

Part XV: Paediatric Intensive Care

Chapter 96: Upper Airway Obstruction in Children

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Upper respiratory tract obstruction (URTO) is a common cause of respiratory failure in infants and children. This reflects the frequency of disorders affecting the upper respiratory tract, the presence of narrow airways, and the compliant nature of the chest wall. The majority of children with critical airway obstruction are otherwise healthy, and expert management results in a normal life expectancy. Improper management has dire consequences for the child, parents and staff.

Pathophysiology

Although the ratio of airway diameter:body weight is relatively large in the infant, in absolute terms, airway diameter is small, and a minimal reduction in diameter causes a devastating increase in airway resistance. For example, the diameter of the newborn's cricoid ring is 3 mm. A 50% reduction in airway radius will result in turbulent flow and increase the pressure (and work) required to maintain breathing by 32 times.

Symptoms and signs vary with the level of obstruction, the aetiology of the lesions and the age of the child. Airway obstruction may be either extrathoracic or intrathoracic. Extrathoracic obstruction increases during inspiration and is characterized by inspiratory stridor. Intrathoracic obstruction of both large and small airways increases during expiration and is characterized by expiratory stridor, wheeze and air trapping. These features reflect the intrapleural and airway pressure changes of the respiratory cycle. Retraction of the chest wall reflects the negative intrapleural pressures generated and the compliant nature of the chest wall. Large negative intrapleural pressures are also transmitted to the interstitium of the lung and may result in pulmonary oedema. Cor pulmonale may develop secondary to chronic obstruction, hypoxia and pulmonary hypertension.

Clinical Presentation

Stridor is the cardinal feature of URTO. Parents complain that their child has "noisy breathing" and is "sucking its chest in". The pitch and timing of stridor provides information about the degree and level of obstruction.

Voice sounds may also be informative. Nasal obstruction results in hyponasality. Oropharyngeal obstruction may cause "hot potato" voice. Supraglottic obstruction is characterized by muffled voice. Children with glottic lesions may be aphonic or have a harsh quality to the voice.

Retraction of chest wall develops as obstruction progresses. Retraction is a less prominent feature in older children as chest wall structure stabilizes. As obstruction worsens, work of breathing increases and the *accessory muscles* become active. The *alae nasi* (vestigial muscles of ventilation) begin to flare. Fever increases minute volume and magnifies any degree of obstruction. Whereas infants and older children can maintain an increased work

of breathing, premature infants and neonates rapidly fatigue and many respond to increased load by the development of *apnoeic episodes*.

Auscultation over the neck and larynx may identify the site of obstruction. A foreign body in the airway may produce a mechanical or slapping sound. Decreased or absent breath sounds may occur with greater degrees of obstruction.

Chronic URTO is a cause of *failure to thrive, chest deformity* (pectus excavatum) and *cor pulmonale*. Some infants present with *recurrent chest infections*, and *abnormal posturing* (head retractions) may be a feature.

Initially, the child with airway obstructin exhibits tachypnoea and tachycardia. If obstruction is severe and persistent, exhaustion eventually occurs and the child develops bradycardia, bradypnoea, cyanosis and respiratory failure.

Aetiology

Common causes of URTO are listed in Table 1. The neonatal causes are predominantly due to congenital structural lesions. Acute inflammatory lesions, foreign bodies and trauma predominates in older infants and children. The more common lesions are discussed in detail below.

Table 1. *Causes of Upper Airway Obstruction in Children*

Level	Newborn	Older Infant and Child
Nasal	Choanal atresia	
Oro-Pharyngeal	Pierre Robin syndrome Thyroglossal cyst Vallecular cyst	Macroglossia Retropharyngeal absces Enlarged tonsils Obstructive sleep apnoea
Laryngeal	"Infantile larynx" Vocal cord palsy Subglottic haemangioma Laryngeal web Laryngeal cysts	A c u t e l a r y n g o - tracheobronchitis (croup) Bacterial tracheitis Acute epiglottitis Post-intubation oedema and stenosis Laryngeal papillomata Laryngeal foreign body Inhalation burns Caustic ingestion
Tracheal	Tracheomalacia Vascular ring	Foreign body

Diagnosis

The cause of URTO can often be determined from hstory and clinical features. Radiographic examination of the upper and lower airways with anteroposterior and lateral

views may provide useful information about soft tissue swelling or the presence of foreign bodies. In the presence of respiratory distress, these should be performed in the ICU rather than the radiology department.

In the past, barium swallow and aortography have been used to confirm the diagnosis of vascular compression of the trachea. Computed tomography (CT) has assumed importance in the assessment of fixed lesions such as intrinsic stenosis and extrinsic compression. Magnetic resonance imaging (MRI) and CT with contrast are useful in the assessment of vascular anomalies. Tracheobronchography may provide excellent anatomical delineation of the proximal tracheobronchial tree.

Direct visualization of the airway may be necessary and may also prove therapeutic (eg, removal of a foreign body). Nasoscopy, flexible fiberoptic bronchoscopy and rigid laryngoscopy, tracheoscopy and bronchoscopy all have a place in assessment of the paediatric airway. Investigation of the child's airway should only be carried out in specialized centres by experienced endoscopists, radiologist and anaesthetists.

Blood gas determination is rarely used and it is dangerous practice to await respiratory failure before intervention.

Specific Airway Obstructions

Epiglottitis

Epiglottitis is a life-threatening lesion caused almost exclusively by *Haemophilus influenzae* type B. Some cases are caused by streptococci, staphylococci or pneumococci. The diagnosis is usually obvious from history and clinical features. There is an acute onset of high fever, toxemia and noisy breathing. The child adopts a characteristic posture, preferring to sit with mouth open, drooling saliva. Cough is usually absent. These features are the legacy of an intensely painful pharynx. Due to the accompanying septicaemia, the severity of illness often appears out of proportion to the degree of airway obstruction. Typically, a low-pitched inspiratory stridor is present accompanied by an expiratory snore.

Sudden total obstruction is not infrequent and may be precipitated by examination of the pharynx, the supine position or stressful procedures (eg, intravenous cannula insertion). When the diagnosis is in doubt, lateral X-rays of the neck in the sitting position should be taken in the ICU. Examination of the pharynx must not be undertaken unless both personnel and facilities are available for immediate intubation.

Management

1. Parenteral Antibiotics

Until recently, ampicillin (200 mg/kg/day) or chloramphenicol (100 mg/kg/day) have been the antibiotics of choice. The emergence of resistant strains of *Haemophilus* has led to increased use of cefotaxime (200 mg/kg/day).

2. Relief of Airway Obstruction

All but the mildest cases require an artificial airway. Nasotracheal intubation is the optimal treatment but tracheostomy is a satisfactory alternative, depending on the available personnel. Anaesthesia for relief of airway obstruction is described below. A tube of size appropriate to age is chosen. (See Chapter 101, Equipment for Paediatric Intensive Care.) Extubation can be undertaken when the temperature falls and the child no longer appears ill. Most can be extubated in less than 18 h. Only cases complicated by pulmonary oedema, pneumonia or cerebral hypoxia will require intubation for longer than 24 h. It is not necessary to re-examine the larynx prior to extubation. Racemic adrenaline is of no benefit in this condition. Pulmonary oedema, when it occurs, is due to airway obstruction, septicaemia and increased capillary permeability. It is managed according to standard principles.

Croup

Croup or acute laryngotracheobronchitis is due to inflammation and oedema of the glottic and subglottic regions. The narrowest part of the upper airway of the child is the subglottic region, and this is the point at which critical narrowing occurs. Retained secretions due to the bronchitic component may compound the obstruction. Three subgroups are recognized:

1. Viral Croup

Viral croup, due to *para-influenza viruses* and occasionally *respiratory syncytial virus* (RSV), *rhinovirus* and measles, is characterized by a coryzal prodrome, low grade fever, a harsh barking (croupy) cough and hoarse voice. The progression of airway obstruction in severe cases is presented in Figure 2.

2. Spasmodic Croup

Spasmodic or recurrent croup occurs in children with an allergic predisposition. It usually develops suddenly, often at night and without prodromal symptoms. Endoscopy reveals pale watery oedema of the subglottic mucosa. Such children probably represent part of the asthma spectrum and wheeze may be a feature.

3. Bacterial Tracheitis

Bacterial tracheitis is uncommon but should be suspected in the presence of high fever, leucocytosis and copious purulent secretions. There is a significant risk of sudden complete obstruction with these children. *Staph. aureus* is usually identified as the cause, although *H. influenzae* and group A *Streptococcus* have also been isolated.

Croup is uncommon under 6 months of age, and is suggestive of an underlying structural lesion such as subglottic stenosis or haemangioma with super-imposed infection. Endoscopy is warranted with a prior history of stridor or with persistent symptoms.

Management

1. Minimal Disturbance

Minimal disturbance is important as handling will increase minute ventilation, oxygen consumption and signs of obstruction.

2. Adequate Hydration

Oral fluid intake must be encouraged to avoid dehydration. Gavage feeding is contraindicated and occasionally IV fluids will be necessary. In view of the propensity for pulmonary oedema, overhydration must also be avoided. Hyponatraemia and convulsions due to inappropriate antidiuretic hormone secretion have been observed in airway obstruction.

3. Oxygen Therapy

Oxygen therapy may mask the signs of respiratory failure but should be given to prevent hypoxaemia. Its use can be guided by pulse oximetry (ie, keep oxygen saturation greater than 90%). The mode of administration may stress the small child. The need for oxygen therapy is often an indication for intubation.

4. Corticosteroids

Controversy remains over their efficacy in uncomplicated croup. They appear to be beneficial in spasmodic croup. A trial of steroids may be considered in cases refractory to extubation but they are not routinely recommended.

5. Humidification

Humidification of inspired gases has been the mainstay of supportive care for decades. Controlled studies showing efficacy are lacking. A recent study failed to demonstrate benefit and its use has been abandoned in many centres.

6. Nebulized Racemic Adrenaline

Nebulized racemic adrenaline (a 2.25% solution, ie, 1:88 L-adrenaline) will often provide at least temporary relief of acute obstruction. Indications for racemic adrenaline nebulization are:

(a) Acute laryngotracheobronchitis, where relief usually lasts 1-2 h, but may be longer if secretions are expelled. It is debatable whether the natural history of the disease is altered. If given prior to induction, it will facilitate inhalational anaesthesia for intubation.

(b) Spasmodic croup where one or two inhalations may obviate the need for intubation.

(c) Post endoscopy or intubation oedema where the benefit is often dramatic.

(d) Transport, where administration will render the child safe for interhospital transfer.

The empirical dose is 0.05 mL/kg of racemic adrenaline diluted to 2 mL with saline and nebulized with oxygen. It is possibly more effective when administered by intermittent positive pressure breathing, although this may be more distressing to the child. It should be noted that the same mass of L-adrenaline is provided by 0.05 mL/kg of the standard 1:1000 solution of adrenaline and that this is equally effective.

7. Antibiotics

Antibiotics are indicated only for bacterial tracheitis where anti-staphylococcal cover is recommended.

8. Mechanical Relief of Airway Obstruction

Mechanical relief of airway obstruction is required in 2-5% of cases. The need for intubation is indicated by increasing tachycardia, tachypnoea and restlessness. An oxygen saturation persistently less than 90% is a further reason for concern. One should not wait for the development of bradycardia, bradypnoea, cyanosis, exhaustion and respiratory failure. Blood gases are not a useful guide.

Nasotracheal intubation is the preferred technique. An orotracheal tube is first inserted under anaesthesia (see below) and the use of a stylet is important to overcome the resistance of the subglottic region. The appropriate endotracheal tube size is one with an internal diameter 1 mm less than that predicted by age (Table 2). The tube is changed to a nasotracheal tube immediately after aspiration of secretions. Subsequent care of the endotracheal tube is described below.

Extubation is performed when the child is afebrile, secretions are diminished, and a leak is audible around the tube with coughing or positive pressure. The duration of intubation averages 5 days. Children less than 1 year of age have a higher incidence of needing intubation and a longer duration of intubation. Reintubation may be required in some cases. Tracheostomy is suitable alternative for some situations although the complications are more significant.

Table 2. *Nasotracheal Tube Size in Croup*

Less than 6 months	3.0 mm
6 months to 2 years	3.5 mm
2 years to 5 years	4.0 mm
Over 5 years	4.5 mm.

Other Supraglottic Lesions

Retropharyngeal abscess, tonsillitis, peritonsillar abscess, infectious mononucleosis and Ludwig's angina may all mimic the other important supraglottic inflammatory lesion, epiglottitis. Local features will usually provide the diagnosis. A retropharyngeal abscess can be detected by palpation and is obvious on a lateral X-ray of the neck.

Airway relief, antibiotics, drainage, and, rarely, neck incision form the basis of treatment for these disorders. Tonsillectomy is occasionally indicated.

Tonsillar and Adenoid Airway Obstruction

The conservative approach to tonsillectomy and adenoidectomy has led to increased hypertrophy and chronic upper airway obstruction in some children. Such children may present with severe, acute exacerbation due to intercurrent infection, eg, tonsillitis. They may present in a toxic state with drooling, thereby mimicking acute epiglottitis. Obstruction is more marked during sleep. In the most severe cases, it may be necessary to relieve the obstruction with a nasotracheal tube or a nasopharyngeal tube passed beyond the tonsillar bed. Tonsillectomy and adenoidectomy is generally contraindicated in the acute phase because of the increased risk of bleeding, but is performed when the infection has settled.

Obstructive Sleep Apnoea Syndrome

Obstructive sleep apnoea syndrome (OSA) is characterized by intermittent upper airway obstruction during sleep with heavy snoring, stertorous breathing and an abnormal, irregular respiratory pattern. Frequent episodes of chest wall motion with inadequate airflow (hypopnoea) or absent airflow (obstructive apnoea) are a feature. Polysomnography reveals that these episodes are most frequent during rapid eye movement (REM) sleep. They are accompanied by variable degrees of oxygen desaturation. OSA may be associated with enlarged tonsils and adenoids, a large uvula or long soft palate, macroglossia, retrognathia or various neurological disorders. Obesity is a common finding.

If OSA is severe and protracted, cardiac and pulmonary decompensation may occur. Chronic hypoxia and hypercarbia lead to pulmonary hypertension and cor pulmonale. There may also be evidence of left ventricular failure and pulmonary oedema. The urgency of treatment is dictated by the mode of presentation. Critically ill children may require immediate relief of airway obstruction (nasopharyngeal or nasotracheal tube), oxygen therapy, diuretics and digitalization. Antibiotics are indicated if there is evidence of bacterial superinfection.

Surgical intervention is required after stabilization. Tonsillectomy and adenoidectomy is often dramatically beneficial. Even when not grossly enlarged, they are best removed. Other surgical procedures such as uvulopalatopharyngoplasty or tracheostomy may be required when this fails. The use of nocturnal CPAP or nasopharyngeal intubation is rarely feasible in young children.

Pierre Robin Syndrome

This consists of a posterior cleft palate, retrognathia and relative macroglossia. It is a cause of airway obstruction, feeding difficulties and failure to thrive in the newborn period. Differential growth eventually reduces the significance of the deformity. Acute airway obstruction may be relieved by nursing the infant in the prone position or by passage of a nasopharyngeal tube. Occasionally, nasotracheal intubation or tracheostomy is required. Tongue-lip anastomosis is sometimes beneficial.

Burns

Direct airway burns or inhalation of products of combustion may lead to rapidly progressive oedema. Mechanical relief of airway obstruction should be undertaken early to prevent an emergency situation from developing.

Subglottic Stenosis

Neonates with congenital subglottic stenosis may present with severe obstruction requiring intubation at birth. Other infants present with persistent stridor or recurrent croup due to superimposed infection. Subglottic stenosis is also a complication of intubation and reflects mucosal ischaemia and healing by fibrosis. Intermittent intubation, prolonged tracheostomy or various surgical techniques may be indicated.

Subglottic Haemangioma

These lesions often present in the second or third month of life and owe their importance to the anatomical location. Stridor is usually both inspiratory and expiratory. A hoarse cry is indicative of vocal cord involvement. Obstruction may be severe and is aggravated by crying, struggling or superimposed infection. Cutaneous haemangiomas occur in 50% of cases and provide a clue to diagnosis. Definitive diagnosis rests on bronchoscopy. The natural history is of spontaneous resolution between the first and second years of life. Meanwhile, tracheostomy or repeated intubation may be indicated to cover periods of obstruction. Encouraging results are being obtained with laser surgery. Steroids are of dubious benefit.

Foreign Body or Choking

A foreign body must be suspected in any acute obstruction occurring in an infant or child between 6 months and 2 years of age. A foreign body lodged in the pharynx results in gagging, respiratory distress and facial congestion. Laryngeal impaction usually produces stridor, a distressing cough and aphonia. Sudden total obstruction may occur. Symptoms usually develop while the child is playing or eating.

The technique for removal of a pharyngo-laryngeal foreign body without equipment in infants and children is controversial and difficult. The American Academy of Paediatrics has made recommendations to cover various ages. Gravity should be employed by placing the child prone, straddled over your arm with the head down and a hand supporting the jaw. Four backblows between the shoulder blades should be administered. If this fails chest thrusts or finger sweep across the pharynx should be attempted. There is a risk that this latter manoeuvre may impact the foreign body in the larynx. Abdominal thrusts (the Heimlich manoeuvre) are not recommended in infants but may be useful in children older than 1 year of age. Expired air resuscitation should also be tried in an emergency although the risk of gastric distension is great. The best method of removal is extraction under direct vision using a laryngoscope, forceps, suction or finger.

Tracheal or bronchial foreign bodies produce persistent cough and wheeze and recurrent pneumonia. A foreign body lodged in the upper oesophagus may compress the

trachea and present with either acute or more commonly persistent stridor. Radiopaque materials are easily shown radiologically, although both anteroposterior and lateral views may be necessary. Barium studies may prove useful for non-radiopaque material in the oesophagus. The treatment is removal at bronchoscopy or oesophagoscopy.

Anaesthesia for Relief of Airway Obstruction

Inhalational induction and anaesthesia with oxygen and halothane is the preferred technique for intubation. The use of muscle relaxants is hazardous where a doubt exists about the ability to maintain a patent airway. The important points are as follows:

1. A prepared induction should be undertaken with efficient suction apparatus and suction catheters, a range of endotracheal tubes and suitable stylets. One must be prepared to intubate without anaesthesia if sudden obstruction occurs.
2. Inhalational anaesthesia is slow in the presence of upper airway obstruction and lower airways disease.
3. Induction in the sitting position is advocated with epiglottitis. The child is laid flat after induction and prior to intubation.
4. Continuous positive airway pressure or assisted ventilation will reduce obstruction and hasten induction. Care is taken not to distend the stomach.
5. Laryngoscopy is performed and the child intubated only when adequate depth of anaesthesia is achieved (approximately 8-10 minutes of 4% halothane in oxygen).
6. Orotracheal intubation is quickest and safest and should be performed in the first instance. After good tracheal toilet, the tube is changed to a nasotracheal one.

Care of Nasotracheal Tube

Optimal care is crucial to the successful use of nasotracheal intubation in the management of URTO in children. Such children must always be nursed in an ICU.

The nasotracheal tube should be positioned at the level of the clavicular heads (T2) on an A-P chest X-ray. The length of tube required beyond a year of age, in cm measured at the nose, is given by the equation - age in years + 13 cm. A meticulous technique of fixation must be employed to prevent accidental extubation.

Adequate humidification is difficult in the active child. It is, nevertheless, important in order to prevent obstruction of narrow tubes by inspissated secretions. Lightweight condenser humidifiers, eg, Thermovent (Gibeck), and Humidvent (Portex) have proved very useful in this respect. The filter paper should be moistened before application and the humidifier changed every 24 hours to reduce contamination and increased resistance. Oxygen supplementation can be provided, if necessary. Some children will tolerate connection of a humidified T-piece.

Effective bagging and tracheal toilet is vital and should be repeated until the airway is clear. Instillation of saline (0.5-1.0 mL) prior to suction may be useful with tenacious secretions.

Sedation is rarely indicated as tubes are well tolerated if the airway is obstructed and oxygen saturation is adequate. Arm restraints may be advisable to prevent self-extubation.

Signs of obstruction should be relieved by intubation. Mild retraction may persist due to high fever and increased minute ventilation in the presence of a narrow endotracheal tube. The endotracheal tube must be changed or removed if there is a question regarding its patency.

Tracheostomy

Tracheostomy remains a life-saving procedure and must be undertaken if endotracheal intubation is impossible or if equipment or personnel are unavailable. For chronic airway problems, it is more comfortable, allows better nasopharyngeal toilet and permits the child to leave the ICU and eventually go home. It is best performed under endotracheal anaesthesia with the neck extended. A longitudinal slit is made through the second and third tracheal rings without removal of cartilage. Stay sutures in the tracheal wall lateral to the incision aid recannulation should accidental dislodgement occur prior to formation of a tract (after 4 days). A chest X-ray should be obtained to check the position of the tip of the tracheostomy tube and to exclude pneumothorax.

Care of a newly-created tracheostomy is similar to that of an endotracheal tube with the additional problem of some discomfort and blood in the airway. The first tracheostomy tube change is usually performed between 5-7 days.

Cricothyrotomy

A wide bore plastic intravenous cannula (14 or 16 gauge) passed into the trachea via the cricopharyngeal membrane may be lifesaving if alternative procedures are unavailable. This should be performed with the neck extended as for tracheostomy. In small children, it may be difficult to remain in the midline. A system of connection to a low pressure oxygen supply must be planned in advance. One method is to attach the plastic sleeve to a 2-3 mL syringe (without plunger) and an adapter from a 7.5 mm OD endotracheal tube and a breathing circuit.