Anaesthesia for ear nose and throat surgery in children
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Monday, 13 June 2011 8:30 - 9:15 Room: G106-107

Ear nose and throat (ENT) surgery accounts for 12% of all anaesthetics given in France amounting to ~ 670 000 cases annually [1]. Almost two-thirds of surgical procedures on children aged from 1 to 4 years are ENT related. Some of these procedures may be associated with significant morbidity and are conducted in a variety of hospitals including private and academic institutions. Furthermore, in most cases, anaesthesia is performed by teams that are not dedicated to paediatric anaesthesia. Respiratory complications are more frequently observed after ENT surgery compared with other surgical disciplines [2], and certain ENT procedures are frequently undertaken in patients presenting with risk factors for respiratory complications, such as anatomical abnormalities, obstructive sleep apnoea or pre-existing bronchial hyperreactivity.

This lecture will concentrate initially on the management of one of the most common ENT operations undertaken in children, tonsillectomy, and thereafter discuss the management of endoscopic ENT procedures, which although less frequent, require careful management of upper airway and ventilation skills.

Paediatric anatomy and physiology

Anatomy of the upper airway in children

The anatomical relationships between airway structures change as growth in childhood occurs [3]. When compared with the adult airway, differences are particularly marked in children < 1 year old. During the first months of life an infant breathes primarily through the nose. Therefore, it is important to maintain nasopharyngeal patency. However, if nasal obstruction occurs, a baby is only able to breathe through the mouth primarily by crying. This explains why conditions such as bilateral congenital choanal atresia are poorly tolerated and require correction early in the neonatal period.

Infant craniofacial morphology is associated with a large tongue that can occlude the palate and easily obstruct the airway especially if the infant becomes hypotonic during normal sleep or anaesthesia. The larynx is higher with a larger and more vertical epiglottis than in adults. During inspiration, the epiglottis may come into contact with the posterior soft palate, which will also favour nasal breathing. The pharynx, unlike the nasal passages or the larynx, does not have rigid walls. The tone of the dilator muscles of the pharynx is responsible for maintaining patency of this part of the airway in both children and adults. Thus maintenance of laryngeal patency is based on a balance of the negative pressure caused by diaphragmatic and intercostal muscle activity during inspiration on one hand, and on the pharyngeal dilator muscle tone on the other. Consequently, the use of jaw advancement manoeuvres or oropharyngeal airways is essential to address the reduced muscle tone caused by anaesthesia.

The classical image of the paediatric airway is that until adolescence the shape of the larynx appears as an inverted cone, with the circular cricoid cartilage representing the lowest and narrowest part that is most vulnerable to oedema and post-traumatic stenosis. Transition to adulthood is associated with a change in the shape of the larynx that becomes cylindrical. However a recent anatomical study using a video bronchoscopic technique under general anaesthesia suggests that the glottis, rather than the cricoid cartilage, is the narrowest part of the paediatric airway and that the paediatric airway, just like the adult airway, is more cylindrical than funnel shaped [4]. These new findings will need to be confirmed by further studies. The trachea is short (~ 4 cm in the neonate), increasing the risk of bronchial intubation. Therefore, bilateral lung auscultation is essential after tracheal intubation and each time the patient is repositioned.
**Pulmonary physiology**

When compared with their respective weights, all the physiological respiratory parameters in children are similar to those in adults, except for the respiratory rate that is about twice as high. Indeed the tidal volume, the dead space volume and the functional residual capacity (FRC) expressed in ml/kg are similar, but as the oxygen consumption is two to three times higher in children or neonates compared with adults, the increased respiratory rate is the only way to increase oxygen supply.

When respiratory mechanics are considered, newborns are characterized by a low lung compliance associated with a high chest wall compliance potentially favouring development of atelectasis (residual volume close to small airway closing volume). Physiological features in healthy awake infants may counteract this tendency. The presence of subglottic narrowing and a physiological tachypnoea generate an element of auto-peep; similarly, maintenance of diaphragmatic tone limits the extent of post inspiratory-expiratory alveolar collapse. Anaesthesia and tracheal intubation inhibit these compensatory mechanisms and expose the lungs to alveolar collapse and atelectasis. In addition, the ratio of alveolar ventilation to FRC is much higher than in adults, reflecting rapid exchange of alveolar gases and lower oxygen reserves. This explains the rapidity of inhalational induction associated with the speed of arterial desaturation in the case a decreased supply of oxygen when, for instance, apnoea occurs. These features illustrate the importance of pre-oxygenation before any period of anticipated apnoea, which mike should be kept as short as possible.

**Commonly presenting problems**

**The difficult airway**

Unanticipated difficult intubation occurs rarely in children with the exception of subglottic causes of airway occlusion [5]. In the context of ENT anaesthesia, the incidence of anticipated difficult intubation is more prevalent than in other specialties. Some syndromes include facial features that have significant implications for the management of the supraglottic airway. Among them, the most common are:

- Goldenhar syndrome (unilateral facial hypoplasia)
- Franceschetti or Treacher-Collins syndrome (mandibular dysplasia)
- oto-mandibular syndrome
- Pierre-Robin syndrome (micrognathia, cleft palate, glossoptosis)

Additionally, difficult intubation should be considered in children with:

- Down’s syndrome
- morbid obesity
- certain metabolic disorders associated with an increase of the soft tissues, such as mucopolysacharidosis

Similarly, clinical features associated with other pathological conditions may be considered to indicate a difficult airway:

- facial dysmorphism
- abnormal implantation of the ears (microtia) and lower jaw abnormalities [6]
- a thyromental distance < 15 mm in newborns, < 25 mm in infants, and < 35 mm in children <10 years of age
- mouth opening that accommodates < 3 of the child’s fingers
- Nocturnal snoring with or without obstructive sleep apnoea syndrome

(Note: the Mallampati classification is not validated in children below the age of seven)

As a child develops the degree of difficulty encountered with tracheal intubation may be reduced or get progressively worse. Irrespective of this, algorithms for the management of difficult intubation should be available and familiar to every member of the anaesthetic team. One of the principal advantages of anaesthesia for ENT based procedures is the availability of difficult airway equipment (specific laryngoscope blades and fibreoptic laryngoscopes) and clinicians trained in the skills of fibreoptic intubation and emergency tracheostomy.
Upper respiratory tract infection and airway hypereactivity

Among the risk factors that increase peri-operative respiratory complications, bronchial hypereactivity is the most frequent underlying pathophysiological condition encountered in paediatric anaesthesia. Bronchial hypereactivity commonly underlies many pulmonary conditions in children, among them asthma and upper respiratory tract infection (URTI), which have a high prevalence in routine paediatric anaesthetic practice, especially in ENT surgery. This is a common condition in children from 1 to 5 years of age and is usually viral in origin. Viral infection of the upper airway leads to airway hypereactivity persisting for 2-4 weeks [7-9]. This hypereactivity may be responsible for severe bronchospasm during airway manipulation in the absence of deep anaesthesia. In children, surgery performed after a recent airway infection increases the incidence of respiratory complications including laryngospasm, bronchospasm and peri-operative oxygen desaturation. This risk is increased in children under one year and where there is pre-existing lung disease (such as asthma and bronchopulmonary dysplasia) [9]. Children with an URTI scheduled for routine surgery should have the procedure postponed for 2 to 4 weeks to allow them to recover. If the surgery cannot be postponed, pre-operative administration of inhaled beta2-agonists (bronchodilator effects) may be useful [10]. The use of supraglottic devices to control the airway may be preferable. If the intended surgery allows use of a face-mask rather than a tracheal tube, then the face-mask should be employed. The more experienced the anaesthetic team, the better the management and anticipation of respiratory complications. For maintenance of anaesthesia sevoflurane, in contrast to desflurane, is preferable because it does not cause bronchoconstriction [11].

Obstructive sleep apnoea syndrome

Respiratory apnoea is defined as a cessation of ventilation of >10 seconds during sleep-related obstruction of the upper airway [12]. The most frequent aetiology in children is hyperplastic tonsils leading to pharyngeal airway obstruction. Many other pathological conditions can be associated with obstructive sleep apnoea syndrome (OSA), in particular facial dysmorphism or systemic diseases associated with large tongue or soft tissue hypertrophy. OSA is frequently responsible for episodes of hypoxaemia or hypercapnia or both; alterations of gas exchange may be particularly deleterious in some diseases such as sickle cell disease, and hence tonsillectomy is widely advocated for this condition.

Obesity increases the risk of OSA and it is an independent risk factor for respiratory complications postoperatively. These complications are more frequent following ENT surgery in children under 10 years, especially when OSA or upper airway hypereactivity is present (asthma or URTI) [13]. The diagnosis is mainly clinical and should be suspected if nocturnal snoring associated with pauses in breathing and nocturnal awakening is present. These sleep disorders are sometimes associated with hyperexcitability in the day. If OSA is due to hypertrophic tonsils, failure to thrive and eating disorders may be observed.

Morbidity associated with OSA is linked to both the respiratory effects (recurrent episodes of hypoxaemia and hypercapnia) and the cardiac consequences (pulmonary hypertension). Echocardiographic assessment may be required in more advanced forms.

In patients with OSA, anaesthetic induction is more often associated with significant airway obstruction, especially when using sevoflurane inhalation induction. In order to avoid this situation, some anaesthesiologists prefer intravenous induction which allows a shorter induction time. In an emergency, severe obstructive sleep apnoea syndrome and associated co-morbidities are risk factors for post-adenotonsillectomy respiratory complications. Atropine administration at induction may decrease the incidence of these complications [14].

Adenotonsillectomy for the treatment of OSA is associated with a significantly higher rate of postoperative respiratory complications in children below the age of 3 compared with children aged 3 to 5 years [15]. Hypoxaemia occurring with OSA is associated with increased sensitivity to morphine administration. Therefore, opioid dosing in children with OSA must take into account such a history [16, 17]. Consequently, severe forms of OSA in young children justify prolonged respiratory monitoring in the recovery room or post-anaesthesia care unit. Adenotonsillectomy for OSA results in a dramatic improvement in respiratory parameters as measured by polysomnography in the majority of healthy children. Quality of life also improves significantly [18].
Tonsillectomy

Although the absolute number of tonsillectomies is falling, the procedure is still frequently performed. The main indication for surgery is for children around the age of 3 years old with symptoms of obstruction attributable to hypertrophic tonsils. The aim of the pre-operative evaluation is to assess the respiratory and haemorrhagic risks and to provide appropriate peri-operative information to the child and its parents. Routine blood tests are not mandatory if clinical evaluation and examination are normal [19]. However, in the presence of clinical signs, or personal or familial history suggestive of increased tendency to bleed, a platelet count and activated partial thromboplastin time should be requested to evaluate the haemorrhage potential, especially in a child under the age of 3. The risk factors for respiratory complications and their management have already been discussed and can be summarised as severe obstructive sleep apnoea or bronchial hyperreactivity mainly due to URTI or asthma. Normal fasting rules apply to pre-operative anaesthetic management. Anxiolytic premedication may be useful except in cases where the patient presents with severe obstruction. Induction of anaesthesia by inhalation is the most commonly performed technique [20]. Intravenous induction may be preferred in older children or in cases of severe obstruction. Maintenance of anaesthesia by inhalation is often by a halogenated agent in combination with an intravenous opioid. Intra-operative fluid intake is based on the rule of '4-2-1', using an isotonic saline solution with a low concentration of glucose [21].

Optimal control of the airway is ensured by using a cuffed tracheal tube [22]. The can prevent the risk of aspiration and intra-operative laryngospasm (potentially caused by the failure of analgesia or stimulation laryngeal secretions or bleeding). A pre-formed oral tracheal tube is most often used to limit the risk of compression by the Boyle–Davis mouth gag - a device used to visualize the oropharynx and stabilise the tracheal tube during tonsillectomy. The administration of intra-operative anti-emetic doses of dexamethasone is recommended to reduce the incidence of PONV and the consequential delay before resuming food intake; however, some authors have recently questioned this strategy in view of the association postoperative bleeding [23]. Although the use of prophylactic antibiotics is commonplace, there is no objective recommendation for their routine prescription. For patients at risk for endocarditis, amoxycillin 30 min before incision is recommended.

Safe extubation is performed in the presence of an anaesthetist on a fully awake child, established by observing eye opening on demand. Postoperative monitoring in the recovery area is essential, especially to observe and monitor respiratory and bleeding complications. The length of stay in the recovery area should be extended in the case of young children with severe OSA. Discharge from the recovery area is based on the usual discharge criteria and verification by the surgeon that bleeding from the tonsillar bed is absent. Postoperative fluid administration is continued until the ability to drink has been re-established. Clear fluids can be introduced by the second hour postoperatively [24]. Due to the risk of early bleeding, the resumption of feeding should take place some hours postoperatively. Post-tonsillectomy pain can be severe and there is an important inflammatory component. The duration is, on average, eight days, with maximal discomfort during the first three days [25]. Postoperative pain management is based on IV morphine in the recovery area followed by administration of paracetamol and weak opioids such as codeine. The oral route of administration should be employed as soon as possible. Non-selective NSAIDs are not recommended because they may be associated with an increased frequency of re-operations for bleeding [26].

Respiratory complications, bleeding and PONV can all manifest during the first 24 hours postoperatively [27]. The main risk factors for respiratory complications are the severity of OSA and the degree of pre-operative arterial desaturation. Among patients with OSA, 70% of major respiratory complications occur in the first postoperative hour, whereas minor complications usually occur within six hours. Postoperative haemorrhage occurs in 0.5-3% of patients. Eighty percent of primary haemorrhages also occur within six hours. Approximately 25% of cases of postoperative bleeding will require further surgery. Patients requiring re-operation to establish haemostasis should be considered as having a full stomach and require a rapid sequence induction.

PONV is observed in 40 to 70% of patients. The use of nitrous oxide does not alter this incidence. PONV occurs less frequently after intra-operative propofol injection and prophylactic use of 5HT3 antagonists and dexamethasone. Protocols for the management of PONV should be provided and accessible in the postoperative period.
Day-case tonsillectomy can be achieved if consensus can be established between the surgeon, anaesthetist, and parents [28]. Day-case tonsillectomy should be achievable if:

- the child is more than three years old
- no co-morbidity likely to increase respiratory risk is present
- no coagulopathy is present
- severe sleep apnoea syndrome is not present
- the usual criteria regarding accompaniment by family a member and proximity of dwelling for safe discharge home are met

Discharge after the sixth postoperative hour is appropriate if:

- the surgeons have confirmed no bleeding from the tonsillar beds
- pain is controlled
- there is no PONV
- there are written instructions from the surgeon and anaesthetist

**ENT endoscopy**

Endoscopy can be employed both as a diagnostic tool and a method of delivery of treatment when visualisation of the upper airway (for example, the pharynx, larynx, trachea) is required. Endoscopy can be used to diagnose functional or anatomical abnormalities of the larynx, trachea and or proximal bronchi. Clinical signs that may lead to such an investigation may include stridor, dyspnoea, tachypnoea, repeated episodes of coughing and aspiration. Endoscopic resection of the aryepiglottic folds as a consequence of severe laryngomalacia is often associated with prematurity. Recurrent laryngo-tracheal papillomatosis invariably requires repeat endoscopic procedures either to permit submucosal injection of antiviral treatment or papilloma resection by laser therapy. Inhaled foreign bodies constitute the commonest indication for endoscopy in an emergency. Such procedures are commonly performed in children, often in specialist units that are able to combine paediatric and ENT expertise. It is unusual to perform procedures such as this as day-cases because of the risk of development of postoperative laryngeal oedema.

Anaesthetists face a challenge during ENT endoscopies because of the dual requirement to control the airway without unduly interfering with the surgeon’s ability to operate. Inevitably a compromise is sought between maintaining safe anaesthesia and surgical expediency. Airway management will be dependent on the nature of the surgery and the age of the patient. Whilst tracheal tubes (possibly a laser safe product when laser treatment is scheduled) provide the most secure airway from the point of view of anaesthesia, they impair the view of the supra- and subglottic regions and may cause trauma to particularly friable laryngeal and tracheal tissues.

High frequency jet ventilation uses a tracheal tube adaptor in place of the normal adaptor. A high pressure ‘jet’ of very brief duration, (~ 0.02 seconds) and at high frequency (~ 4-11 Hz) can be directed into the airway. The combination of small tidal volumes each delivered for a very short period of time creates the lowest possible distal airway and alveolar pressures produced by a mechanical ventilator. Depending on the position of the tip of the jet catheter, three modes of jet ventilation can be performed:

- supraglottic ventilation, the catheter is placed above the glottis. This position provides good visualisation of the glottis but control of ventilation is poor and this technique is not recommended in case of laryngeal stenosis
- translaryngeal ventilation, the tip of the jet catheter is positioned below the vocal cords and only impairs the surgical view moderately. There is the potential risk of barotrauma if the end-tidal airway pressure is not monitored
- the use of a transcutaneous trans-tracheal jet cannula allows excellent visibility within the operative field for the surgeon but has the potential to expose infants and young children to significant complications such as cervical emphysema, pneumothorax, bradycardia, hypotension [29].

Supraglottic high-/low-frequency ventilation via jet laryngoscopes with an integrated nozzle may provide a minimally invasive ventilation technique for neonates, infants and children to accommodate laryngo-tracheal surgery, and provides an unimpaired operating field for the surgeon especially for laser surgery [30].
Spontaneous ventilation, combined with supplementary nasal oxygen may be considered to be the gold standard for ENT endoscopies because this technique allows excellent visualisation of the laryngo-tracheal structures without the risk of trauma. However, the ability to preserve spontaneous ventilation while avoiding laryngospasm and apnoea can sometimes be difficult.

Whatever the mode of airway control, hypnosis can be provided by short-acting agents with rapid and predictable pharmacodynamics, such as sevoflurane and propofol, especially when spontaneous ventilation is required. From a pharmacodynamic point of view each agent has specific effects on the airways. For instance it has been shown that laryngospasm occurs more frequently during sevoflurane anaesthesia, whereas cough and expiratory reflexes (forceful exhalation without a preceding inspiration) occur more often during propofol anaesthesia [31]. When the effects of these agents are taken into consideration they can be regarded as being complementary and, therefore, may work advantageously if used in combination.

Effective analgesia can also reduce movement, the cough reflex and the risk of laryngospasm and bronchospasm. The pharmacokinetics of remifentanil may be beneficial because of its short context sensitive half-life [32], but there may be an increased risk of apnoea when it is used during spontaneous ventilation.

Lidocaine spray is used as a means of suppressing reflex responses to tracheal intubation. For ENT endoscopies, direct laryngeal/tracheal spray may be performed with 1% or 2% lidocaine (maximum 4mg/kg) as soon as the depth of general anaesthesia is sufficient. A 5% lignocaine spray is easy to use but should be limited to one spray in infants < 10 kg and two sprays if the weight is between 10 and 20 kg.

**Laser microsurgery**

There are three main indications for laser microsurgery within the airway. Treatment of recurrent respiratory papillomatosis is the most common. Other tumours such as the congenital sub-glottic haemangioma are amenable to laser treatment but it is used much less commonly for these indications. The use of laser microsurgery for treatment of severe anatomical abnormalities causing respiratory distress and stridor such as congenital laryngomalacia or acquired sub-glottic stenosis is a novel innovation that has been developed as an alternative to tracheostomy in an attempt to preserve tracheal function. However, use of a laser within the airway is associated with risks that must be fully acknowledged by the operating team. The most important risk is the potential for an airway fire caused by the laser. This risk can be minimised by employing the lowest inspired oxygen concentration possible, the use of air in preference to nitrous oxide, and the use of laser-resistant all-metal tracheal tubes. The threshold for airway combustion is not clearly defined, but some experts advocate an inspired oxygen concentration of 40%, although fires have occurred with inspired concentrations of between 25 and 40%. The use of volatile anaesthetics for laser microsurgery is somewhat controversial because of the potential to generate toxic compounds through the heat induced degradation of the anaesthetic agent, although they are neither flammable nor explosive at low concentrations. Delivery of laser energy at other anatomical sites can cause tissue damage; in particular the patient’s eyes must be protected. An alternative to jet ventilation or tracheal intubation may be spontaneous ventilation under intravenous propofol anaesthesia with a mixture of air and oxygen flow administered through a nasal catheter.

**Foreign body aspiration**

Aspiration of foreign bodies is a major cause of accidental death among young children [33]. This occurs predominantly in children aged < 3 years old. The majority of foreign bodies are found in the bronchial tree, with the remainder becoming lodged in the larynx or trachea. The incidence of right-sided foreign bodies is higher than that of left-sided foreign bodies. The presentation with a history of sudden cough, dyspnoea, wheezing, cyanosis or stridor, is very suggestive of foreign body aspiration. Most foreign bodies are composed of organic materials; only a small proportion are radio-opaque. The common radiographic abnormalities that may suggest an inhaled foreign body are emphysema and air trapping, atelectasis, infiltrates, and mediastinal shift. Although rigid bronchoscopy is the traditional diagnostic ‘gold standard’, the use of computerised tomography, virtual bronchoscopy, and flexible bronchoscopy is increasing. Although children with a pulmonary foreign body are frequently considered as having a full stomach, aspiration of gastric contents was not reported in a recent review of almost 13 000 cases [33]. Pre-operative assessment should determine where the aspirated foreign body has lodged,
what was aspirated, and when the aspiration occurred. The choices of inhalation or intravenous induction, spontaneous or controlled ventilation, and inhalational or intravenous maintenance may depend on the individual circumstances. Although several anaesthetic techniques are effective for managing children with foreign body aspiration, there is no consensus from the literature as to which technique is optimal. Induction and maintenance with spontaneous ventilation is commonly used to minimise the risk of converting a partial proximal obstruction to a complete obstruction. Controlled ventilation combined with intravenous anaesthesia and paralysis provides conditions suitable for rigid bronchoscopy. Close communication between the anaesthetist, bronchoscopist, and assistants is essential. Major complications include hypoxic cardiac arrest during retrieval of the object, severe laryngeal oedema, bronchospasm, pneumothorax, pneumomediastinum, tracheal or bronchial laceration, and hypoxic brain damage [33].

Conclusion

Ear nose and throat related procedures are the most frequent surgical operations performed in children from 1 to 4 years. Most of these procedures are managed in non-specialised hospitals by anaesthetists who are not exclusively dedicated to paediatric anaesthesia. In comparison to other types of surgery, ENT surgery is associated with higher incidence of respiratory complications during and after anaesthesia. These complications are frequently related to existing co-morbidities such as bronchial hypereactivity, obstructive sleep apnoea, facial malformations or obesity. Because tonsillectomy is one of the most common ENT procedures performed in children, the principles governing its management are now well established and due consideration should be given to observation for respiratory and haemorrhagic complications. Endoscopic procedures although performed less frequently required a more specialised environment, with the requirement to provide airway management techniques using equipment appropriate to both the age of the child and the intended surgical procedure.

Key learning points

• The anaesthetist should have a good understanding of airway anatomy and physiology in children, in order to reduce respiratory complications associated with ENT surgery.
• ENT surgery is associated with an increased risk of peri-operative respiratory complications. Other risk factors frequently encountered are Obstructive Sleep Apnoea, airway hypereactivity (URTI and asthma), airway abnormalities and obesity.
• Frequently performed ENT procedures such as tonsillectomy are often undertaken by non-specialised anaesthesia staff in non-paediatric centres. Other more specific procedures should take place in specialised centres.
• In ENT cases involving a shared airway, the aim should be to achieve the best compromise between safe airway management and a clear operating field. This requires close cooperation between anaesthetist and surgeon.

References


