Acute and chronic airway obstruction in children

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Abstract

Airway obstruction is more common in children than in adults. This is because of subtle anatomical differences in the childhood airway and an increased propensity to infection. Effects of obstruction manifest more quickly in children because of a smaller airway diameter, reduced physiological reserve and easily fatigued respiratory muscles. The anaesthetist may encounter airway obstruction in children both outside and within the operating theatre. Problems can be either anticipated or unexpected. The anaesthetist must be able to recognize risk factors for airway obstruction such as a history of respiratory symptoms, including sleep-disordered breathing, and high-risk groups, such as ex-preterm infants. An understanding of the pathophysiology of airway obstruction can help in the recognition, diagnosis and appropriate management of airway obstruction. The pathophysiology of airway obstruction is intimately linked with the anatomy and mechanics of the upper airway and the tracheobronchial tree. The pathophysiology of airway obstruction is reviewed and this knowledge applied to problems occurring inside and outside the operating theatre, including both anticipated and unexpected problems.

Keywords Anaesthesia; child; lower airway obstruction; upper airway obstruction

Royal College of Anaesthetists CPD Matrix: 2A01, 2D00

Learning objectives

After reading this article, you should be able to:

- explain the mechanics behind wheeze and stridor
- recognize the common conditions causing airway obstruction in children
- react appropriately to airway obstruction occurring in the operating theatre

Mechanics of airway obstruction

Upper and lower airway obstruction (Figure 1) present differently because of the different pressures inside and outside the thoracic cavity during the breathing cycle. There is a natural anatomic division between the upper and lower airway at the level of the glottis (or vocal cords). Physiologically, however, the upper airways are those lying above the thoracic inlet (nose, nasopharynx, larynx and upper trachea) and the lower airways are those lying below the thoracic inlet (lower trachea and bronchi). The thorax is separated from the neck at the thoracic inlet formed by the first thoracic vertebra, the first pair of ribs and the manubrium sterni. The airways are termed extrathoracic if they lie above the thoracic inlet and intrathoracic if they lie below.

In inspiration, a negative pressure is generated within the thoracic cavity as the thorax expands by the downward excursion of the diaphragm and the upward and outward excursion of the ribs. Air is drawn into the airways and lungs until the pressure in the lungs rises to atmospheric pressure and airflow (and, therefore, inspiration) ceases. In inspiration the negative pressure generated in the thoracic cavity is transmitted throughout the airways. The structures surrounding the extrathoracic airways in the neck are at atmospheric pressure. This pressure gradient across the extrathoracic airways causes compression in inspiration and produces stridor when collapsible or partially obstructed extrathoracic airways are present (as seen in laryngomalacia and croup).

During expiration, the elastic recoil of the lungs and chest wall generate a positive pressure on the lungs, which drives air from the lungs through the airways. The pressure within the airways is also influenced by the speed of the air flowing through the airways. Bernoulli's principle states that the pressure exerted by the gas is inversely related to the velocity of the gas flow. The total cross-sectional area of airways is reduced as we move from the many small distal airways to the fewer large central airways. The air therefore flows faster in the larger bronchi. As the speed of airflow increases, the pressure falls. In expiration, the positive intrathoracic driving pressure can cause compression and consequently wheeze when collapsible or partially obstructed intrathoracic airways are present (as seen in bronchomalacia and asthma). The distending pressure in the airways drops to less than the positive intrathoracic pressure because of the effect of the fast-flowing air.

In fixed airway obstruction such as subglottic stenosis, the cause and effect are clear: there is a narrow airway with subsequent limitation of airflow. However, even this process can be variable. The limitation may become apparent only if increased demands are put on the respiratory system such as during exercise, or the narrowing may become critical only if there is additional swelling such as during a respiratory tract infection. Other causes of airway obstruction can be more dynamic. In laryngomalacia or (upper tracheomalacia), the calibre of the airway at rest or during expiration is normal. It is only during inspiration that the soft airway collapses under a pressure gradient.

Airway obstruction occurring outside the operating theatre

The anaesthetist is often the first person called in an airway emergency. Emergencies tend to differ by age:

- Neonatal – congenital airway abnormalities.
- Young child – airway obstruction is often upper airway and can be caused by infections or by foreign bodies.
- Older children – airways obstruction often occurs in the lower airways such as that seen in asthma or cystic fibrosis. 'Difficult airways' are common in trauma, either because of injury to the face, neck or chest, or because of the need for cervical immobilization.

Securing an effective airway in the emergency management of airway obstruction requires skill and a structured approach. Both an experienced anaesthetist and an ear, nose and throat (ENT)

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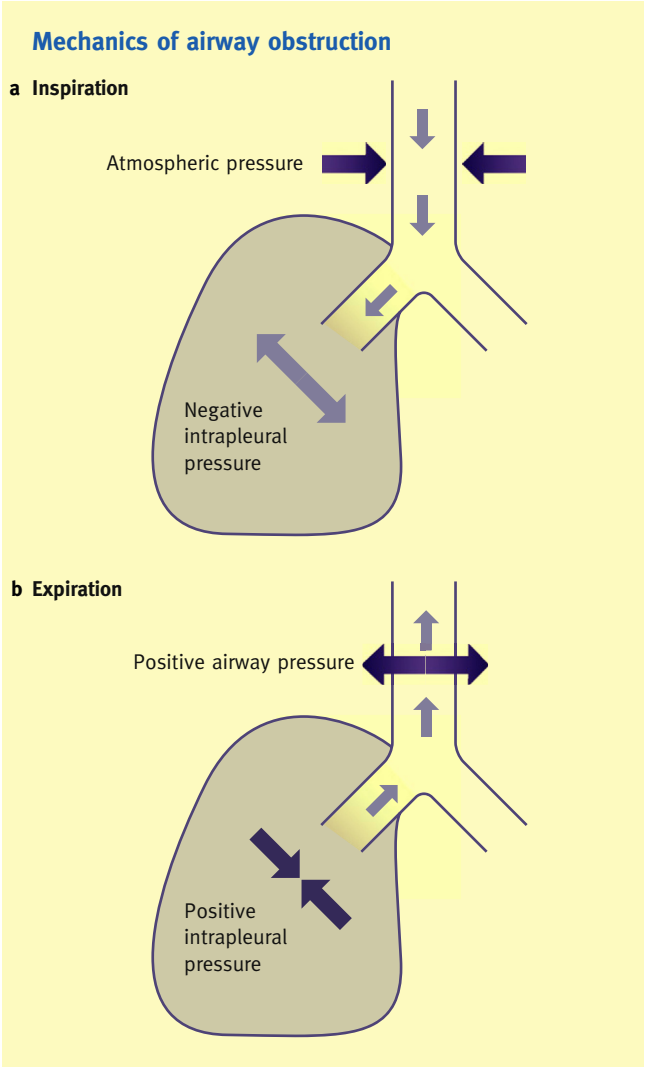

Figure 1 Diagram demonstrating the compressive effect of the pressure gradient across extrathoracic airways during inspiration (**a**) and across intrathoracic airways during expiration (**b**).

surgeon may be needed. Maintaining spontaneous ventilation is vital in airway obstruction and is a useful practice in most children with respiratory compromise. Even laboured respiratory efforts by the child are usually more effective than ventilation with bag and mask following abolition of the child's breathing with neuromuscular blocking drugs. Gradual induction of anaesthesia with oxygen and an inhalational agent is preferable, with the child allowed to adopt the most comfortable position, even sitting on a parent's lap. Intravenous access is usually attempted only after gaseous induction as pain or fear may precipitate total airway obstruction in the child. Neuromuscular blocking drugs should be used only if necessary to aid intubation and only once the anaesthetist has confirmed that bag-and-mask ventilation is consistently possible.[1]

Recognizing airway obstruction in the spontaneously breathing child

In the spontaneously breathing child, extrathoracic airway obstruction produces inspiratory or biphasic stridor, which is usually monophonic. Increased effort is seen with accessory muscle use. Tracheal tug, sternal, subcostal and intercostal recession are exaggerated because of the high negative intrapleural pressures generated by the child in an attempt to overcome the obstruction. This is obvious in younger children with compliant, cartilaginous thoracic walls when even moderate upper airway obstruction can produce quite dramatic indrawing. The child will often spontaneously adopt a position which maximizes the airway diameter and the mechanical efficiency of breathing, hence the 'tripod position'. The practitioner changes this position at their peril. Changing the child's position can precipitate complete airway obstruction and collapse and the anaesthetist should avoid this until they are prepared to take control of a difficult airway and the child's breathing if necessary.

In intrathoracic (lower) airway obstruction, wheeze is usually audible. Wheeze generated from multiple points of narrowing (as in bronchospasm) is a noise characterized by the layering of many slightly different high-frequency notes producing a musical or polyphonic tone. Wheeze generated from a single fixed obstruction is similarly fixed producing a monophonic wheeze. There is usually hyperinflation of the chest and this may be asymmetrical if one lung is affected more than the other (such as with a foreign body). The signs of increased work of breathing are similar to upper airway obstruction (accessory muscle use, recession and tracheal tug). However, hyperinflation of the chest often makes these less apparent. There may be prolongation of the expiratory phase, and active expiration with use of the abdominal muscles.

Inspiratory wheeze is less prevalent in bronchospasm because a combination of hyperinflation and a negative intrathoracic pressure is believed to splint open the airways. However, in severe obstruction of either the extrathoracic or intrathoracic airways, biphasic stridor or wheeze can be heard and this is an ominous sign. When airflow diminishes because of almost complete obstruction, stridor or wheeze can disappear: this is usually a sign of impending collapse.

Typical pathology encountered outside the operating theatre

Some of the causes of acute and chronic airway obstruction are outlined in Table 1.

Nose and nasopharynx

Neonatal airway emergencies are usually due to congenital lesions particularly choanal atresia, Pierre Robin sequence or cystic hygroma. Bilateral choanal atresia usually presents within hours of birth with breathing difficulties, apnoea or cyanotic episodes often associated with feeding. Unilateral choanal atresia can present later in childhood with persistent unilateral rhinorrhoea.

Larynx and upper trachea

Congenital thoracic malformations may produce compression of the lower thoracic airways but this is unusual. Occasionally these will have been anticipated because of antenatal scans. Management plans should be in place for problems anticipated antenatally and the delivery is often by elective caesarean section with the appropriate personnel in attendance. EXIT procedures are occasionally used (EX utero InTrapartum procedures) where the placental circulation is maintained after the baby is delivered until an airway is secured.