheobronchitis in infants and young children caused by parainfluenza viruses 1 and 2." Bacterial causes of airway obstruction should not be forgotten because of the more aggressive therapy these cases typically require, however. In addition to epiglottitis, reports of bacterial infraglottic infections (e.g., bacterial tracheitis) have reemerged in the pediatric and otolaryngologic literature since 1979.

Viral Croup (Viral Laryngotracheitis, Laryngotracheobronchitis, False-Croup)

Epidemiology

The exact frequency of viral croup in the general population is not known. It is likely that many milder episodes do not result in direct physician contact (i.e., mild cases may be treated at home without health care contact or following advice given over the telephone).⁷⁰ Good epidemiologic data, however, exist from children who have been evaluated in the outpatient setting.^{39,64} Denny et al^{38,39} collected cases from a private practice pediatric group in Chapel Hill, North Carolina from 1964 to 1975. Their records revealed 951 instances of croup out of 6165 cases of lower respiratory tract infection (15.4%) reported during that 11-year period. The incidence of croup varied with age, with no cases reported in the first month of life followed by an increasing incidence during the first 2 years of life. The peak incidence was 5.60 per 100 children per year in boys and 3.66 per 100 children per year in girls during the 1-year-old to 2-year-old age group. After 2 years of age, the rate decreased and cases were uncommon in school-aged children. More than 80% of cases occurred in the age group of children younger than 5 years. Gender

differences were noted in all age groups, with an overall ratio of boys to girls of 1.43:1. The higher incidence in boys was greatest in the second 6 months of life (1.73:1) and decreased to an almost even ratio in the age group in children older than 6 years old (1.07:1). The clustering of croup cases in the fall and winter (September–December, with a peak in November) mirrors the seasonal pattern of respiratory viruses. The fall peak appears to coincide with parainfluenza virus infection and the winter peak with RSV infection. In the Chapel Hill experience, mixed infections were uncommon. Virtually all patients (93.7%) had croup as the sole diagnosis, although 1.9% had associated tracheobronchitis, 3% had wheezing, and 1.4% also had pneumonia.^{38,39}

Similar epidemiologic data were gathered from a prepaid medical care group in Puget Sound, Seattle, Washington from 1966 to 1971.⁶⁴ This group reported data from 330 cases of croup that occurred in children younger than 6 years old. The patterns of age, gender, and seasonal distribution were similar to those seen in the Chapel Hill group. The incidence of croup in Puget Sound, however, was only 20% to 30% that reported from Chapel Hill.⁶⁴ The reasons for the difference between the two groups is unknown, although Denny^{37,38} has cited unspecified "procedural differences."

Spasmodic and Recurrent Croup

Spasmodic croup and *recurrent croup* (nocturnal croup, catarrhal laryngitis, stridulous croup, and laryngismus stridulus) are terms used to describe an entity or entities that share many features of viral croup but that may differ pathophysiologically from the typical viral case. The classic findings are croupy cough and inspiratory stridor. Spasmodic croup traditionally has been differentiated from viral croup by the absence of fever and a characteristic onset at night.^{35,71} In addition, some authors require that viral URI symptoms be absent to make the diagnosis of spasmodic croup,¹⁰⁵ although others report that such symptoms may precede some episodes of spasmodic croup.^{33,35,56} There is ongoing debate whether spasmodic croup and viral croup are separate conditions or whether they represent different parts of a spectrum of disease.^{23,176} Theories concerning the cause of spasmodic croup have included muscle spasm, allergy, and viral infection. Descriptions from laryngoscopy in spasmodic croup have reported a "pale, watery edema"³⁵ in contrast to the inflammatory edema present in viral croup. Although the treatment for spasmodic croup is generally the same as for viral croup,³⁵ spasmodic croup generally is considered less severe and may be more responsive to humidification therapy.⁵⁶ Because of these perceived differences between spasmodic and viral croup, failure to distinguish between the two conditions has been a consistent criticism of therapeutic trials for croup.¹⁷⁰

Some individuals experience multiple episodes of croup. Like spasmodic croup, there is evidence to suggest that recurrent croup differs from typical viral croup. Zach et al¹⁸² define this condition as "repeated episodes of barking cough and inspiratory stridor, most often occurring at night and lasting for only a few hours." This description is more consistent with recurrences of spasmodic croup rather than separate episodes of viral croup. Some studies have reported surprisingly high rates for recurrent croup, including one study¹²¹ from Sweden that reported 57% (288/505) of children had recurrent croup (≥ 3 episodes in 30.9%, ≥ 5 episodes in 17%, and ≥ 9 episodes in 6.1%). Children with recurrences may have more frequent allergic symptoms (eczema, urticaria, asthma, hay fever) or history of allergy.¹²¹ Abnormalities in allergy testing, pulmonary function testing (including histamine inhalation), and IgE antibody levels have been reported in patients with recurrent croup.^{134,181,182} The association of croup with asthma has been supported by a higher prevalence of croup in children with asthma as com-

pared with controls (33.2% versus 20.6%)¹⁰⁴ and a higher incidence of airway hyperreactivity in children previously hospitalized with croup.¹⁸¹

Microbiology

The microbiology of viral croup has been well established in studies from outpatient and inpatient populations. Parainfluenza (types 1, 2, and 3) viruses have been the most commonly identified agents and have represented about half or more of all isolates in many studies.^{39, 64, 169} In data from the Chapel Hill group³⁹ parainfluenza made up 74.2% of the isolates from individuals with croup. Parainfluenza virus types 1 and 2 were particularly likely to produce symptoms of croup in affected patients (58% and 60%, respectively). In the same study³⁹ RSV represented 10% of isolates, and influenza types A and B each represented a little more than 3% of isolates. The relative frequency in which specific infectious agents caused croup varied with the age of the child. Parainfluenza was the most common agent in all age groups, whereas RSV occurred in younger children and influenza and mycoplasma were present in children older than 5 years.

Following the large outbreaks of measles that occurred in the United States during the late 1980s, several groups reported the common occurrence of croup in these patients. Three retrospective studies reported a frequency ranging from 18.6% in a combined inpatient/outpatient study¹⁴⁶ to 22% to 31% in hospitalized patients.^{63, 120}

Clinical Manifestations

A case of viral croup usually begins with the signs and symptoms of a mild viral URI (rhinorrhea, mild fever, sore throat, and cough).^{23, 33, 57} Within hours to days, evidence of upper airway obstruction appears. Hoarse cry, barking (described like a seal barking) or croupy cough, and inspiratory stridor are the hallmarks of croup. The degree of respiratory distress may vary from mild to severe, with tachypnea, subcostal and suprasternal retractions, and decreased air entry all commonly reported. Restlessness and cyanosis are markers for hypoxemia resulting from severe croup. Because the viruses responsible for croup can cause other respiratory tract diseases, wheezing and crackles also can be heard occasionally.

Differential Diagnosis

Infectious and noninfectious entities can mimic viral croup.^{8, 128, 140} Other infectious causes include epiglottitis, bacterial tracheitis, diphtheria, peritonsillar abscess, and retropharyngeal cellulitis or abscess. Noninfectious causes include foreign bodies,^{52, 69} intrinsic or extrinsic compression (by lymph nodes, neoplasms, vascular structures—hemangiomas or vascular rings and slings, or other masses—laryngeal polyps, or papillomas),¹⁰⁰ subglottic webs,²⁴ and vocal cord paralysis. Allergic conditions (angioneurotic edema and anaphylaxis), trauma, and burns also can produce manifestations of upper airway obstruction.⁸

Diagnosis and Laboratory Evaluation

For the majority of cases with classical symptoms of a mild nature, there is probably little requirement for diagnostic evaluation beyond the history and physical examination.^{57, 118} Significant historical risk factors are chronic lung disease (e.g., prematurity), subglottic narrowing (e.g., airway intubation), and immuno-

deficiency. For the primary care physician, the typical case of croup is a clinical diagnosis rather than a pathologic (histologic or anatomic) or microbiologic diagnosis. The goal of additional testing is to rule out more worrisome causes when the diagnosis of viral croup is in doubt. As with any illness, the severity or toxicity of the child will influence the likely causes, as well as the appropriateness of further diagnostic evaluation and therapy. Children with suspected epiglottitis or who are otherwise at risk of impending airway obstruction should be managed in a controlled setting by individuals skilled in airway management. In these patients, it is crucial that delays caused by additional diagnostic maneuvers be minimized. For completeness, this discussion includes some of the laboratory costs from the outpatient lab at the University of California, San Francisco.

Nonspecific blood tests (WBC count with differential—WBC cost = \$37; C-reactive protein [CRP]—CRP cost = \$31; erythrocyte sedimentation rate—erythrocyte sedimentation rate cost = \$28) may be elevated in any number of acute infectious processes and offer little to the evaluation of most patients. Although studies using CRP specifically in croup have been reported, the results are mixed. One study (N = 35) of patients hospitalized with epiglottitis, spasmodic croup, and acute laryngotracheitis reported that a CRP of 20 mg/L or more made spasmodic croup unlikely and increased the likelihood of epiglottitis.¹³⁵ Nineteen percent of patients diagnosed with acute laryngotracheitis had a CRP of 20 mg/L or more, however. In a larger study (N = 209) of hospitalized children with "middle and lower respiratory tract infection," about half of patients with bacteria alone or bacterial and viral infections had a CRP of 20 mg/L or more, whereas 35% of patients with viral infection alone had a CRP of more than 20 mg/L.¹⁰⁶

Microbiologic studies (e.g., Gram's stains, cultures, rapid antigen detection studies, and serology) can help in identifying a specific cause, although the results are unlikely to alter management in typical cases.³³ Respiratory specimens can be obtained through sputum production or nasal washings. Currently at the University of California, San Francisco rapid antigen tests can be performed on nasal washings for detection of parainfluenza (types 1, 2, 3), RSV, adenovirus, and influenza virus (\$204). Titers from paired acute and convalescent sera also can be obtained for these same viruses and for mycoplasma pneumoniae (\$54 per paired specimens).

Similarly, radiologic studies usually are not necessary to make the diagnosis of viral croup.⁸ In an informal survey of pediatricians (N = 24) presented with a scenario of a patient with typical viral croup, however, 42% answered they would "always" obtain a roentgenogram.¹²⁵ By comparison, in one study¹⁴ neck roentgenograms were obtained in only 2 of 30 (6.7%) patients hospitalized with croup. If performed, lateral neck roentgenograms have been shown to have a high sensitivity (93%) and specificity (92%) for laryngotracheobronchitis when adequate studies are interpreted by experienced radiologists.¹²⁵ There was no correlation between radiologic findings and clinical outcomes, however, although "uninterpretable" films (13%) were associated with increased clinical severity.¹²⁵ The frequency in which roentgenograms are obtained is likely to depend on the clinical setting, frequency in which croup is encountered, and confidence of the physician in making a clinical diagnosis. Plain films of the neck (anteroposterior [AP] and lateral—cost = \$171) can help confirm the diagnosis of laryngotracheitis (air trapping and dilated hypopharynx, steeple sign secondary to subglottic narrowing) or help rule out epiglottitis (thumb sign, thickened aryepiglottic folds), retropharyngeal abscess, or a radioopaque foreign body. The chest radiograph (AP and lateral—cost = \$187) may show the steeple sign on AP view. Other roentgenograms can be obtained, including decubitus films or expiratory/inspiratory films if foreign body aspiration is suspected.

Monitoring

The degree of respiratory distress in acute laryngotracheitis can range from minimal to severe. A careful physical examination can determine the degree of distress as well as detect evidence of fatigue. Croup scoring systems have been devised to serve patient care and research purposes. In both settings, croup scores attempt to create objective measures of disease severity that allow comparison between serial assessments. Ideally, scores can assist in quantifying respiratory distress, selecting initial therapy, determining response to therapy and requirement for additional therapy, and eventually in determining patient disposition (discharge or admission). An example of one such scoring system is shown in Table 1. The most commonly used scoring systems^{107,164,176} all include color (presence or absence of cyanosis), air entry (normal or varying degrees of impairment), retractions (normal or varying degrees of severity), level of consciousness (including restless, disoriented, or depressed as the most severe), and stridor. The presence of stridor at rest was an indicator of highest severity in all these reports.

In addition to the physical examination, other noninvasive techniques have been used to assess patients with croup. Pulse oximetry has been reported to detect hypoxemia earlier than the clinical examination (e.g., cyanosis or bradycardia).²⁸ One study⁸⁰ in patients with upper airway obstruction admitted to a pediatric intensive care unit showed a good correlation between pulse oximetry and arterial blood gas saturation; however, another group¹⁵⁸ reported a poor correlation between oxygen saturation by pulse oximetry and respiratory rate or duration of hospitalization. Problems with oximetry readings have been attributed to artifact created by patient movement, lighting, and incorrect sensor size.²⁸ In general, although pulse oximetry is a potentially useful adjunct, it is not a substitute for serial observations by an experienced health care provider.

Transcutaneous carbon dioxide monitoring was used in one study of patients with severe croup who were monitored in an ICU.⁵³ The authors suggested that this technique may be useful in monitoring patients and in selecting patients who require intubation.

Treatment

Numerous therapies historically have been advocated in the treatment of croup. The literature is rife with therapies including bleeding and leeches, soap sud enemas, alcohol baths, ice caps, nose drops and sedatives, humidification, hydration, expectorants (e.g., ipecac), antihistamines, cough suppressants, corticosteroids, and adrenergic agonists.^{127,149,159} Some of these therapies have been

Table 1. CROUP SCORE*

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Modified from Fleisher GR, Ludwig S: Textbook of Pediatric Emergency Medicine, ed. 3. Baltimore, Williams and Wilkins, 1993, p 616 as adapted from Taussig LM, Castro O, Beaudry PH, et al: Treatment of laryngotracheitis (croup): Use of intermittent positive-pressure breathing and racemic epinephrine. American Journal of Diseases of Children 129:790, 1975; with permission.

abandoned, some persist despite little evidence of their value, and others remain controversial despite having been the focus of substantial clinical research.^{23,170}

Hydration and Humidification

The use of hydration and humidification has been advocated for decades in the treatment of croup.^{36,133} Davison has been credited with being one of the first to recommend the use of humidified air.^{14,36,133} Steam generated by baths, showers, croup kettles, and croup tents all have been suggested as techniques for generating moisture. Other techniques include hanging wet linens in the room or breathing through a moistened washcloth.¹⁴⁷ Humidification may prevent drying out of mucous membranes, loosen thickened secretions, and lessen irritation in the nasopharynx,¹³³ although the exact mechanism is unknown. In addition, humidification could reduce insensible water loss or act on receptors in the larynx, which reduces respiratory rates.

Humidification has been considered a mainstay of therapy for croup despite the absence of objective evidence of its efficacy in patients with croup.^{56,133} Evidence against the usefulness of humidification includes the fact that inspired air normally becomes completely saturated before reaching the larynx.¹³ Little additional nebulized fluid therefore, passes beyond the nasopharynx.¹⁶¹ A small clinical trial (N = 16) in patients hospitalized with viral croup reported no improvement in outcome measures (transcutaneous oxygen and carbon dioxide and croup score) in the group treated with humidification compared with a control group 12 hours after therapy.¹³ A separate, smaller study (N = 5) found no difference in respiratory resistance at 5, 10, 15, and 25 minutes after therapy with 2 mL of nebulized water.¹¹⁵ Geelhoed and Macdonald⁷¹ report that at a children's hospital admitting from 300 to 550 cases of croup per year, they have not used mist therapy "for many years" because of a "lack of objective evidence to support its use." In his review on the treatment of croup, Skolnik¹⁴⁹ concluded that although there was no evidence for the use of humidified air in hospitalized croup patients, anecdotal evidence suggests that the use of a mist tent was "not unreasonable . . . as long as it is well tolerated by the child." Henry⁸⁴ described the use of a warm moist atmosphere as "reasonable, and at the very least, a harmless step."

It is likely that the usefulness of hot mist, cold mist, or no mist will continue to be debated for the foreseeable future. Hot and cool mist tents can cause discomfort through dampness and isolation.^{84,133} Mist tents also can interfere with visual monitoring of the child. If a child becomes uncomfortable when kept in mist, in the home, office, or hospital, the potential benefits may be far outweighed by the increase in agitation. Choosing the site where a child is most comfortable (e.g., in the arms of a parent compared with the confines of a mist tent filled with cool or warm mist) is an important but overlooked intervention. When humidifiers are used in the home, cold humidifiers often are recommended to avoid the risk of burns to small children. In addition, families should conduct regular cleaning and maintenance of humidifiers to prevent the growth of bacteria and fungi.¹⁶¹

Corticosteroids

Published accounts^{131,132,171} on the use of corticosteroids and related agents in croup are available from the early 1950s. In 1954, Nilsson and Olow¹³¹ reported their use of corticosteroids in croup based on "favorable experience with cortone in various conditions of intoxication and shock." At the time, these agents were believed to work through "anti-exudative and shock-inhibiting effects."¹³² Forty years later, the exact mechanism of action of corticosteroids in croup remains unclear, although many effects have been theorized. Benefits may be mediated by

a reduction in the local inflammatory reaction (including lymphoid tissue) and capillary permeability, resulting in decreased subglottic edema.¹⁶⁰ In addition, corticosteroids may block allergic and immunologic responses.¹⁶⁰ The rapidity with which corticosteroids have been reported to act in some studies suggests other undescribed mechanisms also may be responsible.

In 1960, a randomized, placebo-controlled study by Martensson et al¹²¹ reported significant improvement in more than 500 children treated with oral corticosteroids (prednisolone) for croup. Controversy exists, however, because subsequent prospective trials have yielded mixed results—i.e., not all studies have shown improvement following corticosteroid administration when compared with placebo. Tunnessen and Feinstein¹⁷⁰ cite several reasons for the controversy over corticosteroid use and the conflict in study results. These reasons include (1) the lack of complete diagnostic classification (specifically, not differentiating viral from spasmodic croup), (2) inadequate dosing regimens, and (3) the lack of “clinically relevant” outcomes. A later study tried to address at least one of these concerns by specifically comparing patients with spasmodic croup and acute laryngotracheitis.¹⁰⁵ The sole outcome measure was respiratory rate during sleep during a 6-hour observation period following the administration of dexamethasone or placebo. No difference was noted between dexamethasone recipients and controls in the combined group (spasmodic croup and acute laryngotracheitis) or the acute laryngotracheitis-alone group. When analyzed separately, however, the patients with spasmodic croup who had received dexamethasone had significantly lower respiratory rates than the controls.

In 1989, Kairys et al⁹⁷ reported a meta-analysis of nine randomized studies published in the English language literature and representing a total of 1126 patients. The authors concluded that the administration of corticosteroid was associated with significantly greater clinical improvement at 12 and 24 hours after treatment (treatment versus control: 81% versus 66% at 12 hours and 96% versus 82% at 24 hours). Likewise, the incidence of endotracheal intubation was reduced by approximately 80% (0.17% in the treatment versus 1.27% in the control) in the corticosteroid treated group. Since that meta-analysis was published, even more recent prospective studies have shown similar effects in nonintubated^{108,160} and intubated patients.¹⁶⁶ Super et al¹⁶⁰ showed improvement in croup score at 12 and 24 hours and reduced requirement for racemic epinephrine by 24 hours. Duration of hospitalization along with oxygen saturation and respiratory rates at 12 and 24 hours was not significantly better. Tibballs et al¹⁶⁸ showed a reduction in intubation and requirement for reintubation in prednisolone-treated patients.

In the Kairys et al⁹⁷ meta-analysis the nine randomized studies were separated into “low dose” (< 125 mg of cortisone equivalent) and “high dose” (≥ 125 mg of cortisone equivalent) groups. Although no specific agent (e.g., dexamethasone, prednisolone, methylprednisolone) or dosage was recommended, the authors stated that there “appeared to be a positive relationship between steroid dose and the proportion of subjects improved within 12 hours,” which supported the high-dose therapy. In the same year, Skolnik¹⁴⁹ cited four of six prospective, randomized, double-blind studies in which an “adequate” dose of dexamethasone (> 0.3 mg/kg) showed significant benefit. He suggested an intramuscular injection of dexamethasone at a dose of 0.6 mg/kg be administered on admission. A review of the same literature by other authors¹⁵⁷ concluded that “routine use of steroids in children admitted with croup cannot be justified on the basis of the available information.” In 1992, the Infectious Diseases and Immunization Committee of the Canadian Paediatric Society¹⁵⁶ published a statement about the role of corticosteroids in hospitalized patients. They recommended that a single dose of dexamethasone (0.6 mg/kg, parenteral or intramuscular) “could be used” in hospitalized children with severe croup.

In addition to different steroid preparations and different doses, several dif-

ferent routes of administration of corticosteroids have been used. Although parenteral administration has been the subject of most investigation, oral and, recently, nebulized agents have been evaluated. A survey of 112 pediatricians and family practitioners from 15 counties around the SUNY Health Science Center at Syracuse²⁶ found that almost two thirds of the responders used the parenteral route for inpatients and slightly more than one third for outpatients. The remainder used the oral route or the parenteral or oral as indicated on a case basis. Advocates of oral administration as an alternative to intramuscular injection cite the bioavailability of oral dexamethasone ($78 \pm 14\%$)⁷³ and the avoidance of the discomfort of an intramuscular injection.¹¹⁹ Two studies of oral corticosteroids were included in the meta-analysis by Kairys et al.⁹⁷ Both studies, one of "low dose" (2.5 or 5 mg of prednisolone)¹²¹ and the other "high dose" (6 mg of dexamethasone)¹⁷⁴ corticosteroids reported benefit. A more recent study⁷¹ showed no difference in any outcome measure between patients receiving various doses of oral dexamethasone (0.15 mg/kg, 0.3 mg/kg, and 0.6 mg/kg) as a single oral dose. Although no placebo group was included in this study,⁷¹ the same research group had reported benefits with oral dexamethasone compared with placebo as part of an earlier trial.⁷⁰

Inhaled steroids for croup have been the subject of several recent investigations. In a prospective study⁸⁹ of hospitalized infants and children, the treatment group (2 mg of nebulized budesonide) showed significant improvement in croup score 2 hours after administration versus no improvement in the control (saline) group. A similar prospective study¹⁰³ of nebulized budesonide in outpatients resulted in a reduced croup score, earlier discharge home from the emergency department, and a lower hospitalization rate. Seventy-eight percent of the placebo group and 56% of the budesonide group also had received dexamethasone during the study or in follow-up, however. A comparison of oral dexamethasone versus nebulized budesonide versus no steroid therapy in hospitalized croup⁷⁰ revealed a shorter time to reduction in croup score, shorter duration of hospitalization, and less frequent requirement for epinephrine after 1 hour in both treatment groups relative to the placebo group. In their follow-up study,⁷¹ the same group reported that oral dexamethasone was easier to administer than nebulized budesonide and, based on their initial study, currently use oral dexamethasone. Budesonide is not available in the United States as a medication for nebulization. A recent randomized, double-blind study⁹³ using nebulized dexamethasone found a statistically significant improvement in croup scores at 4 hours. Improvement at 24 hours as well as hospitalization rates did not differ from the placebo group, however. The size of this study ($N = 55$) may have limited its ability to detect significant differences in these latter outcome measures.

The use of corticosteroids in patients not ill enough to be hospitalized only recently has been the subject of initial investigation. Although use in the outpatient setting has been suggested as "reasonable as a therapeutic trial to prevent subsequent hospitalization" in patients with moderate to severe croup,⁵⁷ there has been little if any experimental evidence to support this practice. Despite this, the use of corticosteroids in such settings has been found to be common. In the survey²⁶ from SUNY Health Science Center, 68% (sometimes 64%, always 4%) used them in outpatients. In 1995, the first prospective study³¹ of corticosteroids in outpatients with croup was reported. In this study, a single intramuscular injection of dexamethasone (0.6 mg/kg) or normal saline was administered to patients who were to be discharged home from the emergency department. At follow-up, fewer dexamethasone-treated patients had received additional medical care (5% versus 21%; not statistically significant) and parents were more likely to report improvement at 24 hours in the treated group (84% versus 42%). The time to complete improvement was the same in both groups (mean of 3 days), however.

Reviews^{97,131,149,156} of corticosteroid use in patients with croup have reported

virtually no adverse effects attributable to the medication. Pneumonia has occurred in treatment and placebo groups, and it is not clear that steroids influence the rate of this complication.^{160,174} Cherry⁵⁶ describes an anecdotal report of a child treated with steroids who experienced a "progressive" adenoviral pneumonia, which he believed was worsened by steroid administration. A case of candida laryngotracheitis has been reported in an infant who was treated with corticosteroids and antibiotics.¹⁷ With the increasing outpatient use of systemic corticosteroids in a variety of conditions (e.g., asthma), studies have tried to address the infectious risks of such patients. One study⁴³ looking at "severe" varicella (defined as development of new lesions after 14 days or evidence of viral disease extending outside the skin and mucous membranes) calculated a 178-fold increase in risk in steroid recipients compared with the general population. Lastly, when similar doses of dexamethasone (0.6 mg/kg/d, divided every 6 hours) were used for 4 days in patients with bacterial meningitis (N = 102), two children experienced heme-positive stools and two additional children had episodes of gastrointestinal bleeding that required transfusion.¹¹⁰

In summary, there are many studies that provide evidence supporting the use of corticosteroids in croup. Controversy still exists, however, concerning the effects on clinically significant outcome measures (requirement for hospitalization, requirement for subsequent medical visits, duration of hospitalization, and requirement for intensive care therapy and intubation). There is also difficulty related to patient selection, including the ability to differentiate viral from spasmodic croup and how this can influence the response to various interventions. The task of appropriate selection of patients for therapy will move from research protocols to individual physician offices, and prospective data from the outpatient setting is just beginning to be reported. The onset of action of corticosteroids is believed to be within hours, and a reduction in croup score at 12 hours has been a common outcome measure reported by studies.⁹⁷ Onset of action of systemic corticosteroids before 12 hours is not well documented, although studies with nebulized budesonide have reported benefits as early as 1 to 2 hours.^{70,89} The optimal number of doses of corticosteroids by any route is unknown, and there have been no prospective comparison trials of single versus multidose protocols.²⁶ The long half-life of dexamethasone (36–72 hours)⁷³ and the relatively short duration of symptoms in typical croup may favor use of a single administration. It is possible, but unproven, that a single dose administration also may reduce the risk of adverse effects.³¹ A variety of dosages and dosing regimens exist in pediatric textbooks. Recent recommendations for dexamethasone in croup or airway edema include 0.25 to 0.5 mg/kg/dose (every 6 hours as necessary),⁹² 0.5 mg/kg (single dose),⁵⁷ 0.5 to 0.6 mg/kg,⁷⁸ 0.5 to 2 mg/kg/d (divided every 6 hours),¹⁶² and 0.6 to 1 mg/kg (single intramuscular or intravenous dose).¹⁶

Epinephrine

Like corticosteroids, epinephrine is not a particularly new therapy for croup. Published accounts using racemic epinephrine for the treatment of infectious and postintubation croup first appeared in the 1960s from the anesthesia group at Primary Children's Hospital in Salt Lake City, Utah.^{1,96} Following the introduction of racemic epinephrine, this group reported fewer tracheotomies (a decrease from 7% to none) and fewer as well as shorter hospitalizations despite increased hospital visits for croup. After this impressive debut, however, racemic epinephrine was found to have limitations. A prospective, placebo-controlled study by Gardner et al⁶⁸ failed to show a reduction in duration of hospitalization or tracheotomy rates between the treatment and control groups. In addition, it was found that the immediate effects of racemic epinephrine could wane between 20 minutes and 4

hours. In his review, Skolnik¹⁴⁹ cites five prospective, double-blind, placebo-controlled studies^{51,68,108,164,176} assessing racemic epinephrine, with all except Gardner et al⁶⁸ concluding that racemic epinephrine was effective in reducing symptoms of airway obstruction. It has been suggested that Gardner et al⁶⁸ failed to show benefit because they did not exclude patients who responded to simple mist therapy.^{61,176} Although most early studies administered epinephrine by intermittent positive-pressure breathing, nebulized epinephrine has been shown effective.⁶¹ Although Gardner et al⁶⁸ showed no benefit from nebulized therapy without intermittent positive-pressure breathing, a prospective trial⁶¹ specifically comparing nebulized and intermittent positive-pressure breathing racemic epinephrine showed similar, significant benefits in both treatment groups. Skolnik¹⁴⁹ recommended nebulization over IPPB administration because of a lack of evidence showing superior effects of intermittent positive-pressure breathing.

The mechanism of action of racemic epinephrine is believed to be mediated through alpha-adrenergic stimulation. This stimulation is thought to result in vasoconstriction of the inflamed mucous membrane surfaces and reduction of edema. Epinephrine effectiveness is notable for its rapid onset and short duration of activity. Following inhalation, improvements in croup scores can be seen at 10 to 30 minutes and may decrease over time. The transient nature of racemic epinephrine's benefits has been shown in many studies,^{61,164,176} with a return of croup scores to pretreatment levels by 2 hours in some patients.

The reasons for using racemic epinephrine (containing levorotatory and dextrorotatory isomers in equal amounts) instead of L-epinephrine are not entirely clear, although virtually all studies in croup use racemic epinephrine. It had been believed that racemic epinephrine resulted in less cardiovascular effects, including tachycardia and hypertension in comparison with epinephrine.¹⁷⁵ In addition, racemic epinephrine was believed to be free from "rebound" vasodilatation,¹²⁴ although evidence to support these beliefs could not be found. Because it has been known that the active form of epinephrine was the L-isomer (30 times more active than the D-isomer),¹⁷⁵ there was reason to believe that 1% L-epinephrine could be as effective as 2.25% racemic epinephrine in croup.^{50,164,176} Waisman et al¹⁷⁵ compared racemic epinephrine with L-epinephrine in a randomized, double-blind study in 31 children with acute laryngotracheitis. This study showed similar improvements in croup scores and respiratory rates in both treatment groups. There were no differences in heart rate or blood pressure recordings between the two groups. Based on their one study,¹⁷⁵ the authors recommended L-epinephrine as an alternative to racemic epinephrine with additional benefits of greater availability and lower cost.

Combination Therapy and Outpatient Therapy

One of the earliest studies of racemic epinephrine use in viral croup included a report of successful results in the emergency department setting.¹ Adair et al¹ reported discharging home almost one third of patients from the emergency department following treatment with racemic epinephrine. No specific details on patient selection, degree of improvement, duration of observation following therapy, follow-up, and outcome was given on those patients discharged home, however. Once the short duration of activity and risk of rebound worsening was noted, hospitalization for close observation was recommended for patients who had received racemic epinephrine.⁶¹ Recent studies, however, have renewed interest in the possibility of outpatient management of selected patients following the administration of racemic epinephrine.¹⁰¹ A retrospective study¹⁶¹ of 50 patients receiving racemic epinephrine and corticosteroids reported only 1 patient requiring additional medical care within 48 hours following observation for 2 or more hours

(2 were lost to follow-up). Two prospective studies^{111,139} have attempted to identify patients who could be discharged home following treatment with racemic epinephrine and dexamethasone. Combining both studies, slightly more than half (61/116; 53%) of patients qualified for discharge home following 3 hours of observation. Of the 61 patients discharged home, only 1 patient returned for further therapy¹³⁹ during the 48 hours follow-up period.

Most studies during the past 25 years have looked individually at corticosteroid use or racemic epinephrine use in croup. The rapid onset and short duration of racemic epinephrine and the slower onset and longer duration of corticosteroids would appear to make them a potentially useful combination. Since the 1980s, several studies^{101,111,139} have reported the results of combination therapy. All the studies on outpatient administration of racemic epinephrine mentioned have used combination therapy. One study¹⁰⁸ of hospitalized croup (spasmodic croup in 70/72 patients) created four different treatment groups using various combinations of intramuscular dexamethasone (0.6 mg/kg) and nebulized racemic epinephrine by intermittent positive-pressure breathing (dexamethasone with racemic epinephrine, dexamethasone without racemic epinephrine, racemic epinephrine without dexamethasone, and a group without either therapy). All the therapy groups (dexamethasone and racemic epinephrine) showed greater improvement in comparison to the placebo group. Children who received dexamethasone and racemic epinephrine were discharged home slightly sooner than the dexamethasone-alone group (37 ± 29 hours versus 49 ± 23 hours).

From the literature, it is unclear how widespread the use of racemic epinephrine is in patients who are discharged home from the emergency department or private office setting. Use of outpatient therapy would require careful patient selection, a period of observation in a medical facility following administration of racemic epinephrine, and close follow-up. A recent commentary²⁷ from Salt Lake City, the department that initially described epinephrine use in croup, recommended observation of 3 to 4 hours for "observed-outpatient" administration of racemic epinephrine. Some experts caution against the use racemic epinephrine in the outpatient management of croup.⁵⁶

Other Adrenergic Agonists

Reports on the use of adrenergic agonists center mostly around the use of racemic epinephrine, but there are limited data on other adrenergic agonists, including selective alpha-adrenergic agonists. Based on the theory that nebulized epinephrine activity may be mediated by alpha-adrenergic stimulation (rather than alpha and beta), one study¹¹⁵ used nebulized phenylephrine in a small sample ($N = 8$) of hospitalized children with croup. Treatment with phenylephrine resulted in a reduction in total respiratory resistance in seven of eight patients (the sole nonresponder subsequently grew *H. influenzae* from blood and throat cultures) of 30% (range 17% to 38%) 15 minutes later. This initial improvement was followed by a rebound increase in airway resistance 30 minutes after therapy. The authors could not recommend the use of nebulized phenylephrine in croup, although they did suggest that oral alpha-adrenergic agents may be useful. Others have discussed the possible benefits of oral ephedrine or pseudoephedrine in the treatment of viral croup or spasmodic croup.¹⁵ Outside of a single anecdotal account⁷ of success with oral pseudoephedrine in viral croup, however, no other evidence could be found in the English language literature.

Antibiotics

The decision to administer antibiotics in croup undoubtedly is influenced by the patient's severity of illness as well as the physician's suspicion of bacterial

infection. The acute LTB observed in the first half of this century was a bacterial infection (diphtheritic and nondiphtheritic) associated with significant morbidity and mortality. Once antibiotics were available (initially sulfa-based and subsequently penicillins), they soon became an essential part of the therapy for these life-threatening infections.^{113,131} Various factors already discussed have resulted in the appreciation for the changing microbiology of croup. The croup commonly encountered by physicians today is predominantly a viral infection. The continued administration of antibiotics in children with croup is common, however, despite this realization and admonitions to limit their use.¹¹³ Physicians may feel obliged to consider antibiotics because of concerns over preventing or treating bacterial infection or superinfection. Although case series of bacterial tracheitis have re-emerged in the past 2 decades, it is still an uncommon entity that may have some distinguishing characteristics from viral croup (see following discussion). Also, reports^{66,153} on the use of prophylactic antibiotics in presumed viral URI have not shown benefit. Conclusions of a meta-analysis of randomized, controlled trials on antibiotic use in URI and prevention of lower respiratory infections showed no shortening of the duration of URI and no prevention of developing pneumonia. A study¹³⁷ comparing antibiotic use in croup at three different hospitals (a children's hospital, an urban general hospital, and a rural community hospital) found that the "inappropriate" use varied from 6% at the children's hospital, to 38% at the urban hospital, and 63% at the community hospital. There was no increase in morbidity reported from the children's hospital where antibiotic usage was lowest. Similarly, another study¹⁶⁵ showed no difference in outcomes in viral croup following implementation of an educational program that reduced the antibiotic use from 93% to 22%. In general, experts^{56,149} agree that antibiotics are not indicated in the routine treatment of viral croup.

Outcomes

Rates for morbidity and mortality of croup have decreased overall in this century. Comparison of current rates with figures from the beginning of this century are confounded by the different clinical entities described by the croup syndrome (epiglottitis, bacterial tracheitis, and viral laryngotracheobronchitis). In addition, many new therapies introduced during this century (e.g., immunizations, racemic epinephrine, corticosteroids, diphtheria antitoxin, antibiotics, and intubation techniques) also have influenced the outcomes of the croup syndrome. From relatively recent epidemiologic studies, only a small percent of patients with viral croup will require hospitalization, although reports range from 1.26%^{38,39} and 19% in outpatient populations.⁶⁴ Other reviews of croup have reported a hospitalization rate of less than 5%.³³ Of the hospitalized patients, it has been estimated that less than 10% of hospitalized patients will require services in an ICU and less than 1% will require intubation.^{1,33} A recent report of croup cases at a single hospital during a 7-year period ending in December 1992 showed a decrease in patients admitted to the ICU and a decrease in intubations, despite an increase in emergency department visits and total hospital admissions for croup.¹²² Corticosteroid and nebulized epinephrine use had increased at the study center during this time period. An increase in intubation rates reported by some authors may reflect an increased incidence of "bacterial croup" seen at certain centers.¹⁵⁰ The mortality rate in patients hospitalized with croup previously has been reported at 1%.¹¹⁸

Summary

Viral croup is a common clinical diagnosis characterized by hoarse cry, barking cough, and stridor. Additional laboratory tests usually are not required to assist

in diagnosis or treatment of typical cases. Primary care physicians are faced with the challenge of selecting appropriate therapies for patients. These decisions are made more difficult by the increasing number of available therapies and the controversies surrounding most therapies for viral croup. Humidification has significant anecdotal support and probably little risk if tolerated well by the patient. Dexamethasone as a single dose of 0.6 mg/kg administered parenterally has been supported by clinical research. Likewise, racemic epinephrine can reduce symptoms acutely but with a risk of rebound 2 hours later. Combinations and modifications of these therapies, including dosage and route of corticosteroids, and use of L-epinephrine in the place of racemic epinephrine will probably continue to generate interest. The use of these therapies in the outpatient clinic requires physicians to focus on optimal patient selection, extended observation periods, and the need for close follow-up. It is left to the individual physician to select the appropriate therapy based on an understanding of the scientific literature as well as personal experience and expertise. In addition to disease severity, the importance of other patient factors such as the proximity to medical care, access to car and telephone, compliance, and the observation skills of the family cannot be underestimated. The potential risks and benefits of each intervention need to be considered on a case by case basis. In Table 2, Fleisher⁵⁷ suggests management strategies determined by total score from the croup scoring system by Taussig.

Bacterial Tracheitis

An understanding of bacterial croup or bacterial tracheitis begins well before the twentieth century. Before the availability of diphtheria antitoxin and antibiotics, laryngeal diphtheria was synonymous with croup.¹⁵⁹ Baum¹⁰ is credited with one of the earliest descriptions of acute (nondiphtheritic) LTB,¹⁵⁹ which was published in *JAMA* in 1928. The disease he described almost 70 years ago included cases that are similar to more modern descriptions of bacterial tracheitis. In his report of severe disease (24 cases requiring airway management; 10 deaths), "glue-like" secretions were noted in the tracheobronchial airway. Streptococcus was isolated in 10 of the cases. Authorities who were familiar with diphtheritic and nondiphtheritic LTB reported similarities in clinical manifestations between the two conditions.⁹¹ The character of the tracheal exudate differed, however, with diphtheria producing a more fibrinous exudate compared with the more inflammatory product of LTB. Before the advent of antibiotics, the mortality rate of nondiphtheritic LTB was 50% to 70%,^{62,91} which was significantly higher than the 25% mortality associated with laryngeal diphtheria.⁶²

Table 2. DISEASE CATEGORY BY SCORE*

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Modified from Fleisher GR, Ludwig S: Textbook of Pediatric Emergency Medicine, ed 3. Baltimore, Williams and Wilkins, 1993, p 616; with permission.

Bacterial LTB seems to be a disease that appeared, disappeared, and reappeared during this century. The appearance of bacterial LTB early this century was accompanied by debate whether this condition was newly described or had existed previously along with diphtheritic infections. Despite its seriousness, there was little mention of bacterial LTB in textbooks of the time.⁶² An increasing number of reports (mostly in the otolaryngologic literature) were published from the 1940s and 1950s. In the second half of this century, reports of bacterial LTB disappeared from the pediatric⁴¹ and otolaryngologic literature.^{45,123} A link between its disappearance and the use of antibiotics in "inflammatory pediatric airway diseases" has been suggested.⁴⁵ Fifty years later, this same debate was renewed as reports of bacterial infection of the upper airway of children reemerged. Currently, there is general agreement that bacterial tracheitis and membranous or pseudomembranous LTB all represent a single clinical entity that was redescribed in 1979.

Definitions

Terminology in this area has been split between endoscopic/pathologic (e.g., membranous and pseudomembranous LTB) classifications and microbiologic (e.g., bacterial tracheitis) classifications. In 1979, Han et al⁸² described a condition they termed membranous LTB. In the same year, Jones et al⁹⁵ coined the term *bacterial tracheitis*. These two separate case series almost certainly describe the same condition whose distinguishing characteristic is an inflammatory exudate usually associated with isolation of a pathogenic bacteria. In comparing reports that used endoscopic/pathologic versus microbiologic nomenclature, the principal difference was the isolation rate of bacterial organisms. Studies reporting membranous and pseudomembranous LTB were more likely to include cases in which no bacterial agent was isolated. By definition, reports on bacterial tracheitis included only those cases in which a bacterial agent was identified by Gram's stain or culture.

For the purposes of this review, most of the information presented has been obtained from 15 of the largest series* on bacterial tracheitis published since 1979 (N = 177). All these series represent retrospective reports of cases seen during varying lengths of time during the past 2 decades.

Epidemiology

A comparison of the frequency of hospitalization for viral croup and bacterial tracheitis is available in published reports from three children's hospitals. During a 4-year period at Montreal Children's Hospital, there were 491 admissions for viral croup and nine admissions for bacterial tracheitis (55:1).¹⁶³ In a 1-year period at Primary Children's Medical Center, Jones et al⁹⁵ reported 40 admissions for croup and five for bacterial tracheitis (8:1). This same study also included four admissions for epiglottitis during the same period. During a 3-year period at Children's Hospital of Winnipeg, there were 332 admissions to the hospital for "obstructive upper airway infection," including 28 cases of epiglottitis admitted to the ICU. Of the remaining 304 cases, 23 cases of "croup" were admitted to the ICU, with 7 of those cases subsequently diagnosed with bacterial tracheitis (43:1).¹⁵¹

*References 25, 41, 44, 45, 65, 67, 82, 85, 95, 99, 116, 117, 143, 151, 163.

From nine series* (N = 65) in which the age of individual patients were included, the age range varied from 3 weeks to 13 years old. Twenty-one children were younger than 2 years old, 13 were 2 to 3 years old, 8 were 4 to 5 years old, 9 were 6 to 7 years old, and 14 were older than 7 years old. Overall, most children were in the preschool age group, with one third of patients younger than 2 years old and almost two thirds younger than 6 years old. Similar to viral croup, cases of bacterial tracheitis were more frequent in boys than girls. From 13 of the 15 studies† (N = 139), the ratio of boys to girls was 2.3:1 (97:42). Only 1⁹⁵ of the studies reported a female predominance (5 girls, 3 boys).

Pathophysiology

In the host, local and systemic effects may contribute to the development of bacterial tracheitis. Breaks in the respiratory epithelium and loss of ciliary function impair local host defense, whereas some viral infections may interfere with systemic cellular immune function. In addition, viruses and bacteria may interact to aid in mutual dissemination, multiplication, and host acquisition through any number of events.⁴⁸ Specifically, there is evidence for viral involvement in bacterial adherence to the mucous membranes.^{102,144} Opportunistic adherence has been used to describe the ability of *Pseudomonas aeruginosa* to adhere to the mouse tracheal epithelium following infection with influenza virus.¹⁴⁴

Although the exact pathogenesis of bacterial tracheitis is unknown, hypotheses have included (1) primary bacterial infection,^{40,95} (2) primary viral infection with bacterial superinfection, (3) bacterial and viral coinfection, and (4) severe viral infection with bacterial colonization. Of these, the concept of bacterial tracheitis as a complication of viral croup has the most proponents.^{2,23,47,112,127,129} Support for this hypothesis is based on patients who have had viral and bacterial agents isolated from tracheal cultures. Other conditions besides viral infection have been associated with bacterial tracheitis. Bacterial tracheitis has been reported as a complication of airway procedures, including intubation and tonsillectomy/adenoidectomy.^{11,49,51,54,145} Local tissue injury induced by the endotracheal tube may allow bacterial adherence to the trachea in the same manner as viral infection. This model has been shown in ferrets following endotracheal intubation.¹⁴⁴ Other host conditions such as Down syndrome may predispose to bacterial tracheitis. Three studies^{18,45,117} have reported a total of seven patients with Down syndrome. Defects in cellular and humoral immunity as well as anatomic abnormalities of the airway may result in a higher incidence of bacterial tracheitis in patients with Down syndrome.⁴⁵

Microbiology

Streptococcus had been the predominant agent isolated in bacterial LTB in the first half of this century.¹²⁷ From 13 of the 15 studies‡ included in this review, *Staphylococcus aureus* represented the major isolate (N = 73). Streptococcal species (i.e., *S. pneumoniae*, group A and non-group A beta-hemolytic streptococcus,

*References 41, 44, 45, 85, 95, 116, 143, 151, 163.

†References 25, 41, 44, 45, 67, 85, 95, 99, 116, 117, 143, 151, 163.

‡References 41, 44, 45, 67, 82, 85, 95, 98, 116, 117, 143, 151, 163.

alpha-hemolytic streptococcus, and *S. viridans*) (N = 40) and *Haemophilus* sp. (N = 19) are the next most common agents. Other organisms found less frequently include *Klebsiella* (N = 4), *Pseudomonas aeruginosa* (N = 3), *Corynebacterium* (N = 2), *Escherichia coli* (N = 6), *Neisseria* sp. (N = 5), and *Branhamella* (*Moraxella*) *catarrhalis* (N = 2). In studies* in which data were available, 29 of 132 (22%) cultures yielded more than one organism, whereas 15 of 132 (11%) cultures showed no growth. In addition to the larger cases series, a number of individual case reports of unusual organisms have been published in the last 15 years. Of these, *Moraxella catarrhalis* probably has been the subject of most reports.^{9,51,58,79,98,178}

In 10 of the larger series,† sporadic attempts at isolating a viral agent resulted in 23 isolates, including parainfluenza (types 1, 2, and 3), influenza, RSV, measles, and enterovirus. More viral agents presumably would have been isolated if testing had been more universal. Han et al⁸² isolated viruses including parainfluenza, influenza, and enterovirus in 6 of 12 attempts. Another report¹²⁶ using culture and serology techniques documented influenza B or parainfluenza 2 infection in each of eight children with bacterial tracheitis. Donnelly et al⁴¹ identified virus by culture in five of eight cases (parainfluenza 1—[2], parainfluenza 2—[2], influenza B—[1]) of bacterial tracheitis. Clusters of cases of bacterial tracheitis have been reported in association with community outbreaks of parainfluenza and measles. Liston et al¹¹⁷ recovered parainfluenza type 1 in six of seven viral throat cultures from cases of bacterial tracheitis that occurred during a 2-month-long community epidemic of parainfluenza. Similarly, Conley et al²⁵ reported nine patients with concurrent measles and bacterial tracheitis (measles-associated bacterial tracheitis) that occurred during an epidemic of measles between August 1989 and April 1990. In contrast to these studies, Sofer et al¹⁵¹ failed to identify any viral agents by culture or serologic assay in all five attempts.

Clinical Manifestations

The clinical manifestations of bacterial tracheitis combine features of viral croup and epiglottitis. As in viral croup, a prodromal viral URI may precede other symptoms by hours to days (up to 2 weeks).^{41,65,67,99} These symptoms are followed by development of a barking cough and evidence of increased upper airway obstruction and toxicity.⁴¹ The higher fever and greater degree of toxicity seen in patients with bacterial tracheitis may favor the diagnosis of epiglottitis over viral croup.⁸⁷ The presence of a barking cough in bacterial tracheitis may be the primary distinguishing factor from epiglottitis.⁸⁵ In addition, patients with bacterial tracheitis tend to have a longer duration of symptoms,⁸⁵ and less frequent drooling¹⁵² when compared with epiglottitis. Respiratory distress can progress rapidly to the point of complete airway compromise and cardiorespiratory arrest.

Diagnosis

Just as in viral croup, blood tests provide little additional information. In the case series reviewed, WBC counts generally ranged anywhere from normal to moderately elevated. The mean WBC from five studies^{44,67,95,99,117,151} was 13,579. Many of the studies^{41,45,65,95,99,116,151} noted the predominance of polymorphonuclear

*References 41, 45, 67, 82, 85, 95, 99, 116, 117, 143, 151.

†References 25, 41, 65, 82, 85, 99, 116, 117, 151, 163.

cells and immature neutrophils. The mean neutrophil count from four studies^{95,98,117,151} (N = 41) was 51%, and the mean band count from three studies^{95,98,151} (N = 29) was 29%. CRP levels reported in one study⁴⁵ revealed 8 of 11 patients with normal values. Of the 3 patients with abnormal CRP values, only 1 showed a marked elevation. Although most patients had a blood culture performed, eight studies* combined reported only 2 positive blood cultures^{25,44} of 63 patients cultured. From the remaining seven studies, only two^{98,117} other positive blood cultures, both *H. influenza*, were reported.

Neck roentgenograms are usually abnormal. From nine of the studies† 85 of 100 patients (85%) showed evidence of subglottic narrowing. Other findings included evidence of intratracheal membranes as evidenced by opaque streaks or irregular margins on the lateral neck films^{41,65,82,98} and an enlarged epiglottis in 4 patients.^{44,65,117} Chest radiographs were abnormal in almost half (43/89) of cases,‡ with a range of findings including interstitial infiltrates, linear densities, bronchitis, bronchopneumonia, pulmonary edema, hyperinflation, pneumonitis, and pneumonia.

In general, definitive diagnosis of bacterial tracheitis was made by direct visualization. It has been suggested that this is the only way of distinguishing bacterial tracheitis from other entities.⁴⁵ Laryngoscopy and bronchoscopy can be therapeutic and diagnostic because purulent exudate blocking the airway can be removed and submitted for further examination. A Gram's stain of the material should reveal WBCs and bacteria. A good correlation between Gram's stain and bacterial culture results has been reported.⁹⁵ Microbiologic tests are important in confirming the etiologic agent and selecting or modifying antibiotic therapy. The results of viral and bacterial cultures have been reviewed previously.

The clinical response to treatment with racemic epinephrine also may help distinguish between viral croup and bacterial tracheitis in some patients. Many authors^{41,95,117,151} have commented on the lack of improvement following administration of inhaled racemic epinephrine in patients with bacterial tracheitis. The effects of racemic epinephrine in patients with viral croup already have been discussed.

Management/Treatment

Sixty years ago, Jackson and Jackson⁹⁰ emphasized cool, humidified air and rest for bacterial LTB. In general, the same therapies that have been used for viral croup have been used as initial therapy for bacterial tracheitis. The therapy for bacterial tracheitis may be more notable for its failures, however than for its successes. In the studies^{41,95,117,151} reviewed, patients were almost universally unresponsive to the traditional medical therapies used for viral croup, including humidification and racemic epinephrine. Only one study⁶⁷ reported a significant initial improvement to racemic epinephrine (9/11), although almost half of the responders became unresponsive to continued aerosol therapy. Jones et al⁹⁵ suggested that the accumulation of secretions in the trachea may prevent nebulized epinephrine from reaching the mucosal surfaces of the affected areas.

*References 25, 41, 44, 85, 95, 116, 143, 151.

†References 25, 41, 65, 67, 82, 85, 95, 117, 151.

‡References 25, 44, 45, 65, 67, 95, 143, 151.

All the studies emphasized the importance of airway management in bacterial tracheitis. Intubation and tracheostomy were necessary in the majority of patients. In 14 of the 15 studies* intubation was performed in 106 of 147 (72%) patients, tracheostomy in 14 of 147 (9.5%) patients, and no intervention in 27 of 147 (18%). In only 1 study⁶⁵ were the majority of patients managed without an artificial airway. In this study, only 3 of 10 patients required intubation and none required tracheostomies. The preference for intubation versus tracheostomy may be center dependent. Of 15 studies, tracheostomies were reported only from 5 series.^{85,95,116,117,151} Two centers were responsible for 12 of 14 tracheostomies.^{85,116,117} Some groups^{40,85,117,159} reported more ease of removal of tracheal secretions following tracheostomy.

Parenteral antibiotics were administered to cover the most common etiologic agents including *S. aureus*, *Streptococcal* sp., and *H. influenza*. In the studies, antibiotic regimens included various combinations of penicillin/ampicillin, methicillin/nafcillin/cloxacillin/dicloxacillin, gentamicin, chloramphenicol,^{44,85,95,116,143,151} and cephalothin/cefuroxime.^{67,99} Appropriate changes in therapy can be made following the results of organism identification and sensitivities. The individual case reports of *M. catarrhalis* may make this another organism to consider when initiating empiric therapy.

Outcome

Morbidity and mortality from bacterial tracheitis are related primarily to airway obstruction. Although mortality rates of bacterial LTB from the first half of this century were at 70%,⁹⁰ in the studies† reviewed 6 deaths were reported of the 177 patients (3.4%). Other reported complications include pneumonia, subglottic stenosis, and pneumothoraces.^{40,117} In addition, several reports^{21,34,130} have described the occurrence of the toxic shock syndrome in patients with *S. aureus* bacterial tracheitis.

Summary

Bacterial tracheitis most likely represents a superinfection of viral croup. *S. aureus*, *Streptococcal* sp., and *H. influenzae* are the most commonly isolated organisms. Early symptoms mimic viral croup; however, its subsequent course is typically more severe and suggestive of epiglottitis. Respiratory symptoms generally are not amenable to the conventional therapies for viral croup (including humidification and racemic epinephrine). Close monitoring of the airway is the principal therapy, and intubation or tracheotomy usually has been required to prevent obstruction by purulent exudate in the trachea. Antibiotic therapy is directed toward the likely pathogens. Because of the overlap in symptoms with viral croup, physicians need to consider bacterial tracheitis in the differential diagnosis of children with stridor. Suspicion should be even higher in those children who appear unusually ill or who fail to respond to the usual medical therapies for croup.

*References 41, 44, 45, 65, 67, 82, 85, 95, 99, 116, 117, 143, 151, 163.

†References 25, 41, 44, 45, 65, 67, 82, 85, 95, 99, 116, 117, 143, 151, 163.

BRONCHIAL INFECTION

Acute Bronchitis

By dictionary¹⁵⁵ definition, bronchitis represents inflammation of the bronchi. As a part of the contiguous structures making up the respiratory tract, there is no reason to believe that the bronchi should be immune to infection or inflammation. Unfortunately, the step from histopathologic definition to clinical definition is not an easy one. As with the term *croup*, bronchitis probably encompasses many separate clinical entities. Unlike *croup*, bronchitis lacks the characteristic clinical features to separate it from inflammatory conditions involving other parts of the respiratory tract. In addition, the clinical manifestations are usually not severe enough to warrant additional diagnostic studies or confirmatory testing (e.g., bronchoscopy) in the majority of patients. All these factors have resulted in the inability to create simple, effective clinical definitions. These factors, along with a possible misuse or overuse of the term by physicians and families, have resulted in acute bronchitis becoming a poorly understood diagnosis.

Most commonly, bronchitis is separated into acute, chronic, and recurrent forms. Other classification systems imply airway hyperreactivity (wheezy bronchitis, asthmatic bronchitis, and infectious asthma) or are based in part on the quality of sputum (catarrhal, suppurative, and plastic bronchitis).⁴⁶ With an acknowledgment of the limits of current information, this discussion is aimed primarily at acute infectious bronchitis.

Epidemiology

Data collected from the National Ambulatory Care Survey: 1991 Summary¹⁷² reported that 2,774,000 office visits in children younger than 15 years of age resulted in a diagnosis of bronchitis. Although the report did not separate visits into acute or chronic bronchitis, the frequency of visits made bronchitis just slightly less common than nonsuppurative otitis media and slightly more common than asthma. Bronchitis represented 2.2% of all visits for this age group. The same Chapel Hill pediatric group^{20,76} that studied the incidence of *croup* also collected epidemiologic data on other lower respiratory tract infections, including tracheobronchitis. During the study period from 1966 to 1975, 2200 of 5489 (40.1%) cases of lower respiratory tract disease were classified as tracheobronchitis. In a follow-up report³⁸ from Chapel Hill, tracheobronchitis (34%) continued to be more common than bronchiolitis (29%), pneumonia (23%), and *croup* (15%).

Tracheobronchitis rates were highest during the first 2 years of life, with a combined attack rate of 6.71 in boys and girls of 6.71 per 100 children per year occurring from 1 to 2 years of age.²⁰ Overall, the rate in boys was higher than in girls, with a relative risk of 1.18. In younger children (< 6 years old), the relative risk was even higher (1.27), whereas the effect of gender decreased with age so that boys and girls had virtually equal the attack rates. Data from the United Kingdom also showed the highest attack rates for acute bronchitis in children younger than 5 years old, although no data on gender distribution were available.⁵ Seasonally, tracheobronchitis rates peak in the winter months and have a nadir in the midsummer.^{20,76} Peak months in younger children were January, February, and March and in older children starting 1 month earlier (December, January, and February). The peak months in younger children corresponded primarily to RSV, parainfluenza 1 and 3, and influenza season. Peak times in older children corresponded mostly with influenza or mycoplasma outbreaks and only occasionally during RSV or parainfluenza season. This prevalence in winter and a nadir in August also was reported in the United Kingdom.^{5,6}

Chronic and Recurrent Bronchitis

An in-depth discussion of chronic and recurrent bronchitis is beyond the scope of this article. In data from the Chapel Hill group,²⁰ recurrent episodes of tracheobronchitis made up only 16% of the total 2200 cases (12.3% had two episodes and 3.7% had three or more episodes). Although there are conceptual similarities with spasmodic/recurrent croup, chronic and recurrent bronchitis suffer from some of the same problems in definition and diagnosis as acute bronchitis.

One major diagnostic problem is the considerable overlap between chronic and recurrent bronchitis and childhood asthma. Because of this, early epidemiologic reports^{72,112,154,177} on bronchitis may have included episodes of acute asthma. Several epidemiologic surveys in the United States and United Kingdom have investigated the changing frequency of asthma and bronchitis diagnoses. Rates of both diagnoses increased during an 11-year period (1976–1987) reviewed by the Royal College of General Practitioners and the Communicable Disease Surveillance Centre of the Public Health Laboratory Service.⁶ Based on the simultaneous increases, the authors suggest that the rise in asthma rates in recent years is real and not the result of changes in diagnostic labeling. In contrast, hospitalization discharge rates from 1979 to 1987 collected from the National Hospital Discharge Survey⁷² showed an increase in asthma admissions and a decrease in bronchitis admissions. There has been speculation that recent increases in asthma incidence are the result of more willingness on the part of health care workers to diagnose asthma in children. It has been suggested that primary care physicians may use the diagnosis of bronchitis as a way to avoid labeling a child with asthma.¹⁵⁴

Infection, especially viral, and airway hyperreactivity may play central roles in producing the similar clinical manifestations in all these conditions.^{22,74} Episodes of acute bronchitis in children are primarily viral infections (see following discussion). In addition, viral infections may be responsible for initiating episodes of chronic and recurrent bronchitis. Similarly, there has been increasing interest in documenting the role of viruses in exacerbations of asthma. A recent study⁹⁴ in school-aged children used sophisticated viral detection techniques (e.g., polymerase chain reaction, immunofluorescence, and serology) to determine how often respiratory viral infections accompanied exacerbations of asthma. Of the 108 children who completed the longitudinal study, "common cold viruses" (e.g., rhinovirus and coronavirus) were detected in 80% to 85% of asthma exacerbations. It is possible that chronic and recurrent bronchitis are manifestations of the spectrum of childhood asthma.^{136,178} Therapeutically, because of the possible close relationship of recurrent and chronic bronchitis and asthma, a trial of bronchodilator therapy may be indicated.⁷⁴

Microbiology

The majority of episodes of acute bronchitis in children are thought to be of viral cause. The American Thoracic Society⁴ includes acute tracheobronchitis under the heading of "clinical syndromes of known viral etiology." Cases of bronchitis in the fall mirror the isolation of parainfluenza in the community, whereas the winter rise in bronchitis parallels a rise in RSV and influenza virus.⁶ Of the 2200 cases of tracheobronchitis in the Chapel Hill study,²⁰ an agent was isolated from 515 (23.4%) including viruses and *M. pneumoniae*. Ten patients had two organisms bringing the total number of isolates to 525. Parainfluenza virus (types 1 and 3) was the most commonly isolated (131/525; 30%), followed by influenza (types A and B and untyped) (110/525; 21.0%), RSV (104/525; 19.8%), *M. pneu-*

moniae (95/525; 18.1%) and adenovirus (45/525; 8.6%). Although not reported in the Chapel Hill data, rhinovirus⁸⁷ and measles virus^{22,56} also have been associated with acute bronchitis.⁴⁶ Rhinovirus was reported as the most commonly identified agent in children with recurrent episodes of "acute wheezy bronchitis" in an outpatient clinic representing 24 of 35 isolates (69%) in one study⁸⁷ and 70 of 152 isolates (46.1%) in another study by the same group.⁸⁸ The association of rhinovirus with exacerbations of asthma already has been discussed.⁹⁴ Unlike parainfluenza, influenza, and RSV, rhinoviruses and adenoviruses have shown no seasonal patterns in epidemiologic surveys.⁶

Age of the patient influences the likelihood that a particular agent will be the cause of bronchitis.²⁰ RSV and parainfluenza were the predominant agents in younger children, whereas mycoplasma tended to occur in older children. RSV represented 33% of the isolates in children up to 4 years old, whereas it represented only 2% of the cases in children 12 years and older. Similarly, parainfluenza types 1 and 3 represented 28.5% of isolates in children up to 6 years old and 13.8% in children 12 years and older. Adenovirus also declined in incidence with age. Mycoplasma rates increased with increasing age, whereas influenza rates remained relatively constant throughout all age groups. Mycoplasma and influenza each represented 34.3% of all isolates in children 6 years and older. Showing a propensity for the older-aged children, more than half of mycoplasma isolates (49/95) occurred in children 9 years and older and almost 80% (74/95) occurred in children 6 years and older.

Chlamydia pneumoniae recently has been identified in patients with bronchitis. In an adolescent and adult population from the University of Washington (Seattle, Washington),¹⁶⁶ *C. pneumoniae* was responsible for 4% of cases. *M. pneumoniae* and viral agents (including influenza A and B, RSV, and adenovirus) made up, respectively, 3% and 13% of cases in the same study. The remaining patients (81%) were listed in an unspecified "other" group.

As in bacterial tracheitis, bacterial bronchitis may follow local breaks in the respiratory epithelium, including the effects of primary viral infection.²² Suspected bacterial agents include *S. pneumoniae*, *S. aureus*, *H. influenzae*, and *M. catarrhalis*. A primary bacterial infection can be seen with *Bordetella pertussis* and *Corynebacterium diphtheriae*.²²

Differential Diagnosis

In general, attempts at clinical classification of acute respiratory illnesses is difficult primarily because of the overlap of clinical signs and symptoms. Acute bronchitis, bronchiolitis, and pneumonia in particular may share the same symptom complex, including cough, fever, and wheezing.³⁰ Court³⁰ suggests that dyspnea, rapid respirations, and chest radiographic abnormalities may help distinguish bronchiolitis and pneumonia from bronchitis. A recent study¹⁷³ attempted to compare children who were diagnosed with acute bronchitis, first-time asthma, and URI with cough. A history of sputum production and the presence of rales or rhonchi on examination were associated more commonly with a diagnosis of bronchitis. Each characteristic was present at most in slightly more than one third of patients, however. Both signs were absent in 44% of patients.¹⁷³ In addition to respiratory tract infections and airway hyperreactivity, irritant exposure (e.g., pollution, gastric acid) may mimic acute infectious bronchitis.²²

Clinical Manifestations

Acute bronchitis would appear to lie symptomatically and anatomically between viral URI and pneumonia. In the Chapel Hill report,²⁰ bronchitis (tracheo-

bronchitis) was defined as a "respiratory illness characterized by deep cough and rhonchi audible in the larger airways." Bronchitis is described as an illness that begins with symptoms of a mild viral URI, including fever, rhinitis, and a non-productive cough.^{22,77} The cough progresses to become productive, and older patients may report chest pain.^{4,22,56,77} The cough, typically lasting less than 2 to 3 weeks, is the primary and, at times, only symptom of bronchitis.^{22,77} On auscultation, rhonchi,^{4,20,56,86} wheezing, and "referred breath sounds"⁵⁶ may be detected. One report found wheezing present twice as often (two thirds of cases) in patients diagnosed with bronchitis when compared with bronchiolitis and pneumonia.

Diagnosis

At every step in this discussion, we are confounded by the lack of a clear clinical definition in an illness that is considered a clinical diagnosis.²² The primary care physician's most reliable tools, history and physical examination, are better aimed at ruling out other conditions than in confirming a diagnosis of bronchitis. The primary symptom, cough, is nonspecific,²² pathognomonic physical findings are lacking, and the common screening laboratory tests are nondiagnostic. In the clinic, there is little available to the physician to help localize or quantify the degree of inflammation in the bronchi.

Nonspecific tests to distinguish viral versus bacterial infections (WBC counts and CRP) have been discussed in other sections. Markedly elevated neutrophil counts or CRP could increase the suspicion for a bacterial cause. Viral studies including antigen testing, serology, or cultures from superficial or deep nasopharyngeal specimens may support a specific etiologic agent. Tests for mycoplasma (cold agglutinins \$77; *M. pneumoniae* titers acute and convalescent \$25 each) are widely available, whereas tests for *C. pneumoniae* have limited availability. Bacteria uncommonly are reported causes of acute bronchitis in children, and obtaining suitable specimens for Gram's stain and bacterial culture is difficult in smaller children. In general, nonspecific screening tests (CBC and CRP) along with specific microbiologic studies may not be indicated for the typical case.^{56,60} In addition, results for some tests (e.g., paired sera) may not become available until after the symptoms are expected to have resolved.

The chest radiograph in bronchitis should be normal,^{22,56,77} although peribronchial thickening may be seen.²² Radiographs may be more helpful in ruling out the presence of another lower respiratory tract disease than supporting a diagnosis of bronchitis.⁴

Because it is uncommon that a patient would be ill enough to require hospitalization, fewer still would require bronchoscopy to verify the diagnosis by documenting inflammation of the bronchi. In acute bronchitis, laboratory tests may be indicated in cases unusual in their severity or persistence of symptoms or when epidemiologic factors may suggest a bacterial agent.

Based on the data reviewed, bronchitis is an easy diagnosis to make, but a difficult diagnosis to confirm.

Treatment

As a result of the difficulty in confirming a diagnosis of acute infectious bronchitis, no prospective data exist on the effects of various treatments on outcome in the pediatric age group. Most commonly, simple supportive measures have been advocated.^{16,56} As in other viral respiratory infections, rest, hydration, humidification, and avoidance of environmental irritants (e.g., smoke) are often the

mainstays of therapy.^{47,56,77} The American Academy of Pediatrics³ has advised against the use of cough suppressants (including dextromethorphan and codeine) in individuals with productive cough and only limited use in patients with non-productive cough (e.g., cases with vomiting or marked sleep disturbances). Patients in whom wheezing is a significant component may benefit from bronchodilators.¹⁶ Antiviral agents may be indicated in certain severe cases.⁵⁶

One of the most challenging questions for clinicians is when, if ever, antibiotics are indicated. Based on the epidemiologic data already presented, the large majority of identified infections are viral.²⁰ Patient, family, and physician all may be inclined toward antibiotic administration in someone with a productive cough, however. In addition, *M. pneumoniae* has been identified in older children with acute bronchitis.²⁰ It has been suggested that diagnosing bronchitis may be a method of justifying antibiotic therapy by the physician.¹⁷³ This can help explain why more than 70% of children diagnosed with bronchitis were treated with an antibiotic in one study.¹⁷³ Experts^{16,22,38,56,77} uniformly oppose the use of antibiotics in the usual, uncomplicated case of bronchitis. Only in the minority of cases, when nonviral cause is strongly suspected, should empiric therapy be begun. This may be in cases with "prominent"⁷⁷ or recurrent fever⁵⁶ or in cases in which symptoms persist without improvement for 1⁵⁶ to 2 weeks.^{22,77} Risk of infection with *M. pneumoniae* may be increased in older children and during community outbreaks. Gooch⁷⁷ recommends erythromycin as a "reasonable empirical therapy" when bacterial infection is suspected, although Feigin and Cherry⁵⁶ report that treatment for *M. pneumoniae* will "... usually not show an impressive response." It should be considered that persistent cough may be an indication of airway hyperreactivity rather than bacterial infection or superinfection.

Unfortunately, there is a lack of data on how any therapy (including antibiotics) influences the severity or duration of symptoms in acute bronchitis.

Outcome

Acute bronchitis severe enough to require hospitalization is uncommon when compared with the frequency in which the diagnosis is made. In comparing mean annual attack rates with hospital data in the United Kingdom, the hospitalization rate for acute bronchitis was estimated at less than 0.25%.¹² The authors stated that "acute bronchitis is a common illness managed largely by general practitioners." More specific morbidity and mortality data would require clearer clinical definitions.

Summary

The study of acute bronchitis is limited seriously by the lack of a clinical definition. The diagnosis of an infectious process that primarily is isolated to the bronchi is difficult to confirm in the outpatient clinic. Signs and symptoms as well as typical screening laboratory tests (e.g., CBC and CRP) are nonspecific. More invasive diagnostic procedures (e.g., bronchoscopy) are unreasonable in cases that typically are benign and self-limited. From the data that exist, acute bronchitis is most often the result of a viral infection (e.g., RSV and parainfluenza and influenza viruses). In those patients in whom this diagnosis is made, therefore, the therapy is generally supportive. Antibiotic therapy probably is indicated only in those few cases that are unusually prolonged or severe.

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