Chapter 106: Stridor and Management of Airway Distress in Children

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This chapter discusses how stridor is used to locate the site and cause of airway obstruction in children. The treatment of the more common causes of stridor and airway obstruction is also discussed.

Stridor is the audible result of turbulent airflow. Bernoulli's principle is an aid to understanding stridor and how it can be used diagnostically. Simply put, this principle states that whenever a fluid (gas or liquid) flows over a surface, the pressure exerted on the surface decreases as the velocity of the fluid increases. A common application of this principle is seen in a wing, where the upper surface is more curved than the lower surface (Fig. 106-1). The result is faster flow along the top of the wing, thereby providing relatively greater pressure on the lower surface. The wing then provides lift as a result of the pressure differential.

Stridor may or may not be associated with respiratory distress, and it may emit from more than one site. A common type of audible turbulent airflow is snoring or stertor. This may be associated with a large amount of turbulence or very limited or complete cessation of air flow, but the condition is rapidly reversed by improved tone and increased patency of the nasopharynx and hypopharynx. Stridor, however, is sound emitting from the supraglottis, larynx, or trachea. Its phase during the respiratory cycle and its characteristics can help locate the site of the obstruction.

Supraglottic stridor occurs on inspiration because the corniculate and cuneiform cartilage and the aryepiglottic folds fall into the laryngeal inlet on inspiration. As the velocity of airflow increases through the supraglottis during inspiration, the walls collapse because of the relative negative pressure. As the patient expires, the velocity decreases and the positive pressure of expiration is greater than the Bernoulli effect, causing a patent airway.

Glottic stridor may be inspiratory or expiratory, depending on the lesion. Webs are located primarily in the anterior glottis and are fixed. The stridor in these situations is usually byphasic, but the inspiratory stridor is more prominent because of the greater velocity of airflow during inspiration. If the lesion is a laryngocele or saccular cyst, the obstruction can be intermittent, manifested primarily by stridor during the inspiratory phase.

Subglottic lesions are always fixed an present with biphasic stridor. The inspiratory phase is always more prominent because of greater airflow during the inspiratory phase. Careful listening reveals an expiratory component, but it is not as loud because the flow is less. Placing a stethoscope over the larynx brings out the less prominent expiratory phase.

An intraluminal thoracic tracheal lesion presents as predominantly expiratory stridor because the airway narrows secondary to the positive pressure created during expiration.

History

It is important to assess the urgency of the situation as soon as possible. This process starts with the initial contact with the patient or referring physician. A cursory history allows one to determine whether the distress is new and rapidly progressing and whether there has been any possibility of foreign body ingestion. One should determine whether there have been signs of agitation, cyanosis, or airway distress. Decisions about airway management and immediate intervention have to be made. Preparation for endoscopic evaluation of the stridor must be made even if the chances of intervention are relatively remote.

If the airway distress is not acute and there is no evidence of progression, then it is appropriate to proceed with a more thorough history and physical examination.

The age at the time of onset is an important factor. Stridor during the first 4 to 6 weeks is most likely secondary to laryngomalacia, whereas immediate onset is most likely secondary to vocal cord paralysis or choanal atresia. Croup is unlikely to occur before 6 months of age. Adenotonsillar hypertrophy usually presents at 3 to 8 years. Foreign body obstruction is most likely to be manifested at 1 to 3 years of age. One should always inquire about the chance of foreign body ingestion or aspiration.

Fluctuations in the stridor provide good clues to the site of the obstruction. Stridor that worsens with increased airway demands such as crying, agitation, or feeding may be secondary to laryngomalacia or subglottic hemangioma. If it worsens on sleeping, it is most likely secondary to adenotonsillar hypertrophy or laryngomalacia. If the obstruction is improved with the mouth open or during crying, the obstructive site is most likely secondary to adenoid hypertrophy, choanal atresia, or sinusitis.

A history of the nature of the pregnancy, prematurity, and evidence of respiratory distress at the time of delivery should be obtained. A history of previous intubation is particularly important, and obstruction during the first 3 weeks of life suggests laryngomalacia or congenital subglottic stenosis. Respiratory distress that occurs between 1 and 3 months is likely secondary to subglottic hemangioma. Stridor after extubation may be secondary to subglottic edema or a mucous plug. If the distress occurs several hours later, it is likely secondary to subglottic edema. Distress that starts 2 to 3 weeks after intubation indicates early subglottic stenosis or vocal cord granuloma formation.

Physical Examination

The initial examination should be nonthreatening, with the child in the parent's arms. The examination should not agitate the child if there is significant distress. The history and the degree of airway distress allow one to make a decision about securing the airway.

The respiratory rate is one of the first parameters to be measured. It is most accurately measured with the child at rest. The normal respiratory rate is faster in the neonate and younger child. *Tachypnoea* is an increased rate of respiration, which can occur in children who are anxious or who have high fevers, severe anemia, metabolic acidosis, or respiratory alkalosis. It is also observed in pneumonia, pleural effusions, asthma, and pulmonary edema. *Bradypnea* is a slow respiratory rate, which occurs in children who have metabolic alkalosis,

respiratory acidosis, and some central nervous system disorders.

The rhythm should next be assessed. The rate should be assessed for periodicity and apnea. *Cheyne-Stokes respiration* is a waxing and waning of the depth of respiration with periods of apnea. This pattern is observed most frequently in association with congestive heart failure, cerebral injury, and increased intracranial pressure.

One should also assess the ease of respiration. A normal child breathes effortlessly, a state known as *eupnea.* If it is easier for the child to breath sitting up, the condition is known as *orthopnea;* if difficulty occurs in all positions, it is known as *dyspnea.*

The degree of airway obstruction can be assessed from several feet away with the child in the parent's arms. Specific features that indicate respiratory distress include head movements with respiration (head bobbing), nasal flaring on inspiration, and circumoral pallor. If the shirt can be easily removed, the patient can be examined for intercostal or supraclavicular retractions. Asymmetric inspiration indicates possible obstruction of one mainstem bronchus. The side having the obstruction may be underinflated in the presence of complete obstruction or overinflated in the presence of a ball valve obstruction. Paradoxic movement of the thorax occurs when one side moves out of phase with the other.

If these conditions are present and there is a history of progressive distress, airway intervention will be required in the near future and preparations should be started immediately with this goal in mind.

Agitation should be interpreted as a sign of hypoxia and treated with oxygen as an initial step. If the patient improves, this should not be interpreted as adequate treatment but as an indication for securing the airway. Cyanosis is a very late sign, and one should never wait for its appearance before securing the airway.

The chest is auscultated to evaluate for asymmetry, wheezing, and audible clicks and to locate the site of greatest intensity. If the child can cooperate, the mandible should be gently pulled forward. If there is an improvement in the stridor, it will likely be caused by a lesion in the oral cavity or hypopharynx. Placing the child in the prone position allows the pharyngeal soft tissues to fall away from the larynx and tends to decrease the stridor in laryngomalacia. A tongue blade can be used to examine the oropharynx, however, in children with suspected supraglottitis, this procedure should be rarely used. This issue is discussed in greater detail in the section on management.

Ancillary Examinations

If the patient manifests progressive airway distress, there are no test results that should deter one from securing the airway. It would therefore not be appropriate in such a case to order lateral films of the neck, fluoroscopy, arterial blood gases, and so on.

If the patient is deemed stable, anterior-posterior and lateral radiography of the neck would be useful. The study should be performed in the emergency room or as a second alternative in the radiology suite, in the presence of personnel and instrumentation capable of treating an acute airway problem. Once the study is obtained, the patient is accompanied

by staff capable of managing the airway. The radiograph result obviously requires immediate interpretation and communication to the treating physician.

The hallmarks of supraglottitis are an edematous epiglottis and arytenoid cartilage, best seen on lateral projections (Fig. 106-2). Croup, however, presents with a narrowing of the subglottis, which is most readily observed on the anterior-posterior projection (Fig. 106-3). A paralyzed true vocal cord may also yield findings similar to subglottic masses (Fig. 106-4).

Blood analysis, such as evaluation of arterial blood gases, hematocrits, and complete blood counts, adds little to the decision-making process of securing the airway. The risks outweigh the benefits in ordering these studies.

Differential Diagnosis

There is a relatively limited number of lesions that produce stridor and acute airway distress. The most common presentation is with croup or supraglottitis. Other lesions that must be considered are foreign bodies of the larynx or trachea, spasmodic croup, bacterial tracheitis, and recurrent papillomatosis. Details on diagnosis are given in the discussions of each disease.

Mauro et al (1988) found on physical examination that drooling, absence of spontaneous cough, and agitation were particularly diagnostic of supraglottitis. However, they recommended examining the airway with a tongue blade or with a laryngoscope with the patient in the sitting or supine position. This method of examination did not take place in situations where there was adequate instrumentation available to secure the airway, and in this author's opinion the procedure described should be condemned because of the risk. As Dr. Bailey rightfully indicates, "This is a disease that kills, and I believe that rigid endoscopes and the experienced personnel in an operating room may be absolutely essential in some instances, however rare they may be" (Bailey and Paparella, 1989).

Causes of Stridor and Airway Obstruction

Croup

Croup is characterized by a louder inspiratory stridor and less prominent expiratory stridor of varying degrees for respiratory distress, cough, and hoarseness. Croup is the most common inflammatory disorder of the airway and is primarily of viral origin. Parainfluenza and influenza viruses types A and B are the most frequently implicated pathogens (Baugh and Gilmore, 1986). Respiratory syncytial virus (RSV), adenoviruses, Coxsackie virus A, enteric cytopathogenic human organ (ECHO) virus, and measles virus account for smaller proportions of the cases. Parainfluenza-induced croup, especially type 1, occurs in clusters in the spring and fall in 1- to 3-year-olds (Baugh and Gilmore, 1986). The age range for croup, 6 months to 2 years, is fairly narrow. Croup in a child less than 6 months of age with no history of intubation should be considered congenital subglottic stenosis until proved otherwise.

The clinical picture is usually that of low to moderate fever with varying degrees of respiratory distress. The distress is progressive but slow compared to supraglottitis. If there is stridor at rest, retraction, restlessness, or respiratory rate greater than 30, hospital admission

is mandatory to observe the airway. These children will be comfortable lying on the side or back, whereas children with supraglottitis can rarely lie down without a significant increase in stridor and respiratory distress.

The management of croup consists primarily of maintaining adequate hydration and providing cool humidification through a mist tent in an effort to keep the ciliary activity functioning. The use of nebulized racemic epinephrine (2.25% solution) is generally accepted but requires observation in the hospital for possible rebound (Postma et al, 1984). One-half milliliter (0.5 mL) of 2.25% racemic epinephrine solution is diluted in 2 mL physiologic saline solution for this purpose. Side effects include tachycardia, hypertension, and occasionally arrhythmia; therefore, this should be cautiously used in children with a history of heart problems.

Low and high doses of steroids have been used for croup, but the results are equivocal. Koren et al (1983) used 0.6 mg/kg dexamethasone in a single dose, which showed a significant effect only in spasmodic croup. If an adequate dose (1 to 1.5 mg/kg to a maximum dose of 30 mg) is given initially, the maximum effect is observed 4 to 6 hours after administration (Postma et al, 1984). Postma recommended steroids (1 to 1.5 mg/kg) for all patients with croup severe enough to warrant treatment with racemic epinephrine. Antibiotics (ampicillin 100 mg/kg/day or amoxicillin 40 mg/kg/day in divided doses) should be considered for patients with symptoms lasting more than 48 hours. Airway intervention is required in 6% to 10% of patients. Recently intubation has been used more frequently than tracheotomy (Gonzalez et al, 1986). The duration of the intubation is 3 to 5 days unless the child has a complicated course. Intubation has been found acceptable by some authors (Clark et al, 1983; Diaz, 1985), but there is cause for concern, since the tube is placed through an already narrowed subglottis. A more thorough discussion of the issues involved can be found in the section on airway management.

Spasmodic croup is most likely a variant of viral croup and is characterized by a sudden onset, usually during sleep, associated with sudden respiratory distress. The symptoms may be recurrent and commonly occur in children between 1 and 3 years old. Cold, humid air is helpful, and the symptoms may resolve as quickly as they occur. Steroids have been helpful in the treatment of this entity (Koren et al, 1983).

Supraglottitis

Supraglottitis affects children 2 to 6 years of age most frequently but can occur in children as young as 6 months and in adults. This condition and infection is usually secondary to *Haemophilus influenzae* type B. The inflammation affects the epiglottis, aryepiglottic folds, and cuneiform and corniculate cartilages. Occasionally *staphylococcus* and group A beta-hemolytic *Streptococcus* are implicated (Lacroix et al, 1986).

Supraglottitis is diagnosed by direct laryngoscopy, preferably in the operating room, and one must have a high index of suspicion. The symptoms are not as clear-cut as those of croup. Most children are toxic, with elevated temperature and increased pulse and respiratory rate. The inspiratory stridor is exacerbated by the supine position or by anything that causes an increase in respiratory effort. Dysphagia, odynophagia, and mild inspiratory stridor rapidly progress to drooling and severe inspiratory stridor with a muffled but clear voice. As the

disease progresses, there is marked inspiratory stridor, and supraclavicular, intercostal, and substernal retractions begin. At its full manifestation, the child sits erect with the chin forward, showing anxiety, increasing exhaustion, drooling, and air hunger. The chin is thrust forward with the neck hyperextended and the tongue protruding to help maintain the airway. At earlier stages, lateral films show the thrust tongue, but this is not diagnostic of supraglottitis (Fig. 106-2). Radiographs are used to confirm the diagnosis only if the patient is in no distress and there is some question about the correct diagnosis. The most important differential possibilities are croup and foreign bodies of the hypopharynx, upper cervical esophagus, larynx, and trachea. Supraglottitis is demonstrated radiographically by swelling and rounding of the epiglottis with thickening and bulging of the aryepiglottic folds (Fig. 106-2).

The appropriate method of making the diagnosis and treating the patient acutely is through direct examination of the larynx and intubation to secure the airway. The mucosa occasionally appears desquamated and ulcerated and on rare occasions may slough. Blood culture results are positive in most patients (Gonzalez et al, 1986). This disease tends to occur more frequently in winter and spring.

Controversy about the use of intubation versus tracheotomy in securing the airway continues. A factor that should be taken into account is the relatively short amount of time the patient will require airway maintenance. The hospital setting and the surgeon's experience most appropriately dictate which treatment is used. Various published reports give similar mortality rates of 0% to 1% for both methods of treatment. If the hospital is *not* equipped to handle a tenuous pediatric airway in an intensive care unit, then a tracheotomy may be the most appropriate method of securing the airway. If the child is intubated, it is important to maintain sedation to prevent self-extubation and to limit laryngeal trauma secondary to the endotracheal tube.

Administration of antibiotics is started in the operating room after the blood and surface cultures have been taken. The blood cultures yield positive findings in 50% to 86% of children (Lepow and Hetherington, 1990). Ampicillin and chloramphenicol are used to cover both resistant and nonresistant strains of *H. influenzae.* Recently cefuroxime and ampicillin have been recommended because of the emergence of strains resistant to chloramphenicol (Marks et al, 1986). If there are household contacts younger than 4 years of age, the entire family should receive rifampin prophylaxis (20 mg/kg/day for 4 days to a maximum of 600 mg) and the ill child should be treated before returning home (Peter et al, 1991). Frequently within 36 to 48 hours the infant's temperature has returned to normal and extubation is possible.

Bacterial tracheitis

Bacterial tracheitis is an acute upper airway infection characterized by subglottic edema and purulent tracheal secretions (Friedman et al, 1985). The clinical features are intermediate between those of croup and supraglottitis and may develop as a secondary bacterial infection in patients with croup (Friedman et al, 1985; Mahajan et al, 1985; Sofer et al, 1983). The symptoms include croup-like stridor, barking cough, and hoarseness that progress over 2 to 3 days. The patient usually has a high-grade temperature and is toxic. Securing of the airway with an endotracheal tube and frequent suctioning are usually required.

Many patients require tracheotomy (Donaldson and Maltby, 1989; Donnelly et al, 1990; Weinberg et al, 1984). Not infrequently the airway distress is secondary to inspissation of the purulent secretions, which require removal with foreign body forceps. Deaths have occurred secondary to airway obstruction. The cultures most frequently yield *Staphylococcus aureus* but may also yield *H. influenzae* type B, group A *Streptococcus,* and *Neisseria* species (Donnelly et al, 1990; Friedman et al, 1985; Liston et al, 1983; Mahajan et al, 1985; Sofer et al, 1983). Medical therapy should be directed to coverage of these bacteria.

Papilloma

Recurrent papilloma may present acutely with respiratory distress. There is usually a long history of hoarseness with progressive airway distress of 1 week's duration. The airway obstruction may suddenly become worse with an upper respiratory tract infection. The only way to make the diagnosis definitively is through direct laryngoscopy and biopsy of the tissue. The initial treatment is to remove the papilloma with biopsy forceps or preferably with the laser after the biopsy has been performed. Papilloma frequently recurs, but once the diagnosis has been made, subsequent episodes are easier to diagnose.

Foreign bodies

Tracheal and laryngeal foreign bodies are rare but life-threatening. They must be promptly diagnosed and removed endoscopically. The techniques for foreign body removal are beyond the scope of this chapter; the reader is referred to Chapter 132.

Airway Management

As a general principle, securing the airway should take place at the most opportune time under ideal circumstances, that is, in the operating room. As already noted, the physical examination is performed in a nonthreatening manner. Within a few minutes it is possible to assess the need to intervene in the near future. Agitation, lethargy, cyanosis, and significant respiratory distress are indications that the airway will probably have to be secured. Once this decision is made, there is no need to do anything but proceed to the operating room for an orderly intubation. The patient is transported with oxygen and a mask for positive pressure. The appropriate equipment and physicians for intubation must accompany the patient to the operating room. Radiographic and laboratory evaluations waste valuable time and put the patient at increased risk.

If the airway is acutely compromised, one can buy time with positive pressure even in the most compromised situation. As a general rule, a patient who struggles with the mask and positive pressure probably does not need them. It is best to blow by humidified oxygen as preparations are made to go to the operating room. If the positive pressure is helpful, the patient will not resist the mask and becomes quieter.

The operating room is then called with information about the patient and the equipment necessary for intubation. During transportation the room and the bronchoscopes are set up. A calm approach to the patient is essential, and the parents should remain in constant contact with the child.

Once in the operating suite, judgment will have to be used about whether to proceed directly into the operating room or to change into proper operating room clothing. If the patient becomes agitated during separation from the parents, then the parents should accompany the child into the operating room.

One of the first tasks of the surgeon in the operating room is to check the equipment to be used for intubation and bronchoscopy. This must be done regardless of the urgency of the situation. It cannot be overemphasized that this is the surgeon's responsibility, and if not properly set up, the equipment will fail just when it is needed most.

If the patient's airway worsens on reclining, then the induction should take place in the sitting position. No intravenous lines are inserted and no blood gases or blood are drawn before or during the initial stages of induction. Once the child has started to lose consciousness, the parents should be escorted from the operating room and reassured that the child will be managed appropriately. It is preferable that parents not stay in the operating room while the child enters stage II because as the airway become more difficult to manage, the patient's apprehension (and that of those in the operating room) will increase.

The airway must be secured in an efficient manner. If the airway becomes obstructed, the person with the most experience should intubate the patient. This may be the otolaryngologist or the anesthesiologist. Obviously the situation will be calmer if the roles have been defined before induction. There is always time to discuss the plan and how the patient should be anesthetized, although urgency may require that this take place in the operating room while the patient is being transferred to the table.

Proper general anesthesia and intubation techniques are crucial to a successful outcome. Several protocols are available for induction:

Inhalation

Halothane (1.5% to 2.0%) + oxygen
Halothane (1.5% to 2.0%) + nitrous oxide + oxygen 50%

Intravenous and inhalation

Diazepam (0.2 mg/kg) + halothane (1.5% to 2.0%) + oxygen
Ketamine hydrochloride (1 to 2 mg/kg) + halothane (1% to 2%) + oxygen

Intravenous and muscle relaxants

Thiopentone (5 mg/kg) + succinylcholine 1 mg/kg
Diazepam (0.4 mg/kg) + succinylcholine 1 mg/kg

Awake intubation

4% Topical cocaine anesthesia.

Currently, inhalation techniques without nitrous oxide or muscle relaxants are preferred for all patients with respiratory distress. Preoxygenation is followed by rapid halothane and high-oxygen-concentration induction. The induction will be prolonged because of the airway distress and decreased flow of oxygen and anesthetic agents. The most frequent error is to manipulate the airway when the child is not in a deep enough plane of anesthesia. If the patient is only lightly anesthetized, the chances of laryngospasm are increased. It is advisable to give the patient atropine before airway manipulation in an effort to decrease the vagal response. Patience and positive pressure are the keys to successful management of the obstructed airway during stage II of induction. The airway will be much easier to manage as the patient enters the deeper planes of anesthesia. If the airway cannot be managed and the patient's airway becomes obstructed, it is safest to intubate with a rigid bronchoscope. The airway should *not* be manipulated until the patient is deeply anesthetized, preferably apneic. A common error is to examine the airway before the child is deeply anesthetized, causing laryngospasm. The airway is secured with an endotracheal tube or bronchoscope under direct visualization in controlled circumstances.

A nasotracheal tube is more stable than an oral tube, so most surgeons perform nasal intubation after the airway is secured with the bronchoscope or oral intubation (Crockett et al, 1988).

Judgment is required in assessing the appropriate time to extubate the patient. As a general rule children with croup require 4 to 5 days of intubation and children with supraglottitis require approximately 48 hours of intubation. An afebrile patient who has supraglottitis can most likely be extubated. Some authors believe that an adequate air leak is sign of decreased edema and extubation is possible (Crockett et al, 1988). Extubation can be performed in the operating room or in the intensive care unit. It is a matter of judgment in the individual case whether the epiglottis should be examined before extubation. Gonzalez et al (1986) found that daily visualization of the airway decreased the length of time for intubation from an average of 65 hours to 47 hours. The keys to determining when the patient can be extubated are a visible cartilaginous edge of the epiglottis and subsiding of the vocal cord and aryepiglottic fold edema.

As a general rule, the appropriate management of acute airway obstruction requires a combination of good diagnostic skills, experience, and appropriate instrumentation. Each is required for a successful outcome.