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REVIEW ARTICLE

Upper Airway Obstruction in Children

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Abstract Children with upper airway obstruction are both unique and variable in their presentation and management, often posing a challenge to the pediatrician. Several anatomical and physiologic peculiarities make a child vulnerable to develop an obstruction of upper airways. The characteristic finding in upper airway obstruction is stridor–inspiratory, biphasic or expiratory. The etiologies vary widely throughout the age groups and according to the mode of presentation. The approach starts with suspicion, mandates careful clinical evaluation of the degree of obstruction and many a times emergency measures precede any investigation or even precise diagnosis. Maintaining an open and stable airway is of the utmost importance, often requiring a team approach of emergency physician, pediatrician, otorhinolaryngologist and pediatric pulmonologist. The commonest condition presenting with upper airway obstruction in pediatric population is viral croup. Croup is a clinical diagnosis in a febrile child, with barking cough and stridor preceded by upper respiratory infection. It is treated with systemic or inhaled steroids and nebulized epinephrine. Epiglottitis and bacterial tracheitis are acute bacterial infections of upper airways, presenting as true airway emergencies. Though the mainstay of therapy is IV antibiotics, the prime concern is maintenance of airway, which frequently requires endotracheal intubation. Rigid bronchoscopy is the procedure of choice for airway foreign bodies, a common cause of upper airway obstruction in children below 3 y of age. Airway malacias are the commonest cause of chronic stridor and are mostly managed conservatively.

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Introduction

Upper airway obstruction is a common and potentially serious problem in pediatric practice. The etiology varies from simple nasal blockage in a newborn to near fatal epiglottitis in a child. The presentation can be insidious and even intermittent in a baby with airway malacia or stormy, as in a toddler with inhaled foreign body. Similarly, from the management perspective, it can range from merely careful observation to cardiopulmonary resuscitation. Diseases leading to severe compromise of the upper airway are the most frequent causes of cardiac arrest in pediatric population. In one study, severe upper airway obstruction accounted for 3.3 % of all pediatric intensive care unit (PICU) admissions [1].

Pathophysiology

There are several anatomical peculiarities in the airways of a child, which makes it more prone to obstruction. These 'developmental disadvantages' are

- Relatively larger and prominent occiput causing flexion of neck in supine position
- Relatively larger tongue
- Anterior and cephalad position of the larynx
- Soft and omega shaped, vertically positioned epiglottis
- Narrowest portion of the airways is at the level of the cricoid cartilage which is non-distensible

The Poiseuille's law beautifully explains how even a marginal reduction in the caliber of the small pediatric airways can precipitate dangerous obstruction to airflow. But one should also remember that, during periods of turbulent airflow (as in case of a struggling child), the resistance to airflow becomes inversely related to fifth power of the radius of the airways! Newborns and small infants are obligate nose breathers; therefore, mere nasal block can predispose them to have significant obstruction to ventilation, a feature exemplified by choanal atresia/ stenosis.

During inspiration, the intraluminal pressure in the upper (extra-thoracic) airway becomes negative, causing collapse of the airways. The resultant narrowing makes the airflow turbulent producing inspiratory stridor. During exhalation, on the other hand, the intraluminal pressure exceeds the atmospheric pressure and the pressure exerted by the surrounding tissue, dilating the airway in cases of dynamic obstruction and improving the airflow. The configuration of the glottis may also predispose it to collapse during inspiration than exhalation.

The characteristic auditory finding of upper airway obstruction is stridor; associated with extrathoracic lesions (*e.g.,* laryngomalacia, vocal cord lesion) when heard on inspiration; associated with intrathoracic lesions (*e.g.,* tracheomalacia, extrinsic compression) when heard on expiration; associated with fixed lesions (*e.g.,* croup, laryngeal mass or web) when biphasic [2].

Stridor should be differentiated from stertor (a low pitched inspiratory snoring sound typically produced by nasal or nasopharyngeal obstruction) and wheeze (musical, high pitched, polyphonic/monophonic and usually during expiration).

According to the 'Holinger's laws' of airway obstruction [3], in a child with noisy breathing, if the noise is worse during sleep, the obstruction is nasal or pharyngeal. If the symptoms are worse when the child is awake or exacerbated, the obstruction is typically laryngeal, tracheal or bronchial. However, there are exceptions, *e.g.,* a child with recurrent respiratory papillomatosis of larynx presents with progressive airway obstruction most evident during sleep.

Causes

Causes of upper airway obstruction are grouped into acute and chronic and then further reclassified into infectious and non infectious (Table 1). Though, in the west, the etiology and incidence of infectious upper airway obstruction has changed dramatically during the past few decades, especially following introduction of vaccines against Diphtheria and *Haemophilus influenzae*, they continue to remain one of the common causes of upper airway obstruction in the pediatric population.

Approach to Upper Airway Obstruction

Upper airway obstruction is most often a medical emergency requiring rapid evaluation with simultaneous therapy to

Table 1 Common causes of upper airway obstruction in children

Acute	Chronic
Infectious	Infectious
Laryngotracheitis/ Laryngotracheobronchitis (LTB) or croup	Adenotonsillar hypertrophy
Acute epiglottitis	Chronic tonsillitis
Bacterial tracheitis	
Laryngeal diphtheria	
Retropharyngeal abscess	
Tonsillar/ peritonsillar abscess	
Ludwig's angina	
Infectious mononucleosis	
Non infectious	Non infectious
Airway foreign body	Choanal atresia/ stenosis
Angioneurotic edema	Laryngomalacia
Airway trauma (penetrating/ blunt)	Tumor of larynx (hemangioma, papilloma, cystic hygroma)
Airway burns (caustic/ thermal)	Vascular ring
Vocal cord paralysis	Tracheal/ subglottic stenosis
Vocal cord dysfunction	Craniofacial anomalies (*e.g.,* Pierre–Robin sequence)
	Dysmorphic syndromes (*e.g.,* Crouzon syndrome, Treacher–Collins syndrome)

ensure adequate ventilation and oxygenation. It is very important to note that, in most of the cases, the diagnosis is essentially clinical; there may not be enough time to perform laboratory investigations, arterial blood gases or even simple radiography.

When to Suspect

Any child with respiratory distress with or without noisy breathing may have airway obstruction. Patients with upper airway obstruction usually present with inspiratory stridor which can be biphasic as well. However one must be careful as profound degrees of obstruction may manifest silently if airflow is nearly absent (Fig. 1).

History

Onset of stridor: Sudden/acute/intermittent; precipitation by feeding or choking; any relation to posture or cry. Occasionally there may be history of witnessed foreign body inhalation (*e.g.,* child playing with a foreign body in the mouth prior to the onset). Associated symptoms should be asked for, *e.g.,* fever, cough, change in voice, hoarseness, drooling, swelling of lips, erythematous rash, itching *etc.* Exposure to any known allergen or smoke. Underlying medical conditions (*e.g.,* Down syndrome, cerebral palsy) which increase the risk of more severe airway compromise should be looked for.

Clinical Examination

During the initial assessment of a child with suspected upper airway obstruction, the first priority is always to establish a stable, patent airway. Approach to such a patient must be with extreme caution and with minimal manipulation, as catastrophic obstruction can be precipitated even with trivial measures like placing a tongue blade!

Stridor is a musical, high-pitched, harsh sound that may be heard over the upper airways or even at a distance without a stethoscope. The timing of stridor and its exacerbating/ relieving factors help in anatomical localization of the obstruction and knowing whether it's dynamic or fixed. Look at the child's appearance, posture, craniofacial abnormalities, drooling; check for respiratory rate, chest retraction, oxygen saturation, pulsus paradoxus, neck adenopathy and any palpable neck mass. Movement of chest and bilateral air entry should be checked. A sweating, restless child is probably hypoxemic and a drowsy, aphonic child may be in impending respiratory arrest.

Following severe obstruction of upper airway, hypoxemia with resultant cardiac arrest and death can ensue within minutes. Prompt recognition of the pattern of symptoms and

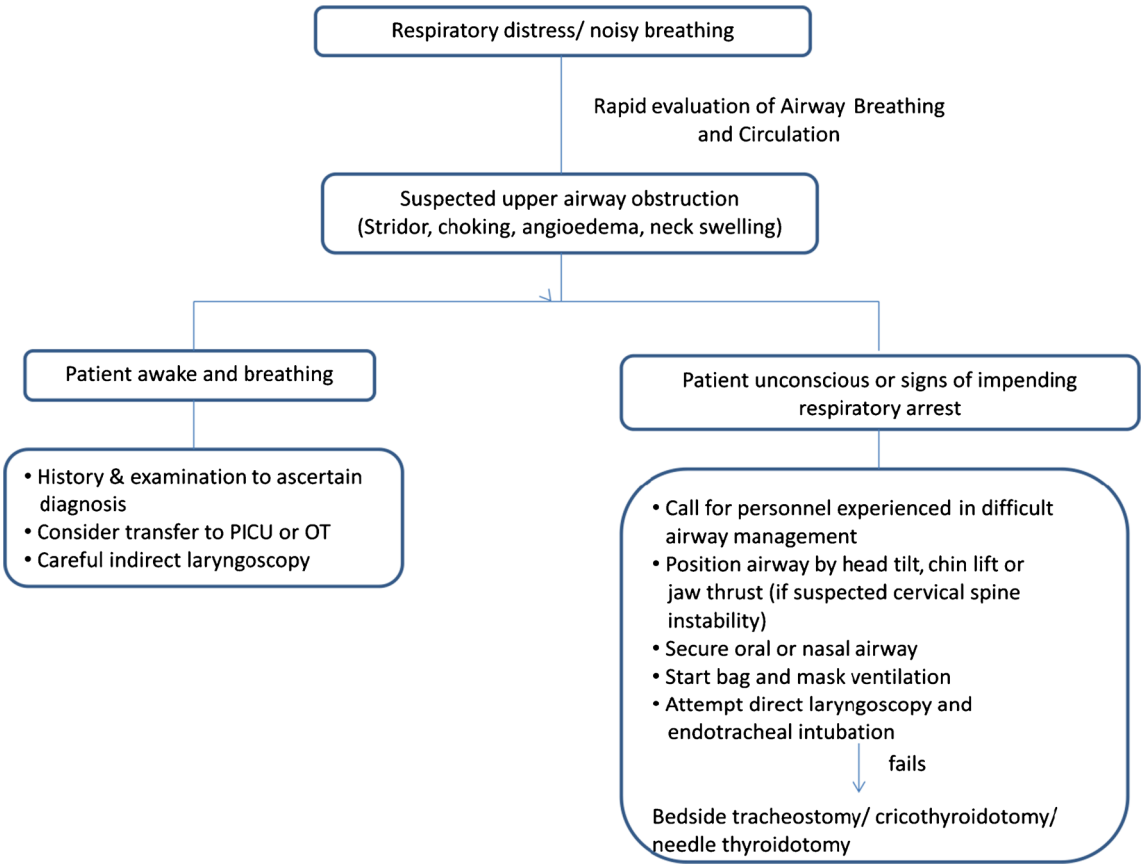

Fig. 1 Algorithm for management of acute upper airway obstruction

signs may guide to a probable diagnosis and buy precious time for the emergency physician for subsequent detailed evaluation and planning patient care. The following clues obtained thus far help to point out the diagnosis:

- Sudden onset – foreign body, anaphylaxis
- Soft or low pitched stridor – epiglottitis, foreign body, tracheitis
- Toxic appearance with high fever – epiglottitis, tracheitis, retropharyngeal or peritonsillar abscess
- Drooling, open mouth, sitting forward – epiglottitis, retropharyngeal abscess
- Muffled voice with dysphagia – tonsillar/ peritonsillar abscess
- Epistaxis, foul smelling blood stained nasal discharge, bull neck, incomplete immunisation – Diphtheria
- Swelling of lips, erythematous rash with itching – anaphylaxis/angioneurotic edema
- Bleeding, bruising or subcutaneous emphysema – trauma (penetrating/ blunt)
- History of previous tracheal intubation – subglottic stenosis
- Intermittent stridor, more on crying/feeding and relieved in prone position – airway malacia

Initial Airway Stabilization

Once initial assessment is over, the most skilled and experienced personnel available are gathered to stabilize the airway and this is best done under controlled conditions in the PICU or operating room. Bag-mask ventilation may be of particular value in stenting open the airway in a child who has cardiopulmonary arrest (Fig. 1).

The following general points should be remembered whenever encountered in a child with suspected airway obstruction:

- Leave the child with parent in a comfortable position.
- DO NOT insert tongue depressor or attempt IV access or blood tests.
- DO NOT force an oxygen mask over face; provide supplementary oxygen by the least frightening method. Oxygen should be administered to decrease work of breathing even if the oxygen saturation is normal.
- DO NOT sedate the child until airway is secured.
- Pulse oximetry is a poor indicator of severity of obstruction especially when supplementary oxygen is being given.

Management

Specific management of common conditions presenting as upper airway obstruction are discussed here.

Croup

Croup or laryngotracheobronchitis (LTB) is the commonest cause of infectious upper airway obstruction in children. It is almost always viral in etiology with parainfluenza virus being the commonest offending agent. Children affected are usually between 1 and 6 y of age, commonest 12–24 mo, with a slight male preponderance (1.4: 1). The 17 point Westley's clinical scoring system [4] is the objective way of severity assessment but is cumbersome in busy clinic or casualty settings. 'Steeple sign' is the radiological hallmark seen in neck radiograph but is seldom required for diagnosis. Mild croup presents with barking cough, with or without inspiratory stridor present only on exertion and there are no other signs of respiratory distress. It may be treated at home with antipyretics and plenty of fluids. A single dose of oral corticosteroids may be considered [5]. Humidified air has been proven to be ineffective [6]. A child with moderate croup has stridor even at rest and may also have some evidence of respiratory distress (tachycardia, mild tachypnea and chest retractions) but is accepting orally and interactive with SpO_2>92 % in room air. Whereas, children with severe croup will be appearing anxious, tired or restless and agitated with decreased oral intake. There is an evidence of marked respiratory distress and hypoxemia on pulse oximetry. The mainstay of therapy is corticosteroids. All the practiced routes (nebulized, oral or intramuscular) seem to be equally effective [5]. Though the conventional practice has been to use intramuscular dexamethasone at a dose of 0.6 mg/kg, doses as low as 0.15 mg/kg are currently advocated [5]. Ceiling dose of parenteral dexamethasone used in various studies has been 10 mg, while oral doses up to 20 mg have been used. In addition to corticosteroids, nebulized epinephrine at a dose of 0.3–0.5 ml/kg (maximum 5 ml) of 1:1000 solution is used for rapid relief of symptoms [7]. Heliox was not found to be beneficial in the management of croup [8].

Epiglottitis

It is a true pediatric airway nightmare! There is acute onset of symptoms with high fever and rapid deterioration over hours. Historically, the commonest causative organism is *H. influenzae*; the epidemiology is changing with immunisation practices and other agents (Streptococcus and Staphylococcus) coming to the forefront. Often the mnemonic 4D's (Drooling, Dysphagia, Dysphonia and Dyspnea) is used to describe this condition [9] with classical description of a child sitting in a 'tripod position'. If lateral radiograph of neck could be obtained, it shows the characteristic "thumb sign", though it is not indicated in an acute setting. All the airway stabilization measures described earlier are to be strictly followed as these children frequently need advanced airway support [10]. Some experts even suggest elective intubation to

avoid complications of emergency intubation [11]. In all suspected cases of epiglottitis, the child should be transferred to the PICU or operating room as soon as possible, accompanied by a team of professionals experienced in the management of difficult airways, pending any further diagnostic or therapeutic interventions. Intravenous antibiotics are administered after taking blood cultures. A third generation cephalosporin (*e.g.,* Ceftriaxone, Cefotaxime) is the empirical treatment of choice, usually given for 7–10 d. Addition of an antistaphylococcal agent active against methicillin-resistant *Staphylococcus aureus* (MRSA) (*e.g.,* Clindamycin, Vancomycin) should be considered when chances of MRSA infection are high. Rifampicin prophylaxis is recommended for close contacts of proven *H. influenzae* infections, at a dose of 20 mg/kg (maximum 600 mg) once daily for 4 d.

Bacterial Tracheitis

Also known as the pseudomembranous croup or bacterial croup, it is most commonly caused by *S. aureus*. The median age of affected children is around 5 y. The typical history is of a child initially having symptoms of mild LTB deteriorating rapidly to develop increasing respiratory distress, toxic appearance, orthopnea and dysphagia. The principles of initial airway management remain the same as in other upper airway emergencies. Endoscopy (flexible or rigid), done under general anesthesia, has a very important role in both diagnosis and management by removal of the exudative pseudomembrane and might also avert the need for intubation [12]. Need for endotracheal intubation has been reported to be between 38 and 100 % [13]. Choice of IV antibiotics is usually a combination of 3rd generation cephalosporin (*e.g.,* Ceftriaxone, Cefotaxime) and antistaphylococcal penicillin (*e.g.,* Cloxacillin) for 10–14 d [14].

Laryngeal Diphtheria

It is caused by toxigenic strains of *Corynebacterium diphtheriae*; classically, it presents as an insidious onset fever, sore throat, cervical lymphadenopathy and neck edema (bull neck). Laryngeal form is typically an extension from pharynx in children. A characteristic thick, dirty, adherent grey membrane which bleeds on attempted removal clinches the clinical diagnosis. A throat swab should be sent for Albert stain and culture for bacteriological confirmation. Endotracheal intubation should be avoided and early tracheostomy is advocated for airway stabilization. The American Academy of Pediatrics recommended medical management comprises of Diphtheria antitoxin 20,000–40,000 U and antimicrobial therapy with penicillin or erythromycin given either orally or parenterally for 14 d. Active immunisation is also advised during convalescence [15].

Retropharyngeal Abscess

It is a diagnosis almost exclusively below 6 y of age and is often a polymicrobial infection. It usually presents with high fever, sore throat, dysphagia, neck pain with limitation of movement of neck or torticollis. A lateral neck radiograph may reveal widening of prevertebral soft tissue and air-fluid level in the retropharyngeal region, though the investigation of choice is a contrast CT scan to establish the diagnosis and also to plan the management. Traditionally, management comprises of surgical drainage with IV antibiotics especially in cases with compromised airway. However increasing number of cases is being successfully treated with antimicrobials alone [16]. The empirical antibiotics are directed towards *S. aureus*. The choice being Ampicillin-Sulbactam or Clindamycin for methicillin sensitive *Staphylococcus aureus* (MSSA) and Vancomycin or Linezolid for suspected methicillin resistant *Staphylococcus aureus* (MRSA) infection with total duration (IV+oral) being typically 14 d [17].

Peritonsillar Abscess

It is the commonest deep-space infection of the head and neck; it usually follows acute tonsillitis and is polymicrobial in etiology with both aerobic and anaerobic bacteria being involved [18]. The clinical picture is of an older child with acute tonsillitis who becomes very sick with high fever, severe throat pain, and dysphagia. On examination, there is trismus, foul smelling breath, cervical adenopathy and edematous uvula pushed to one side. Apart from airway stabilization, these children are managed with needle aspiration or incision and drainage of abscess or tonsillectomy coupled with IV antibiotics [19]. Most commonly employed antibiotics are a combination of 3rd generation cephalosporin with Clindamycin, with other alternatives being Meropenem, Imipenem and Piperacillin-Tazobactam [20].

Foreign Body (FB)

Airway foreign body is most commonly observed in children less than 3 y of age with a male predilection. Food material (especially peanut) followed by toy parts are the commonest objects inhaled [21]. The presentation varies, depending upon the child's age, type of object aspirated, time elapsed since inhalation, degree of airway blockage, and the location of the object in the airways. Even a witnessed episode of chocking has a sensitivity of 76–92 % for the diagnosis [22]. With evidence of complete airway obstruction (aphonia and inability to cough), dislodgement using Heimlich maneuver in older children and alternate back blows and chest compressions in infants, should be attempted. Whereas, this is contraindicated in cases of partial obstruction. The classical triad of cough, wheeze and unilateral diminished breath sound is observed in

only 57 % cases [23]. Other clinical features include stridor, tachypnea, dyspnea, hoarseness, cyanosis and fever. The chronic or missed cases may present with persistent/recurrent pneumonia, collapse, bronchiectasis or lung abscess. Plain radiographs of neck and chest are routinely obtained in suspected cases and the findings may vary from visualized foreign body in the airway, unilateral/ localised hyperinflation, collapse, mediastinal shift but radiographs should never be relied upon to rule out foreign body aspiration [24]. Even virtual bronchoscopy has no role in acute setting [25]. Rigid bronchoscopy is the procedure of choice in all cases of suspected airway foreign body for both diagnosis and management and should be undertaken without delay. It is successful in removing the FB in 95 % of cases, with a very low complication rate (<1 %) [23]. Though flexible bronchoscopy is considered a safe and effective tool for diagnosis and even removal of airway FB [26], it requires a skilled personnel. American Thoracic Society recommends use of only rigid bronchoscopy for this purpose [27].

Angioneurotic Edema

Anaphylaxis or anaphylactoid reaction and hereditary angioedema are characterized by a stormy presentation and are frequently accompanied by circulatory collapse. Presence of lip swelling, urticarial rash and itching points towards the diagnosis; history of recurrent events may be found in hereditary cases. Though the specific treatment of hereditary cases is infusion of C1 esterase inhibitor or fresh frozen plasma [28], the acute agent of choice is adrenaline. Alternate agents for hereditary angioedema include subcutaneous Icatibant (selective competitive antagonist of bradykinin B2 receptor) or Ecallantide (kallikrein inhibitor) [29]. Anaphylaxis is treated with IM or IV adrenaline, fluid support, H1 antagonists, ß2 agonist inhalation and intravenous corticosteroids [30].

Vocal Cord Paralysis

Vocal cord paralysis can be either unilateral or bilateral and congenital or acquired, that may be again idiopathic or iatrogenic, as a result of a neurological abnormality or birth trauma [31]. Children with bilateral vocal cord paralysis are often symptomatic early in life, whereas unilateral paralysis may be missed. Infants present with a weak cry or stridor associated with recurrent aspiration and feeding problems [32]. In children with bilateral cord paralysis, MRI of brain is necessary to rule out intracranial lesions such as Arnold–Chiari malformation or tumors, while in those with unilateral paralysis, intrathoracic lesions involving the recurrent laryngeal nerve must be excluded. Supportive treatment alone is often sufficient in unilateral vocal cord paralysis with nasogastric tube feeding until the child develops a ‘safe swallow’; whereas, tracheostomy may be necessary in approximately 50 % of children with bilateral cord paralysis [31]. As spontaneous recovery rates of up to 70 % are reported, an interval of at least a year is often given before an airway widening procedure is undertaken [31]. CO_2 laser is the treatment modality of choice [33].

Laryngomalacia

It is the commonest congenital laryngeal anomaly and commonest cause of stridor in infancy [34]. The onset of stridor is usually within the first weeks of life. There may be associated feeding problems and gastroesophageal reflux disease (GERD) as well. Laryngoscopy is undertaken to confirm the diagnosis and rule out synchronous airway lesion (SAL). The management is largely reassurance, as the symptoms tend to wean off with increasing age and subside by 2 y of age. In a minority of patients (<10 %), surgical management is warranted, when they present with acute life threatening events or failure to thrive. Surgical options are supraglottoplasty/ aryepiglottoplasty and tracheostomy (especially when associated with neurological or neuromuscular conditions) [35].

Choanal Atresia

It is one of the most common congenital upper airway anomalies (1 in 8000 live births) [36]; it can be either bony or membranous (10 %). Unilateral atresia often goes unnoticed sometimes even till later childhood when the patent nostril is blocked due to some infection. Some children may present with difficulties in feeding or persistent unilateral nasal discharge. On the other hand, children with bilateral atresia present immediately after birth with respiratory distress which improves on crying. Sixty percent of these babies have other associated congenital anomalies, the commonest being CHARGE association [37]. Emergency treatment of severe cases involves insertion of an oral airway; however, a nasal airway should be established as soon as possible. This can be achieved by a transnasal approach using a dilator followed by introduction of a stent, but thicker atresia requires direct drilling [38].

Subglottic Hemangioma

These are usually asymptomatic at birth, present with biphasic stridor during 3 wk to 3 mo of age, thereafter, has a rapid growth till 12–18 mo followed by involution in 2–5 y period. There may be associated cutaneous hemangioma in up to 50 % of cases [39]. The management options include systemic and intra-lesional corticosteroids, laser or open excision, adjuvant therapy with alpha-interferon, cyclophosphamide, vincristine and radiotherapy [40]. Recently, medical management with propranolol for prolonged period has shown such good safety and efficacy that some are advocating it as the first line therapy [41].

Subglottic Stenosis

The secondary form is the commonest, results following endotracheal intubation or laryngeal trauma. Whereas, the congenital form is due to an abnormality of the cricoid cartilage and presents with recurrent episodes of croup like illness [42]. The management options include microlaryngoscopy/ bronchoscopy with bougie dilation, cricoid split, laryngotracheal resection and cricotracheal resection [43].

Conclusions

Upper airway obstruction is a common emergency in children requiring rapid and effective management of acute cases to prevent severe complications and even fatality. The diagnosis is almost always clinical. Acute infectious causes still predominate in the developing countries. Croup is the commonest cause of upper airway obstruction encountered in the clinical practice and is managed with corticosteroids and adrenaline nebulisation. The other infectious etiologies require IV antibiotics coupled with appropriate airway management, frequently mechanical ventilation. Rigid bronchoscopy remains the procedure of choice for diagnosis and management of foreign body aspiration. With improved surgical techniques and supportive care the outlook of the chronic cases has improved much during the last decades.

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References

1. Chan PW, Goh A, Lum L. Severe upper airway obstruction in the tropics requiring intensive care. Pediatr Int. 2001;43:53–7.
2. Bohadana A, Izbicki G, Kraman SS. Fundamentals of lung auscultation. N Engl J Med. 2014;370:744–51.
3. Holinger LD. Evaluation of stridor and wheezing. In: Holinger LD, editor. Pediatric Laryngology & Bronchoesophagology. New York: Lippincott Raven; 1997. p. 41–8.
4. Westley CR, Cotton EK, Brooks JG. Nebulized racemic epinephrine by IPPB for the treatment of croup: a double-blind study. Am J Dis Child. 1978;132:484–7.
5. Russell KF, Liang Y, O'Gorman K, Johnson DW, Klassen TP. Glucocorticoids for croup. Cochrane Database Syst Rev. 2011;1: CD001955.
6. Moore M, Little P. Humidified air inhalation for treating croup. Cochrane Database Syst Rev. 2006;3:CD002870.
7. Bjornson C, Russell K, Vandermeer B, Klassen TP, Johnson DW. Nebulized epinephrine for croup in children. Cochrane Database Syst Rev. 2013;10:CD006619.
8. Vorwerk C, Coats T. Heliox for croup in children. Cochrane Database Syst Rev. 2010;2:CD006822.
9. Blackstock D, Adderley RJ, Steward DJ. Epiglottitis in young infants. Anesthesiology. 1987;67:97–100.
10. Mayo-Smith MF, Spinale JW, Donskey CJ, et al. Acute epiglottitis. An 18-year experience in Rhode Island. Chest. 1995;108:1640–7.
11. Hammer J. Acquired upper airway obstruction. Paediatr Respir Rev. 2004;5:25–33.
12. Gallagher PG, Myer 3rd CM. An approach to the diagnosis and treatment of membranous laryngotracheobronchitis in infants and children. Pediatr Emerg Care. 1991;7:337–42.
13. Eckel HE, Wideman B, Damm M, et al. Airway endoscopy in the diagnosis and treatment of bacterial tracheitis in children. Int J Otorhinolaryngol. 1993;27:147–57.
14. Al-Mutairi B, Kirk V. Bacterial tracheitis in children: approach to diagnosis and treatment. Paediatr Child Health. 2004;9:25–30.
15. American Academy of Pediatrics. Diphtheria. In: Pickering LK, editor. 2012 Report of the Committee on Infectious Diseases. 29th ed. Elk Grove Village: American Academy of Pediatrics; 2012. p. 302.
16. Craig FW, Schunk JE. Retropharyngeal abscess in children: clinical presentation, utility of imaging, and current management. Pediatrics. 2003;111:1394–8.
17. Tebruegge M, Curtis N. Infections related to the upper and middle airways. In: Long SS, Pickering LK, Prober CG, editors. Principles and Practice of Pediatric Infectious Diseases. 3rd ed. New York: Elsevier Saunders; 2012. p. 205.
18. Schraff S, McGinn JD, Derkay CS. Peritonsillar abscess in children: a 10-year review of diagnosis and management. Int J Pediatr Otorhinolaryngol. 2001;57:213–8.
19. Herzon FS, Nicklaus P. Pediatric peritonsillar abscess: management guidelines. Curr Probl Pediatr. 1996;26:270–8.
20. Baldassari C, Shah RK. Pediatric peritonsillar abscess: an overview. Infect Disord Drug Targets. 2012;12:277–80.
21. Passàli D, Lauriello M, Bellussi L, et al. Foreign body inhalation in children: an update. Acta Otorhinolaryngol Ital. 2010;30:27–32.
22. Ruiz FE. Airway foreign bodies in children. Available at http://www.uptodate.com/contents/airway-foreign-bodies-in-children. Accessed 17 March 2015.
23. Rovin JD, Rodgers BM. Pediatric foreign body aspiration. Pediatr Rev. 2000;21:86–90.
24. Chatterji S, Chatterji P. The management of foreign bodies in air passages. Anaesthesia. 1972;27:390–5.
25. Cevizci N, Dokucu AI, Baskin D, et al. Virtual bronchoscopy as a dynamic modality in the diagnosis and treatment of suspected foreign body aspiration. Eur J Pediatr Surg. 2008;18:398–401.
26. Ramirez-Figueroa JL, Gochicoa-Rangel LG, Ramirez-San Juan DH, et al. Foreign body removal by flexible fibreoptic bronchoscopy in infants and children. Pediatr Pulmonol. 2005;40:392–7.
27. Green CG, Eisenberg J, Leong A, et al. Flexible endoscopy of the pediatric airway. Am Rev Respir Dis. 1992;145:233–5.
28. Bork K, Barnstedt SE. Treatment of 193 episodes of laryngeal edema with C1 inhibitor concentrate in patients with hereditary angioedema. Arch Intern Med. 2001;161:714–8.
29. Wahn V, Aberer W, Eberl W, et al. Hereditary angiooedema in children and adolescents—a consensus on therapeutic strategies. Eur J Pediatr. 2012;171:1339–48.
30. Muraro A, Roberts G, Clark A, et al. Position paper of the European academy of allergology and clinical immunology: the management of anaphylaxis in childhood. Allergy. 2007;62:857–71.
31. Daya H, Hosni A, Bejar-Solar I, et al. Pediatric vocal fold paralysis. Arch Otolaryngol Head Neck Surg. 2000;126:21–5.
32. Dedo DD, Dedo HH. Neurogenic diseases of the larynx. In: Stool E, Alper CM, Arjinand EM, Casselbrant ML, Dohar JE, Yellon E, editors. Pediatric Otolaryngology. Philadelphia: Saunders; 2003. p. 1505–10.
33. Worley G, Bajaj Y, Cavalli L, et al. Laser arytenoidectomy in children with bilateral vocal fold immobility. J Laryngol Otol. 2007;121:25–7.

34. Cinnamond MJ. Congenital disorders of the larynx, trachea and bronchi. In: Scott-Brown, editor. Paediatric Otolaryngology. London: Butterworths; 1997. p. 412–9.
35. Olney DR, Greinwald JH, Smith RJH, et al. Laryngomalacia and its treatment. Laryngoscope. 1999;109:1770–5.
36. Cinnamond MJ. Congenital anomalies of the nose. In: Scott-Brown WE, editor. Paediatric Otolaryngology. London: Butterworths; 1987. p. 215–25.
37. Morgan D, Bailey M, Phelps P, Bellman S, Grace A, Wyse R. Ear, nose, throat anomalies in the CHARGE association. Arch Otolaryngol. 1993;119:49–54.
38. Dinwiddie R. Congenital upper airway obstruction. Paediatr Respir Rev. 2004;5:17–24.
39. Meeuwis J, Bos CE, Hoeve LJ, van der Voort E. Subglottic hemangiomas in infants: treatment with intralesional corticosteroid injection and intubation. Int J Pediatr Otorhinolaryngol. 1990;19: 145–50.
40. O-Lee TJ, Messner A. Subglottic hemangioma. Otolaryngol Clin N Am. 2008;41:903–11.
41. Denovelle F, Garabedian EN. Propranolol may become first-line treatment in obstructive Subglottic infantile hemangiomas. Otolaryngol Head Neck Surg. 2010;142:463–4.
42. Ho AS, Koltai PJ. Pediatric tracheal stenosis. Otolaryngol Clin North Am. 2008;41:999–1021.
43. Choo KK, Tan HK, Balakrishnan. Subglottic stenosis in infants and children. Singapore Med J. 2010;51:848–52.