Pediatric Otolaryngology

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Introduction

Otolaryngologic procedures are commonly performed on children. In fact, pressure equalizing tube placement (ear tubes) and adenotonsillectomy are among the most frequent surgical interventions in the pediatric population. Therefore, every anesthesiologist who manages children undergoing otolaryngologic procedures must be familiar with the special implications of sharing the pediatric airway with an otolaryngologist working in the head and neck region. In addition, it is imperative to be skilled in the challenges of compassionately yet safely managing anxious young patients and their parents from the time of preoperative assessment until discharge from the post anesthesia care unit.

While there are few anesthetic challenges as potentially serious as the emergency management of a compromised airway in a small infant, even general otolaryngologists and anesthesiologists need to develop the skills unique to pediatric practice. In addition, the presence of congenital anomalies that alter the architecture of the upper aerodigestive tract poses unique challenges in airway management. The principles outlined in this chapter will serve as a valuable tool in understanding the coordinated effort that is needed to manage the airway in this delicate population of patients.

General Considerations

There are general considerations for every pediatric otolaryngologic patient. These procedures involve the oral cavity, pharynx, larynx, tracheobronchial tree or structures in close proximity to the airway such as the ear and neck. Therefore, close communication between the anesthesiologist and otolaryngologist throughout the procedure is of paramount importance.

Head and neck procedures often require turning of the head for the procedure and/or the operating table 90° or 180°. This renders the endotracheal tube (ETT) relatively inaccessible to the anesthesiologist. Extra care should be taken to ensure that the tracheal tube is securely fastened and that there are no kinks. The anesthesia circuit should be secured; however, it should not be anchored tightly to the patient or the operating room table since the otolaryngologist may move the head during the procedure which may result in inadvertent extubation or mainstem intubation. Also, decisions regarding the placement (e.g., nasal vs. oral, left-side vs. right-side), and the type (e.g., oral RAE, named after the inventors Ring, Adair & Elwyn, nasotracheal) of ETT are primarily dictated by patient considerations, the surgical procedure, and the otolaryngologist's preference. Therefore, a discussion between the anesthesiologist and the otolaryngologist should take place prior to the induction of anesthesia.

The Pediatric Patient: Unique Considerations

Pediatric Airway Anatomy

Anatomically, the pediatric airway is significantly different than the adult airway. This is most dramatic in the infant, becoming less so as the child ages and matures. By age 8–10, the larynx has developed into a configuration close to that in an adult. Marked differences are seen in the infant's head shape, tongue, hypopharynx, and larynx that impact on anesthetic management of these patients (Table 20.1).

In infants, the occiput is large obviating the need to place a pillow under the head to achieve the optimal intubating position ("sniffing") as in the adult. In fact, the large occiput

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A.I. Levine et al. (eds.), *Anesthesiology and Otolaryngology*,
DOI 10.1007/978-1-4614-4184-7_20, © Springer Science+Business Media New York 2013

Table 20.1 Anatomic airway differences and their anesthetic implications

Difference	Implication
Large occiput	Shoulder roll
Relative large tongue	Difficult mask ventilation and laryngoscopy
Epiglottis long, omega shaped, floppy, and angled away from the axis of the trachea	Straight laryngoscope blade
Larynx cephalad (C3–4)	Straight laryngoscope blade
Vocal cords anterior attachment more cephalad than posterior	ETT caught by anterior commissure of vocal cords
Cricoid ring narrowest area	Tight ETT may lead to post-extubation stridor

ETT endotracheal tube

Table 20.2 Uncuffed and cuffed ETT size based on age

Age	Uncuffed ETT size (ID mm)	Cuffed ETT size (ID mm)
0–3 months	3.0	3.0 uncuffed
3–8 months	3.5	3.0
8–15 months	4.0	3.5
15–24 months	4.5	4.0
2 years and older	(16 + age in years)/4	16 + age in years/3.5

ID internal diameter

may result in excessive flexion of the neck that necessitates placement of a shoulder role to provide adequate visualization of the larynx. The tongue is large in comparison with the oral cavity making mask ventilation and laryngoscopy more difficult. The epiglottis is relatively long, omega shaped, floppy, and angled away from the axis of the trachea. This makes visualization of the glottic opening difficult with a curved laryngoscope blade placed in the vallecula. Therefore, visualization of the glottic opening is more easily achieved with a straight rather than curved laryngoscope blade. The infant larynx is more cephalad than the adult larynx, lying at the C3–4 level in contrast to the C4–5 level of the adult larynx. In preterm infants, the larynx is even more cephalad, at the C3 level. The more cephalad position of the larynx makes the straight laryngoscope blade more effective for visualizing the airway than a curved blade.

The anterior attachment of the vocal cords is more caudad than the posterior attachment, in contrast to the adult vocal cords that are perpendicular to the tracheal axis. This can lead to difficulty with tracheal intubation because there is a tendency for the ETT to be caught by the anterior commissure of the vocal cords or the anterior subglottis.

The narrowest portion of a child's airway is in the subglottis at the cricoid cartilage level, as opposed to the glottic opening in the adult. Clinically, this can result in the ETT passing easily through the vocal cords but fitting tightly in the subglottic area. Since the cricoid cartilage forms a complete ring that is not expandable, a snug ETT can compress the tracheal mucosa [1], possibly leading to laryngeal edema, post-extubation stridor or even residual stenosis. Based on this, the traditional teaching is that uncuffed ETTs should be used in the pediatric patient until the age of 8–10 years. The appropriate sized tube is determined by age [2] (Table 20.2).

It is important to confirm the presence of a leak around the ETT once intubation is accomplished and the position is confirmed by the presence of end tidal carbon dioxide ($ETCO_2$) and auscultation of bilateral breath sounds. Since the adult tracheal mucosal capillary pressure is considered to be 30 cm H_2O, the leak should be less than 30 cm H_2O but above the peak inflation pressure (PIP) generated during positive pressure ventilation. The leak is determined by listening over the patient's mouth while the PIP slowly rises by incremental closure of the adjustable pressure-limiting (APL) valve. The pressure at which a leak is first heard determines how snug the fit is. In some instances, the "perfect" sized uncuffed ETT cannot be found and either a "tight" fit must be tolerated or a large leak is compensated by the use of high fresh gas flows.

Over the past two decades, there has been increasing evidence that the use of cuffed ETTs in the pediatric population is not associated with an increased incidence of post-extubation stridor and may in fact be beneficial [3–5]. A cuffed ETT allows for adjustment of the leak around the ETT precluding the need for multiple laryngoscopies in an attempt to find the right size uncuffed ETT that allows for adequate ventilation but that is not too "tight." Multiple laryngoscopies in and of itself may lead to an increased incidence of post-extubation stridor.

Other advantages of cuffed ETTs are decreased operating room contamination with anesthetic gases, decreased fresh gas flows [4], more accurate respiratory parameter measurements (e.g., tidal volume, $ETCO_2$), and decreased risk of pulmonary aspiration [6]. Also, in patients whose pulmonary compliance may change during the surgical procedure (e.g., laparoscopy) or during the postoperative period (e.g., pulmonary edema), a cuffed ETT allows for adjustment of the leak as the need arises without compromising patient safety (Table 20.3).

Because the presence of a cuff increases the outer diameter of the ETT, the ETT placed should be one half size smaller than the calculated uncuffed ETT for that patient. For example, if a 5.0 uncuffed ETT is calculated, a 4.5 cuffed ETT should be placed (Table 20.2). The presence for a leak should be ascertained as described above and the cuff adjusted accordingly.

Table 20.3 Advantages and disadvantages of uncuffed versus cuffed ETT

Uncuffed ETT		Cuffed ETT	
Advantages	Disadvantages	Advantages	Disadvantages
Largest internal diameter • ↓Airway resistance • ↓Work of breathing	Multiple laryngoscopies • Trauma to larynx • Post-extubation stridor	Limited laryngoscopies • ↓Trauma to larynx • RSI	Smaller internal diameter • ↑Airway resistance • ↑Work of breathing
Easier to suction secretions	Unable to adjust leak • Need to reintubate when patient critically ill • Unable to accommodate changes in pulmonary compliance intraoperatively	Ability to adjust leak during changes in pulmonary compliance • Laparoscopy • ARDS	Difficult to suction secretions because of smaller size
Less mucosal damage	Pulmonary aspiration risk	↓Pulmonary aspiration risk	Mucosal damage from cuff • Post-extubation stridor
	May need higher FGF	↓FGF	
	OR pollution	↓OR pollution	
	Inaccurate $ETCO_2$ and TV measurements	↑Reliability of $ETCO_2$ and TV measurements	

ETT endotracheal tube, *RSI* rapid sequence induction, *FGF* fresh gas flow, *OR* operating room, *$ETCO_2$* end tidal carbon dioxide, *TV* tidal volume, *ARDS* adult respiratory distress syndrome

Additional evidence to support the use of cuffed ETTs is that the cricoid ring is not circular but ellipsoid, with the transverse diameter being greater than the anterior to posterior diameter [7]. Thus, a round uncuffed ETT may place excessive pressure on the mucosa anteriorly and posteriorly when trying to occlude a leak that is caused by the larger transverse diameter. A cuffed ETT seals the airway at the tracheal level allowing for a more even pressure distribution when inflating the cuff.

Tracheal length varies with age, with infants being 5–9 cm [8, 9]. Appropriate positioning of the ETT is crucial to avoid endobronchial intubation or, if using a cuffed ETT, to avoid herniation of the cuff through the vocal cords. Due to the short length of the trachea in infants, there is less room for error. As measured at the alveolar ridge, appropriate insertion distance is as follows: 10 cm for a newborn, 11 cm for a 1 year old, and 12 cm for 2 years old [10]. The formula 12 + age/2 [11] or 13 + age/2 [12] is used for children older than 2 years. Of course, auscultation for equal bilateral breath sounds should be the final determinant of appropriate ETT position. Flexion of the head displaces the ETT distally whereas head extension displaces the ETT proximally possibly resulting in accidental extubation [9, 13]. Placement of a tongue depressor in the mouth causes distal displacement of the ETT as well [13]. During otolaryngologic procedures, head extension commonly occurs, particularly during adenotonsillectomy, which may displace the ETT proximally. Placement of a mouth retractor may displace the ETT distally. Therefore, after positioning for adenotonsillectomy, position of the ETT should be reconfirmed.

The most common type of laryngoscopy blade used in the pediatric population is the straight blade for reasons described above. A Miller 0 blade is usually used for preterm and full-term neonates. A Miller 1 blade is usually used for neonates up to 18 months of age. A Wis-Hipple 1.5 blade is used for patients 18 months to approximately 6 years of age. Thereafter, a Miller 2 blade is appropriate. A curved blade (Macintosh) may be used in children 2 years and older. It is always a good idea to prepare multiple size laryngoscope blades since not all pediatric patients are the same size despite being the same age.

Pediatric Physiology (Table 20.4)

Respiratory

Closing volume (CV) is increased in infants and is within resting tidal volume [14]. CV is defined as that lung volume at which small airways begin to close. This results in alveoli distal to the airway closure to collapse by absorption atelectasis causing shunt and hypoxia. For this reason, an infant's oxygen saturation decreases rapidly when they breath hold, cough, or "buck" with an ETT in place.

Chest wall compliance is increased in the infant because of predominantly cartilaginous ribs. During periods of increased negative pressure in the thorax, the chest wall collapses to a greater degree than in the older child resulting in an increased work of breathing and decreased ventilation. This is even more evident when airway obstruction exists. Furthermore, the intercostal and diaphragmatic muscles are immature. There are two types of muscle fibers, Type I and Type II. Type I muscle fibers consist of slow-twitch, high-oxidative fibers

Table 20.4 Physiologic changes and their anesthetic implications

Physiologic change	Clinical implications	Anesthetic implication
↑CV	Within tidal volume Absorption atelectasis and shunt	Oxygen desaturation with breath holding and "bucking" on ETT
↑Chest wall compliance	Collapse of chest wall with negative intrathoracic pressure during airway obstruction	Intubation and mechanical ventilation under general anesthesia
↓Type I muscle fibers	Respiratory fatigue with persistent airway obstruction	Intubation and mechanical ventilation under general anesthesia
↑$\dot{V}_A$	Increased respiratory rate	Quicker inhalation induction
↑$\dot{V}_A$/FRC	Low oxygen reserve	Rapid oxygen desaturation during airway obstruction or apnea
↓Cardiac muscle compliance	Stroke volume fixed Cardiac output heart rate dependent	Bradycardia not well tolerated Anticholinergic administration
Immature sympathetic system	Bradycardia with vagal stimulation and hypoxia	Anticholinergic administration

CV closing volume, *ETT* endotracheal tube, $\dot{V}_A$ alveolar ventilation, *FRC* functional residual capacity

Table 20.5 $\dot{V}_A$/FRC at various ages

	Infant (4 kg)	3 YO (15 kg)	5 YO (18 kg)	Adult (70 kg)
$\dot{V}_A$	600 150 mL/kg	1,755 117 mL/kg	1,800 100 mL/kg	4,200 60 mL/kg
FRC (mL)	120	490	680	2,800
$\dot{V}_A$/FRC	5/1	3.5/1	2.6/1	1.5/1
$\dot{V}O_2$ (mL/kg/min)	6–8	4–6	4–6	3–4

$\dot{V}_A$ alveolar ventilation, *FRC* functional residual capacity; $\dot{V}O_2$ oxygen consumption

and are important for sustained activity. Type II muscle fibers consist of fast-twitch, low-oxidative fibers, and are important for short bursts of increased activity. The diaphragm in the infant is composed of 25% Type I muscle fibers in contrast to the adult that has 55% Type I muscle fibers. The infant's intercostal muscles are composed of 45% of Type I muscle fibers whereas in the adult there are 65% Type I muscle fibers. This places the infant at risk for respiratory fatigue when challenged with airway obstruction for a prolonged period of time. The adult composition of muscle fibers is achieved by 1 year of age [15]. For these reasons, decreased chest wall compliance and decreased presence of Type I muscle fibers, it is recommended that infants less than 12 months of age should be tracheally intubated and mechanically ventilated during general anesthesia except for possibly a short procedure lasting less than 1 h.

Alveolar ventilation ($\dot{V}_A$) in the infant is two to three times the adult value and is due to an increased respiratory rate since TV on a per kilogram basis (7 mL/kg) is the same in the infant and the adult. This accounts for the more rapid onset of general anesthesia during an inhalation induction in the infant when compared to an adult.

Young children and especially infants are particularly susceptible to rapid oxygen desaturation with even brief periods of airway obstruction. This is because of their increased oxygen consumption and increased ratio of alveolar ventilation ($\dot{V}_A$) to functional residual capacity (FRC) or apneic oxygen reserve [14]. The $\dot{V}_A$/FRC ratio can be as high as 5:1, as compared to the adult value of 1.5:1. (Table 20.5)

Cardiovascular

Cardiac output is increased in the infant to meet the increased oxygen demand. Cardiac output in the neonate is approximately 350 mL/kg/min and in the infant 150 mL/kg/min as compared to the adult value of 75 mL/kg/min. The heart of the infant is less compliant than the adult heart because of a decrease in the contractile muscle mass [16]. Because of this, the stroke volume is relatively fixed and the infant cannot compensate for a decreased cardiac output by increasing stroke volume. Therefore, the infant's cardiac output is heart rate dependent and bradycardia should be treated expeditiously.

The infant is considered "vagotonic" because of an immature sympathetic system. Therefore, vagal stimulation, such as during laryngoscopy, and hypoxia will result in significant bradycardia that in turn will result in a decreased cardiac

Table 20.6 Indications for anticholinergic medication

1.	Age <6 months
2.	Development of bradycardia
3.	History of bradycardia during induction or intubation
4.	Procedures inducing the vagal reflex (e.g., oculocardiac reflex)
5.	Succinylcholine
6.	High-dose opioids
7.	Ketamine
8.	Excessive secretions
9.	Oral surgery
10.	Position other than supine

output. Also, succinylcholine has been described to cause bradycardia with the first dose. In the past, most pediatric patients arrived to the operating room significantly sedated. When these sedated patients were induced with halothane, the induction agent of choice before sevoflurane, significant bradycardia and hypotension occurred. For this reason, many anesthesiologists routinely administered anticholinergic premedication, either atropine or glycopyrrolate, prior to or during induction. This practice has changed over the last two decades [17, 18] because of the use of newer anesthetics that do not cause excessive secretions or bradycardia. In addition, although premedication is still used, the depth of sedation is much less than it was in the past and bradycardia is rarely seen on induction of general anesthesia. Even the premise that succinylcholine causes significant bradycardia with the first dose has been challenged [19]. Indications for anticholinergic premedication are listed in Table 20.6.

The dose of atropine depends on the age of the child. A minimum dose of 0.1 mg has been advocated because of the theoretical concern of bradycardia occurring if a smaller dose is administered. However, this would be a massive dose on a per kg basis if given to a preterm infant and has resulted in tachycardia greater than 200 for a prolonged period of time. The current recommendation for atropine dosing is as follows:

<5 kg: 20 mcg/kg

≥5 kg: 10–20 mcg/kg with a minimum dose of 0.1 mg

Laryngospasm

Laryngospasm is more common in the pediatric patient [20], especially in the patient with a URI or recent URI [21], use of a laryngeal mask airway (LMA) [22], and after surgical procedures involving manipulation of the airway, particularly adenotonsillectomy [23]. Stimulation of the larynx, either by laryngoscopy or secretions, during "light" anesthesia may result in either partial or complete laryngospasm [24]. Both partial and complete laryngospasm share the same clinical

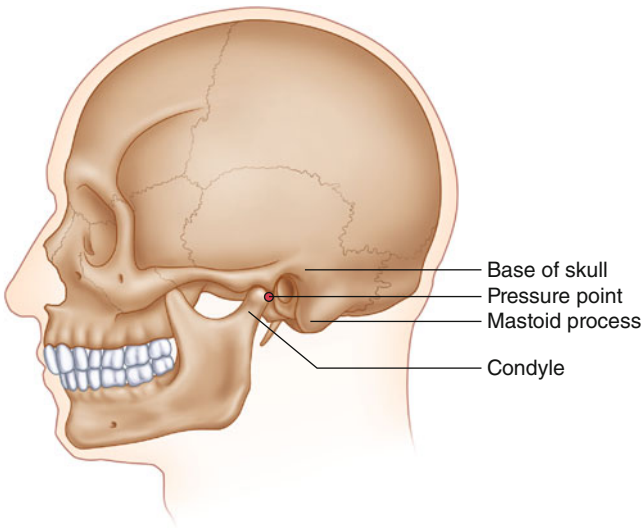

Fig. 20.1 Laryngospasm notch

signs of tracheal tug and paradoxical movement of the chest and abdomen. They are differentiated by the presence of a high-pitched inspiratory sound in partial laryngospasm versus the absence of respiratory sounds in complete laryngospasm [25]. If not treated expeditiously, rapid oxygen desaturation and bradycardia will ensue. Therefore, atropine and succinylcholine should always be available, in both intravenous (IV) and intramuscular (IM) doses, when caring for these patients. Treatment of partial laryngospasm consists of removing the noxious stimulus (surgical stimulus, secretions), applying positive pressure to the airway with 100% oxygen, and deepening the anesthetic with either a volatile agent or propofol (0.5 mg/kg) [26]. If these maneuvers fail, succinylcholine, 1–2 mg/kg IV or 4 mg/kg IM, should be administered. Atropine, 20 mcg/kg IV/IM, should be administered if hypoxia and bradycardia occurs [27]. Complete laryngospasm rarely resolves with positive pressure alone and a jaw thrust maneuver should be applied [27]. Alternatively, pressure on the laryngospasm notch (Fig. 20.1) has been shown to cause relaxation of the vocal cords. The laryngospasm notch is located behind the ear in the area posterior to the ascending ramus of the mandible, anterior to the mastoid process, and caudad to the base of the skull. Pain caused by pressure in this area results in afferent input to the vocal cords causing them to relax [28, 29].

Upper Respiratory Infection

Upper respiratory infections (URI) are very common in children, especially during the winter months. The decision whether to proceed with elective surgery as scheduled or to postpone the procedure still remains difficult and controversial. There is often considerable pressure to proceed in

less than optimal circumstances for nonmedical reasons (such as parent's work obligations or a child's school calendar). While not every minor cold necessarily precludes a safe anesthetic, one must never compromise the patient's safety out of deference to convenience.

URI in the pediatric patient undergoing general anesthesia is associated with an increased risk of laryngospasm, bronchospasm, secretions clogging the ETT, post-extubation stridor, and desaturation in the post-anesthesia care unit (PACU) requiring supplemental oxygen [30, 31]. Although these complications are real, multiple studies have shown that they do not result in significant morbidity when identified and treated appropriately [30, 32, 33]. Risk factors associated with increased incidence of adverse respiratory events are listed in Table 20.7 [30]. The type of procedure, necessity of tracheal intubation, and the general health of the child preoperatively should all be considered in deciding whether to delay or proceed with elective surgery. A reasonable approach to the child with an URI is summarized in Fig. 20.2.

If surgery is postponed because of an active or recent URI, considerations for rescheduling should be made to minimize the risk of the aforementioned complications.

Table 20.7 Risk factors associated with increased incidence of adverse respiratory events in the child with a URI [30]

1. Copious secretions
2. Nasal congestion
3. Use of ETT in children <5 years of age
4. History of prematurity
5. History of reactive airway disease
6. Parental smoking
7. Surgery involving the airway

URI upper respiratory infection, *ETT* endotracheal tube

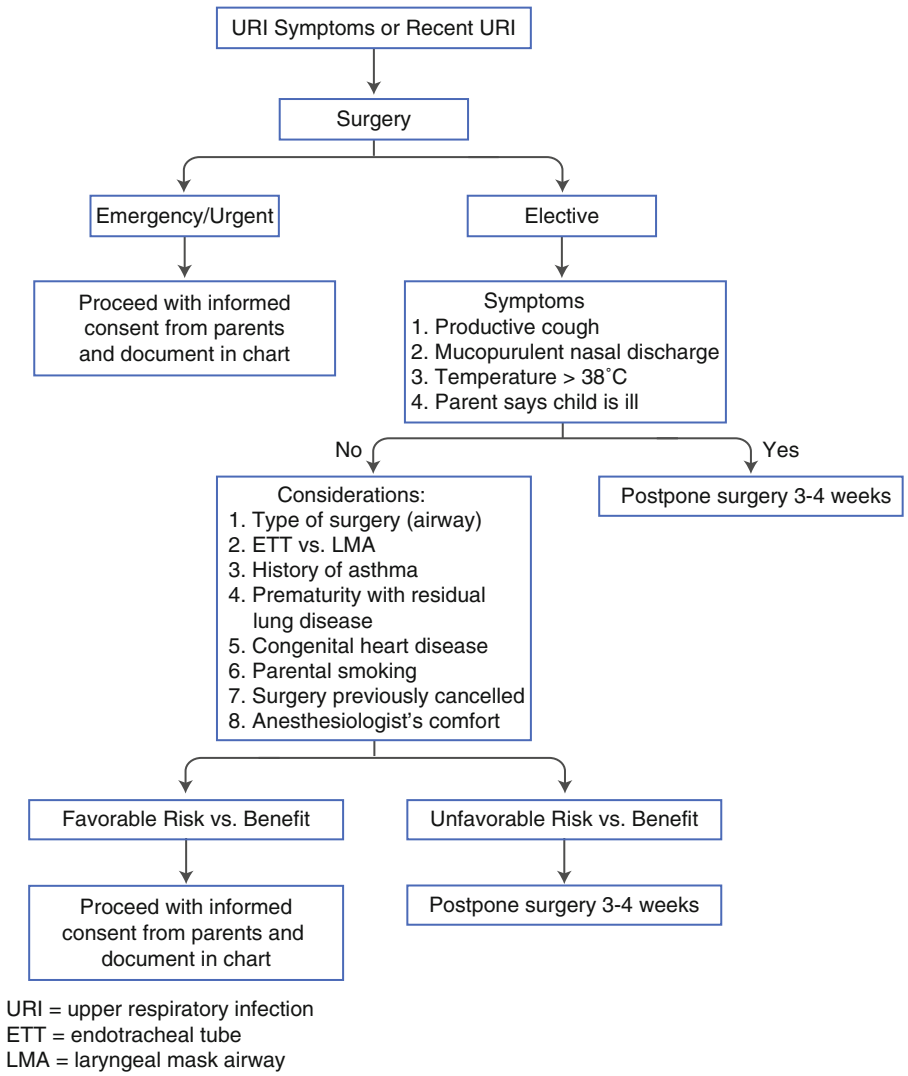

Fig. 20.2 Approach to the child with URI symptoms

The literature has shown that despite symptom resolution, the airways remain hyperreactive even 4–6 weeks after an URI [34, 35]. Due to the frequency with which pediatric patients have URIs, waiting such a long interval to proceed with surgery may not be feasible or practical. It is the authors' opinion that postponing surgery for 3–4 weeks is a reasonable option. If the anesthesiologist and otolaryngologist agree to proceed with surgery, the parents must be informed of the potential risks and benefits of proceeding with surgery. The parents must be active participants in the decision and the discussed plan documented in the medical record. Although a more in-depth discussion of this issue is beyond the scope of this chapter, a good review is available [36].

Malignant Hyperthermia

Malignant hyperthermia is a pharmacogenetic disorder of skeletal muscles that is triggered by potent inhalation agents and/or succinylcholine [37]. This hypermetabolic syndrome is the result of a massive release of calcium in the muscle that causes sustained muscle contractures. The incidence of MH varies but what is clear is that there is a higher incidence of MH in the pediatric versus adult population [38]. However, the incidence of MH may be decreasing because of the decreased routine use of succinylcholine in the pediatric population secondary to reports of hyperkalemic arrest in patients with undiagnosed muscular disease [39]. Therefore, any anesthesiologist caring for the pediatric patient should be aware of the clinical manifestations of MH and know how to diagnose and treat it. Additionally, obtaining a prior history of MH, in the patient and family, should be part of every preoperative evaluation so that appropriate preparation can be made prior to the initiation of any anesthetic. The reader is referred to the Malignant Hyperthermia Association of the United States website (www.mhaus.org) and to other major pediatric texts for an extensive review of this disorder as well as how to manage these patients.

Preoperative Preparation

The induction of general anesthesia and the anticipation of surgery are both extremely anxiety provoking, both for children and their parents. One of the more difficult skills to master is the appropriate tone to take in the perioperative period. In addition, different families require different approaches, and it takes an experienced practitioner to determine whether to be serious, jocular, authoritarian, or deferential in order to put patients and their parents at ease. Unfortunately, there is little that we can add to this chapter that will supplant experience.

Our approach to minimizing perioperative stress for our patients and their families involves a multimodal, educational program that starts before the day of surgery and includes written material, phone interviews, and on-site visitation. In addition to providing handouts that cover frequently asked questions about anesthesia (Appendix A), telephone access to members of the pediatric anesthesia team is made available since many questions are best answered before the stressful morning of surgery. Another extremely successful intervention offered by the child life service at our institution is the "Meet Me at Mt. Sinai" program that includes a pediatric nurse practitioner, pediatric social worker, and pediatric child life specialist. A developmentally appropriate program is designed based on the needs of the individual pediatric patient and includes a tour of the hospital, a video of a typical induction of general anesthesia, and introduction to some of the anesthetic equipment (e.g., face mask). Younger children are provided with a medical kit and a doll they can "doctor" to play out their upcoming surgical experience. While this program may not be appropriate for all children, many older children find the experience interesting and extremely effective in addressing anxiety ahead of time. This program has received very favorable feedback from patients and their families.

Premedication

Premedication can be administered to decrease preoperative anxiety. However, it should not be routinely used in all children but rather a judicious decision made based on the child's age, degree of preoperative anxiety, duration of surgery, and possible delay in discharge from the PACU. Other factors such as availability of appropriate monitoring in the preoperative area and the presence of comorbidities (e.g., airway compromise) must be taken into consideration as well. Parental request for premedication should be granted if possible. Children who are difficult to control preoperatively, particularly those with developmental delays and behavioral disorders, may benefit from premedication.

Midazolam is commonly used for premedication [40] through a variety of routes [41–43]. However, concern has been raised about its potential for neurotoxicity when administered intranasally since there is a direct communication from the nasal mucosa to the central nervous system via the cribiform plate [44, 45] Therefore, when administering midazolam via the intranasal route, the preservative-free formulation should be used. The same applies to intranasal ketamine.

Ketamine as a premedication is usually reserved for the difficult, uncooperative patient, particularly those with severe developmental and behavioral disorders. Although it may be administered via the oral or intranasal route, this is often difficult in the uncooperative and combative patient. In these cases, the intramuscular route becomes the only available option. Side effects of ketamine include excessive oral secretions and postoperative hallucinations and nightmares [46]. For these reasons, an antisialagogue, atropine or

Table 20.8 Commonly used premedications

Medication	Dose (mg/kg)	Route	Onset (min)	Duration (min)
Midazolam	0.5–0.75 0.2	Oral Intranasal	15–30 10–15	60–90 60
Ketamine	3–6 3–5	Oral Intramuscular	10–20 5	30–90 30–60

Table 20.9 Comparison of halothane and sevoflurane MAC values

Halothane		Sevoflurane	
Age	MAC	Age	MAC
Neonate	0.87%	<6 months	3.3%
1–6 months	1.2%	1–10 years	2.5%
>1 year	1%	>10 years	2–2.5%
Adult	0.87%	Adult	2%

glycopyrrolate [47], and midazolam should be administered to counteract these possible side effects [46].

An extensive review of pharmacologic agents available and their various routes for administration is not possible in this chapter and the reader is referred to major pediatric anesthesia texts for more detailed information. The most common pharmacologic agents and their routes are listed in Table 20.8.

Finally, the question often comes up regarding the presence of a parent in the operating room during induction. This is frequently requested, and we have developed guidelines balancing the potential positive and negative effects on anxiety for the patient and parent, as well as, our concern about patient safety. For children over 9 months of age, we allow one parent to be present during induction. While parents of younger children may also request this, the potential for a difficult induction as well as the lack of separation anxiety in very young infants leads us to deny this request in most circumstances. Furthermore, the presence of two parents often introduces new variables into an already stressful situation, and it is not uncommon for underlying unfavorable interpersonal dynamics to become evident. Parents with any condition that could put them at risk for syncope or the need for attention, such as extreme anxiety, unstable cardiac disease, or pregnancy, are also excluded from the operating room.

Anesthesia Induction

Preparation for the administration of an anesthetic is of paramount importance to the safety of your patient. Checking the anesthesia machine and preparing appropriate sized equipment should be performed prior to every anesthetic. Monitoring of the pediatric patient is in line with the standards set by the American Society of Anesthesiologists. The only caveat is that appropriate sized electrocardiogram pads, pulse oximeter probes, and blood pressure cuffs should be available. Although every effort should be made to apply these monitors prior to induction of anesthesia, this is not always possible. The combative, uncooperative child may not allow for placement of these monitors, or if placed remove them. Of all the monitors, the pulse oximeter probe provides the most valuable information, oxygen saturation and heart rate, and all efforts should be made to at least place this monitor prior to induction. In the rare circumstance when this is not possible, induction of anesthesia can proceed but the pulse oximeter probe should be placed as soon as possible. A precordial stethoscope is beneficial as well by providing the ability to assess breath and heart sounds continuously.

The most common method of induction in the pediatric patient is an inhalation induction by facemask with a nonpungent volatile agent. Sevoflurane has nearly replaced halothane because of its faster onset and its favorable cardiovascular profile [48]. The minimum alveolar concentration (MAC) of the volatile agents varies with age. Comparison of the MACs of halothane and sevoflurane is in Table 20.9 [48–50].

As the anesthetic depth deepens, there may be a period of excitation and agitation prior to entering the surgical plane of anesthesia. This period, Stage 2, is manifested by increased muscle tone, divergent eyes, large pupils, increased heart rate, increased respiratory rate, and at times difficulty in maintaining a patent airway. It is during this stage that laryngospasm is likely to occur, particularly if the patient is stimulated such as during IV placement. The surgical team should not be examining the patient at this time as well. Therefore, it is beneficial to quickly advance to Stage 3 (surgical plane). Maintaining a high concentration of sevoflurane until this stage of anesthesia is bypassed will decrease the time spent in Stage 2. These authors do not turn down the sevoflurane concentration until a decrease in the heart rate is seen heralding the onset of Stage 3. The patient should not be stimulated by anyone until the anesthesiologist has determined that the patient is at an appropriate depth of anesthesia.

The Difficult Airway

Before proceeding to specific recommendations for individual otolaryngologic procedures, a few words are appropriate about the pediatric "difficult airway." This is a term that is poorly defined, and often misunderstood in our experience. It is frequently used to describe a patient in whom previous attempts at elective endotracheal intubation have been problematic or unsuccessful, or who by physical examination is noted to have anatomic features that would predict difficult mask ventilation and/or intubation. Physical

findings that would suggest difficulty are large tongue, small mouth opening, micrognathia, cervical spine abnormalities, and congenital anomalies (e.g., Goldenhar) involving the airway. The best way to think critically about a patient with a difficult airway, and to prepare for intubation, is to realize that there are two main categories of this patient class—children in whom it is difficult to pass the endotracheal tube *through* the glottis (group I), and children in whom it is difficult to maneuver the endotracheal tube tip *to* the glottis (group II).

Group I includes primarily glottic and subglottic obstructive lesions—laryngeal webs, foreign bodies, papilloma, subglottic stenosis, or intraluminal mass lesions (e.g., hemangiomas or cysts). Although these conditions are described elsewhere in this volume, a review of the techniques of airway surgery used to address them is beyond the scope of this chapter.

Group II includes patients with craniofacial malformations, especially those involving micrognathia: the Robin anomalad, Treacher–Collins syndrome, or Trisomy 18. Another set of conditions that may limit exposure of the larynx include macroglossia (e.g., Beckwith–Wiedermann syndrome, Down syndrome), and other situations in which soft tissue is obscuring the approach to the airway (e.g., hypopharyngeal cysts or tumors). Patients with trismus (e.g., temporomandibular joint ankylosis) also does not allow for standard direct laryngoscopy intubation techniques.

These patients are a challenge for the otolaryngology-anesthesiology team. Before induction of anesthesia, a full range of primary and backup plans for securing the airway must be planned and agreed upon, with all appropriate equipment immediately available. Consideration should even be given to a temporary tracheotomy done under local anesthesia if orotracheal intubation is not feasible. Even if this is not the primary plan, and other approaches to intubation are preferred, an open tracheotomy set must be in the room in case intubation is unsuccessful and ventilation by facemask becomes impossible during the administration of the anesthetic.

Many options exist for managing the difficult airway and include flexible fiberoptic intubation, Bullard laryngoscope [51], videolaryngoscope [52], lighted stylet [53], LMA [54], and retrograde wire-guided intubation [55]. It is not feasible to be an expert in all these techniques but rather the anesthesiologist should become very familiar and comfortable with one or two of them. The most commonly used options are the flexible fiberoptic bronchoscope, videolaryngoscope, and LMA.

The advent of small caliber flexible bronchoscopes, over which an endotracheal tube may be threaded, has been a great advance in the management of group II difficult airways. Flexible fiberoptic intubation is the gold standard; however, its use in difficult airways requires previous extensive practice in the normal airway and is not easily mastered. Careful advancement of the endoscope is key, as is the avoidance of airway trauma that can lead to hematoma formation, edema or mucosal hemorrhage. The use of adequate preoxygenation and topical anesthetics in the airway will facilitate this procedure. As always, there is no substitute for a thorough familiarity with the anatomy of the pharynx—it is easy to get disoriented when passing a small endoscope (limited field of view) through this space. The operator must identify known landmarks, maintain the correct orientation of the video feed, and keep the scope tip clear of obstructing secretions.

In the adult patient, flexible fiberoptic intubation is usually performed while the patient is awake. This option is often not possible in the uncooperative awake pediatric patient. In these patients, sedation or anesthesia is required but with great care to maintain spontaneous ventilation. This can be accomplished either with a potent inhalation agent and 100% oxygen or judicious use of intravenous agents. Remifentanil infusion can provide adequate intubating conditions [56] and is easily reversed in case of significant respiratory depression. Propofol should be used with extreme caution in that it may cause cessation of spontaneous ventilation or potentiate respiratory depression when used in combination with opioids. Dexmedetomidine may be useful in this situation as well [57, 58] . Muscle relaxants should never be administered unless manual control of the airway is assured. Caution should be exercised, however, since at times muscle relaxation can make an easily ventilated airway impossible.

Another good option for patients in which exposure of the glottis is compromised is the videolaryngoscope, a modified intubating laryngoscope with a fiberoptic video feed embedded in the tongue blade. Although the use of a videolaryngoscope should first be learned on normal airways, the learning curve is steep and makes this modality a popular one.

The LMA is advantageous in situations when ventilation and/or intubation are extremely difficult [54, 59] and as a conduit for intubation [60–62]. Once the LMA is situated, a flexible fiberoptic scope is placed through the LMA into the trachea over which an ETT is advanced into the airway. The difficulty with this technique arises during withdrawal of the LMA causing the ETT to withdraw as well. Different solutions for this problem have been proposed [63–66] with no one solution being superior. These include leaving the LMA in place, splitting the LMA, shortening the LMA, and using longer ETTs.

Although the rigid bronchoscope can be very useful in securing an airway in which there is glottic or subglottic obstruction, it is less applicable to group II patients who generally lack a straight path from mouth to glottis.

Finally, it must be kept in mind that in cases of elective surgery in group II patients, the option always remains of aborting the procedure and trying again in the future, especially if more experienced personnel will be available at another time. While multiple trips to the OR are typically discouraged by parents and physicians alike, discretion is the

better part of valor in such challenging cases. If the option exists to optimize the patient's care, this will always be a better choice than to persist against all odds until the elective anesthetic becomes an airway emergency.

Otolaryngologic Surgical Procedures

Bilateral Myringotomy and Pressure Equalizing Tubes (BMT)

The sequelae of the immature pediatric eustachian tube, recurrent acute otitis media, and persistent middle ear effusion are among the most common conditions of childhood. Recurrent otitis can lead to the excessive use of antibiotics as well as frequent symptoms of otalgia (ear pain) and hearing loss. Chronic middle ear effusion results in a persistent hearing loss that can impair the development of communication skills. For children who reach a certain threshold, in terms of the number of infections or months with effusion, BMT placement is indicated to bypass the dysfunctional eustachian tube(s), ventilate the middle ears, reduce the need for antibiotics, and improve hearing. The average age for BMT is 1–3 years, and approximately 10–15% will require tube replacement following spontaneous extrusion of the tubes.

Although the surgery normally takes about 5–10 min, there are a few variables that may affect the duration of the procedure. Small ear canals, as seen in patients with Down syndrome, or significant bleeding from middle ear granulation tissue can make the operation more challenging and therefore lengthier. Furthermore, children who have had multiple sets of tubes may have little tympanic membrane area left appropriate for myringotomy that may also make the procedure more complex and longer.

Preoperative Assessment and Optimization

For the healthy child, a focused history and physical examination is all that is needed. Further evaluation will be dictated by the existence of comorbidities. Premedication with sedatives is rarely used for this procedure since most sedatives outlast the duration of the procedure. If premedication is chosen, midazolam 0.5 mg/kg may be given orally.

Intraoperative Management

General anesthesia is induced and maintained with a potent inhalation agent with or without nitrous oxide. Sevoflurane, because of its non-pungent odor and lack of irritation to the airways, has become the favored inhalation agent in pediatric anesthesia. Given the short duration of the procedure, IV access does not need to be obtained. However, IV equipment should be readily available should difficulty arise and access is needed emergently. Because there is no IV, it is especially important to ensure that an adequate depth of anesthesia is obtained prior to the start of the procedure to avoid laryngospasm from occurring (see above). Signs that the procedure may begin include convergent eyes with small pupils, normal muscle tone, and a relatively normal to low heart rate for age.

An oral airway may be needed to maintain airway patency while the head is turned from side to side during surgery. Continuous positive airway pressure (CPAP) of 5–8 cm H_2O can also be helpful in maintaining airway patency. Alternatively, an LMA may be used [67]; however, IV access should be considered prior to manipulation of the airway.

During the procedure, the anesthesiologist must not move the patient's head or manipulate the airway without first informing the otolaryngologist. Any patient movement, even minimal, will distort the otolaryngologist's microscopic view and could potentially result in injury to the ear canal or tympanic membrane by the surgical instrument present in the ear. Whenever an airway issue arises, it is important to remember that the "airway before ear" rule should apply. Once the anesthesiologist identifies an airway problem, the otolaryngologist is immediately informed so that the instrument present in the ear can be removed and the procedure stopped. When the problem is resolved, the otolaryngologist is informed that the procedure may resume.

Postoperative analgesia may be accomplished in a number of different ways with equal efficacy. Acetaminophen suppository may be given rectally at the start of the procedure. The analgesic dose of *rectal* acetaminophen is 40 mg/kg [68] in contrast to the intravenous dose of 15 mg/kg. This higher dose should not be given orally. Subsequent dosing is 15 mg/kg and should not be given until 6 h later to avoid exceeding the maximum daily dose of 100 mg/kg/day. The parents should be informed that acetaminophen was given rectally, and advised as to the next time they may give the child more medication if needed. It is rare that additional analgesics will be needed since the discomfort of tube placement usually subsides within 2 h.

Intranasal fentanyl (1–2 mcg/kg) given during the procedure has been shown to decrease pain scores and postoperative agitation without increasing vomiting, hypoxemia, or discharge times [69]. Peripheral blockade of the auricular branch of the vagus nerve (nerve of Arnold) has been shown to be as effective as intranasal fentanyl for postoperative pain relief [70]. This block is performed by everting the tragus, penetrating the cartilage with a small bore needle, and injecting 0.2 mL of 0.25% bupivacaine with 1:200,000 epinephrine bilaterally (Fig. 20.3).

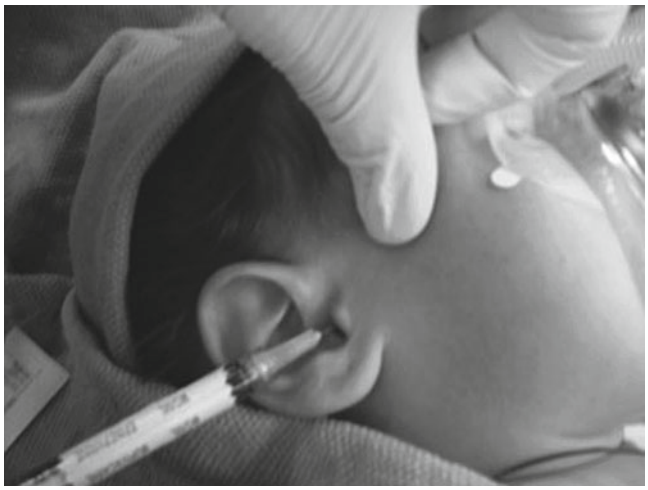

Fig. 20.3 Nerve of Arnold Block

Postoperative Management

BMT is almost exclusively performed as an outpatient procedure. Patients may be discharged home as soon as they meet standard discharge criteria. The average stay in the PACU is less than 30 min; however, patients with a preexisting URI may require a longer stay. The addition of a second analgesic to acetaminophen (e.g., intranasal fentanyl) has not been shown to decrease the incidence of emergence delirium in these patients [71].

Tonsillectomy and/or Adenoidectomy

Adenotonsillectomy (AT) is an extremely old operation, described by the Roman aristocrat and physician Celsus in 50 AD. During the early part of the twentieth century, this operation was done frequently and in many cases on a routine basis without regard for specific indications. Backlash against this indiscriminate "kitchen table" surgery arose later in the century, and at one point tonsillectomy, like circumcision, was derided as "ritualistic surgery" [72].

Inflammatory disease of the pharynx was initially the predominate indication for AT. During the twentieth century, the pathophysiology of pediatric sleep disordered breathing was recognized. As adenotonsillar hypertrophy was identified as the cause of the vast majority of obstructive sleep apnea (OSA) in otherwise normal children, this became an increasingly common indication for AT. Even children with other contributing factors to their OSA, such as craniofacial abnormalities or obesity, may see symptomatic improvement after AT (Table 20.10).

Currently, the majority of AT (approximately 80%) is being done for OSA or other more limited forms of sleep disordered breathing. The indication for the remaining cases is primarily recurrent pharyngitis, specifically streptococcal infections. Adolescents and young adults may undergo the procedure for severe symptoms of chronic inflammation (e.g., halitosis, dysphagia, and tonsilloliths) even in the absence of documented bacterial infections. Other indications for tonsillectomy and/or adenoidectomy include adenoidal hypertrophy, peritonsillar abscess, asymmetric tonsillar hypertrophy, and post-transplant lymphoproliferative disorder (PTLD).

Table 20.10 Conditions associated with obstructive sleep apnea

1. Acromegaly
2. Cleft palate (following palatoplasty or pharyngeal flap)
3. Craniosynostoses (e.g., Crouzon, Apert or Pfeiffer syndrome)
4. Mucopolysaccharidoses (e.g., Hurler or Hunter syndrome)
5. Micrognathia/retrognathia (e.g., Treacher–Collins Syndrome, Goldenhar syndrome or Pierre Robin anomalad)
6. Trisomy 21
7. Neuromuscular disease involving hypotonia

OSA and Adenotonsillar Hypertrophy

The pharyngeal airway (from the oropharynx to the glottis) may be thought of as a collapsible tube, the lumen of which is maintained patent by the tone of the pharyngeal musculature. In most neurologically normal children, this tone is adequate to keep the airway open during respiration. While the muscle tone diminishes cyclically during sleep, the pressure in the airway is generally above the critical closing pressure (CCP), which is needed to maintain airway patency. However, the airway can collapse when muscle tone is inadequate to maintain a patent lumen, as with sedative drugs, alcohol, or in patients with neuromuscular hypotonia. The airway can also collapse if the luminal air pressure, which is holding the tube open, drops sufficiently. This latter phenomenon is seen when the airway is compromised from adenotonsillar hypertrophy resulting in increased airspeed and concomitant diminished air pressure (i.e., Bernoulli effect).

The intermittent cessation of ventilation will result in progressive hypoxia and hypercapnea, until the point that the brainstem arousal reflex is triggered, increasing pharyngeal tone and restoring airflow. The problem with a cyclical interruption of the natural sleep architecture is that physiological rest is denied, resulting in the many symptoms of sleep apnea (e.g., daytime somnolence). In severe cases, this cycle can lead to cardiovascular complications such as arrhythmias and pulmonary hypertension. Longstanding pulmonary hypertension results in right atrial enlargement, right ventricular hypertrophy, and ultimately cor pulmonale (right-sided heart failure). Polycythemia may also be present. Furthermore, the brainstem carbon dioxide (CO_2) "set point" can be reset,

resulting in a diminished respiratory drive after the adenotonsillar hypertrophy has been addressed surgically. This latter effect can be exacerbated by the administration of supplemental oxygen, which effectively shuts down the hypoxic component of the respiratory drive, as oxygen can diffuse into the alveoli even when volume ventilation is poor.

While the criteria for pediatric OSA are evolving, there are some standards that may be documented by polysomnography (PSG) during a formal overnight sleep study. In many cases, the decision to proceed with surgery will be a clinical one, based on parental observation or informal sleep videos or even home sleep studies. While the role of these guidelines remains controversial, it is certainly acceptable to recommend surgery in selected cases based on criteria short of PSG. However, PSG is the "gold standard" and is critical for the management of complex cases with hypotonia, obesity, craniofacial abnormalities, or any other condition in which AT alone may not suffice to address the OSA. Even if AT results in some improvement in the sleep disorder, PSG may be necessary to manage other adjuvant therapy such as nasal continuous positive airway pressure (CPAP) or biphasic positive airway pressure (BiPAP).

Post-transplant Lymphoproliferative Disorder

Post-transplant lymphoproliferative disorder (PTLD) is a complication of organ transplantation immunosuppressive therapy. Epstein–Barr virus (EBV) infection, which is generally self-limiting in the immune competent individual, can result in significant lymphoid hyperplasia in the immunosuppressed individual, resulting in adenotonsillar hypertrophy, airway obstruction, and death [73]. Heightened awareness of the implications of adenotonsillar hypertrophy secondary to PTLD and timely surgical and medical interventions are crucial to improve patient outcomes [74].

Preoperative Assessment and Optimization

During the preoperative assessment, particular attention should be directed toward the evaluation of the airway and those end-organs potentially affected by OSA, including the cardiac and pulmonary systems. A personal or family history of coagulopathy should also be sought. Airway evaluation is crucial in this patient population. The degree of tonsillar hypertrophy should be evaluated and the potential for difficulty with mask ventilation and intubation assessed. The presence of any craniofacial abnormality may make management of the airway even more difficult. In such cases, alternative airway management tools (e.g., LMA, fiberoptic intubation equipment, videolaryngoscope) should be readily available.

In those patients with long-standing or severe OSA, further pulmonary and cardiovascular evaluation may be warranted. An arterial blood gas should be obtained to determine the presence of CO_2 retention. The degree of retention will aid in managing ventilation parameters in the operating room and postoperatively. In these patients, a chest X-ray (CXR) may show an enlarged cardiac silhouette.

A pediatric cardiac consultation should be sought if evidence of pulmonary hypertension exists including an electrocardiogram looking for right-sided heart changes, such as right atrial enlargement, right ventricular hypertrophy, and/or right axis deviation. Echocardiography may be necessary if there is concern about cardiac function or cor pulmonale.

A preoperative hematocrit should be considered in the child with chronic hypoxia because the presence of polycythemia may be further evidence and indicative of long-standing OSA. An accurate baseline measurement is also crucial if significant blood loss is encountered.

Although bleeding in the postoperative period may occur after tonsillectomy, routine coagulation studies are not universally obtained [75]. Patients undergoing tonsillectomy are at no greater risk for the presence of an undiagnosed coagulopathy than the general population. Even in those patients with inherited coagulation disorders, preoperative coagulation studies may not be diagnostic, and the standard international normalized ratio (INR), prothrombin time (PT), or partial thromboplastin time (PTT) may be normal. Furthermore, routine preoperative screening of coagulation may not be cost-effective [76]. Of greater importance in detecting the possible presence of abnormal coagulation is the preoperative history. Parents should be asked about the presence of excessive bleeding after cuts, tooth extractions, previous surgeries, easy bruisability, recurrent nosebleeds, or any familial coagulation disorders. If the history is suggestive of the existence of a coagulation disorder either in the patient or family, coagulation studies should then be obtained prior to surgery. A hematology consult should be secured if the coagulation studies are abnormal and/or the history is strongly suggestive of a coagulopathy.

Premedication, if used, should be given cautiously to patients with a history of airway obstruction, particularly those with the diagnosis of OSA. These patients tend to be more sensitive to sedatives and opioids and may develop significant airway obstruction when sedated. If premedication is administered, it should be done in a monitored setting with pulse oximetry and the personnel and equipment available to manage airway problems should they develop.

Intraoperative Management

AT is performed under general anesthesia using a number of competing methodologies: cold dissection, electrocautery,

Coblation®, or microdebrider. There is controversy about the appropriate indications for extracapsular tonsillectomy, intracapsular tonsillectomy, or partial tonsillectomy. A discussion of this is beyond the scope of this chapter, and variations in technique have little impact on anesthetic management. Intraoperative anesthetic considerations include management of the airway, sharing the airway with the otolaryngologist, and intraoperative and postoperative bleeding.

Both inhalation and IV inductions are appropriate for these patients. However, the usual induction technique in the pediatric patient is inhalational to avoid the need for a needle stick in an awake, anxious child. It also has the advantage of preserving spontaneous ventilation. Airway obstruction during induction of anesthesia is common but can usually be relieved with the placement of an oral airway once the patient is adequately anesthetized, as well as administration of CPAP to stent the airway, and positive pressure ventilation. In the patient with symptoms consistent with severe OSA, a preinduction IV may be indicated, even though an inhalational induction is planned, to allow for immediate access if emergency medications become necessary. When performing an IV induction, the anesthesiologist should be confidant that they can manage the patient's airway since spontaneous respirations will likely not be preserved once anesthetized.

If not already done, IV access should be obtained once the patient has reached an acceptable plane of anesthesia. An appropriate sized angiocatheter should be used and the function should be assured, as intraoperative bleeding may necessitate rapid volume resuscitation.

Airway Management

Airway management for these cases can be accomplished with either an ETT or LMA. If tracheal intubation is chosen, the use of a muscle relaxant is at the discretion of the anesthesiologist. An advantage of not using a muscle relaxant and maintaining spontaneous ventilation throughout the procedure is the ability to titrate opioids to the patient's respiratory rate. Since OSA patients are sensitive to opioids, this technique would ensure that the patient does not receive an excessive amount of these medications, resulting in apnea and inability to extubate at the end of the procedure.

An oral RAE tube, with its preconfigured bend, minimizes kinking and is optimal for these cases. Standard ETTs may obstruct the view of the otolaryngologist or may kink when bent out of the way. A mouth retractor (Crowe-Davis, McIvor, Boyle Davis) is placed to maintain oral patency and keep the tongue and ETT away from the adenotonsillar area. During placement of the mouth retractor, it is important to make sure that the ETT does not become obstructed or dislodged. The use of an RAE tube does not entirely prevent this from occurring. If mechanical ventilation is used, peak airway pressures should be noted prior to placement of the mouth gag. If peak airway pressure increases significantly during placement of the mouth retractor, the otolaryngologist should be asked to adjust the mouth retractor accordingly. ETT dislodgement may occur, either distally into the right mainstem bronchus or out into the pharynx or esophagus. Therefore, particular attention should be paid to the presence of breath sounds and $ETCO_2$. During the procedure, continued vigilance is necessary since ETT obstruction or displacement may occur at any time.

Although many pediatric anesthesiologists are using cuffed ETTs, there are still those who prefer uncuffed tubes. However, for AT surgery most anesthesiologists would place a cuffed ETT to provide additional protection against aspiration of blood from the airway during the procedure. In instances where electrocautery is used, a cuffed ETT provides the additional advantage of protecting against the possibility of airway fires when compared to uncuffed ETTs. The leak around an uncuffed ETT allows for an increased oxygen concentration in the oropharynx thereby increasing the potential for an airway fire to occur during electrocautery [77].

Reinforced LMAs may be used for these cases [78]; however, tonsillar hypertrophy may make placement difficult. Since the LMA stem is larger than that of an ETT, obstruction and dislodgement of the LMA occurs more frequently during mouth retractor placement [79]. During the procedure, dislodgement or obstruction of the LMA may require its removal and replacement with an ETT. This may be difficult in the face of a partially removed tonsil or bleeding in the airway. Airway fires with the use of LMAs and electrocautery have not been reported. Advantages of an LMA are a decreased incidence of postoperative stridor, hoarseness, and laryngospasm [62]. LMAs have also been shown to protect against aspiration of blood [62, 80]. Examination of the larynx and the underside of the LMA at the conclusion of surgery showed no blood contamination in the LMA group [62, 64] whereas aspiration of blood was seen in 54% of children intubated with an uncuffed ETT [62]. However, these advantages must be weighed against the disadvantages mentioned above.

Analgesia

Intraoperatively analgesia should be judiciously administered. The goal is to provide for postoperative pain management while minimizing the possible respiratory complications that may occur in this patient population postoperatively. The optimal pain management regimen is yet to be determined. Hence, the regimen employed is usually based on the patient's medical condition and the individual anesthesiologist's preference. Confounding considerations include postoperative nausea and vomiting (PONV), sedation, respiratory depression, and airway obstruction. Options for pain control include opioids, nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and local anesthetics. Postoperative pain management commonly consists of multiple modalities.

Opioids, such as fentanyl or morphine, are most commonly used. As described above, titration to respiratory rate would ensure that these patients do not have excessive respiratory depression and can be safely extubated at the end of the procedure. Although the total dose of fentanyl administered during these cases will vary, in a patient with minimal OSA symptoms, approximately 3 mcg/kg would be a reasonable amount for adenotonsillectomy and 2 mcg/kg for adenoidectomy alone. PONV and sedation are a common side effect of opioid therapy.

NSAIDs, such as ketorolac, provide effective pain control as compared to morphine with a lower risk of nausea and vomiting [81]. However, the literature is unclear as to whether NSAIDs cause an increased risk of post-tonsillectomy bleeding [82–84]. Regardless, the majority of otolaryngologists prefer that NSAIDs not be administered in the perioperative period.

Acetaminophen 40 mg/kg may be given rectally as an adjunct to other analgesic modalities and should be given after induction but prior to the start of surgery to allow time for adequate plasma levels. Acetaminophen at this dose has been shown to decrease postoperative and at home requirement of analgesia [85]. In November 2010, the United States Food and Drug Administration approved the intravenous acetaminophen formulation. This can be administered in lieu of the rectal formulation in a dose of 15 mg/kg every 6 h not to exceed 75 mg/kg/day [86, 87]. The current labeling for intravenous acetaminophen is for patients 2 years and older.

Local anesthetics may be administered by the otolaryngologist directly at the surgical site. Tonsil packs soaked with local anesthetic are placed in the tonsillar beds for topical absorption. Alternatively, local anesthetic may be infiltrated. A recent study comparing the use of IV ketamine 0.5 mg/kg with peritonsillar bupivacaine 0.25% (3–5 mL per tonsil), versus only bupivacaine, versus only saline found that the ketamine/bupivicaine combination was safe and effective in reducing post-tonsillectomy pain [88]. Care should be taken to avoid the use of any solution containing vasoconstrictive agents in the surgical field, as they have been associated with cardiovascular complications and even mortality [89].

Postoperative Nausea and Vomiting

There is an increased incidence of PONV after AT [90]. Causes of PONV include opioids, the presence of blood in the stomach, and swelling and inflammation of the posterior pharynx and uvula. Dexamethasone, at a dose of 0.05–0.15 mg/kg, is commonly administered to decrease airway edema, and has the added benefit of antiemetic properties. The perioperative administration of dexamethasone is not associated with an increased incidence of bleeding postoperatively [91, 92] A second antiemetic (e.g., ondansetron), may also be administered or used as a rescue drug in the PACU. Adequate hydration may also play a key role in preventing PONV.

At the conclusion of the procedure and prior to removal of the mouth retractor, the otolaryngologist should pass an orogastric tube under direct vision to suction any blood present in the stomach. The oropharynx should be suctioned as well. This will result in removal of secretions and blood that may contribute to PONV and laryngospasm.

Emergency and Extubation

Extubation of the trachea can be accomplished either while the patient is still deeply anesthetized or when fully recovered. The advantage of deep extubation is less chance of disrupting hemostasis from the patient coughing with the ETT in place. However, the disadvantage is increased risk of airway obstruction and laryngospasm. Awake extubation has the advantage of assuring intact airway reflexes thereby decreasing the risk of aspiration and laryngospasm.

An uncommon complication of AT in the severely obstructed patient is the development of negative pressure pulmonary edema (NPPE) once the airway obstruction is relieved [93, 94]. When chronic airway obstruction is relieved by adenotonsillectomy, the capillary wall pressure gradient is increased by a forceful inspiratory effort causing fluid leakage into the interstitial space [95]. This may become evident once the ETT is removed at the end of the procedure. Treatment is the same as for negative pressure pulmonary edema which consists of oxygen, diuretic administration, and, if need be, re-intubation to provide CPAP or positive end expiratory pressure (PEEP). This complication is self-limiting and usually resolves within 24–48 h [79].

Postoperative Management

Patients should be placed in the lateral decubitus position with the head down with supplemental oxygen for transport to the PACU. Analgesic and antiemetic medications should be ordered.

The most serious postoperative complication is postoperative hemorrhage that will be discussed in detail in the section on post-tonsillectomy bleeding.

Since pain on swallowing and nausea and vomiting occur frequently in these patients, discharge from the PACU should occur only when the child has demonstrated that they are able to swallow fluids and not vomit. Adequate analgesia and antiemetic therapy are, therefore, important to facilitate discharge.

Although tonsillectomy for OSA can be done as an ambulatory procedure, there is a subset of patients who should be observed in the hospital overnight in a monitored setting for apnea. In general, the most common criteria used for overnight monitoring are age less than 3 [96], the presence of craniofacial or neuromuscular abnormalities, the continued need

for supplemental oxygen, or airway obstruction in the PACU. Postoperative airway obstruction may be due to post-surgical airway edema, residual anesthesia, and/or ongoing analgesic therapy, particularly with opioids.

AT is associated with a painful recovery that can last up to 2 weeks. The pain tends to peak between days 5 and 10, as the eschar separates from the tonsil beds. Good pain control is crucial, as the lack of appropriate analgesia will result in poor oral intake, and a vicious cycle in which the patient becomes even more uncomfortable and dehydrated. Acetaminophen with codeine elixir (120 mg/12.5 mg per 5 mL) works well in this population and may be alternated with plain acetaminophen when the pain is not so severe, to avoid the gastrointestinal side effects of codeine. Aggressive hydration also helps break the pain cycle, and should be encouraged.

Post-tonsillectomy Bleeding

Introduction

The incidence of post-tonsillectomy bleeding ranges from 2% to 4% [97, 98]. It is more common in teenagers and young adults than in small children. The vast majority of postoperative bleeding occurs between days 5 and 10, when the eschar separates from the tonsil beds. In rare cases, bleeding may occur in the immediate postoperative period. Initial management is tailored to the degree of bleeding. The clot in the tonsillar bed should be suctioned, as spontaneous hemostasis is rare with the clot in place. Minimal bleeding may resolve with ice water gargle, and older children may tolerate the application of a cautery stick with silver nitrate while awake. Significant bleeding in a young child, however, typically involves a return to the operating room for a thorough examination of the pharynx and electrocautery hemostasis.

Preoperative Assessment and Optimization

The preoperative assessment should be directed at airway evaluation and volume status (Table 20.11). Although it may be difficult to assess the airway in depth in the agitated child, observation of the external anatomy and information about airway management from the prior anesthetic should provide sufficient information. Even though airway management was uncomplicated previously, it may be more difficult at this time because of postoperative edema and blood obscuring visualization of the larynx.

Assessment of volume status is of paramount importance. It is easy to underestimate the degree of blood loss, since much of it may have been swallowed. Heart rate, blood pressure, and, if possible, orthostatic testing will provide information regarding volume status and guide volume resuscitation. Assessing for the presence of tears, moist mucus membranes, skin turgor, and urine output will be helpful as well. Adequate IV access should be obtained, if not already present. Intraosseous access should be entertained in the hypovolemic, hypotensive patient if IV access cannot be obtained in a timely fashion. Volume resuscitation should be initiated with non-glucose containing isotonic fluids. If the patient is hypotensive, 20 mL/kg boluses of isotonic fluid should be administered until the blood pressure normalizes. Once the bleeding has been controlled and the patient is normovolemic, maintenance fluids should be continued. Maintenance fluids are calculated by the following formula:

0–10 kg: 4 mL/kg/h

11–20 kg: 2 mL/kg/h

≥21 kg :1 mL/kg/h

Laboratory tests should be obtained, specifically hematocrit, platelet count, electrolytes, and coagulation studies. A specimen should also be sent for serotyping and crossmatch, as transfusion is a very real possibility. Surgery should not be delayed waiting for test results, since bleeding will continue without surgical intervention, and abnormal values would rarely by themselves preclude a general anesthetic.

Table 20.11 Preoperative assessment of the post-tonsillectomy bleeding patient

Assessment	Action
Airway	Evaluate airway anatomy Obtain previous intubation records
Volume	Assess volume status Start large bore intravenous catheter Consider intraosseous access if intravenous access attempts not successful Resuscitation with isotonic non-glucose containing fluids Transfuse red blood cells if hemodynamically unstable and hematocrit is low
Hematology	Send hematocrit, type and cross, coagulation studies Proceed to OR even if results are unavailable Check results as soon as possible

Intraoperative Management

Management of the airway is of major concern, particularly the ability to visualize the larynx in the presence of ongoing bleeding. In preparation for induction, the following should be prepared: multiple laryngoscope blades, a styletted cuffed ETT, and two large bore suctions (a double suction setup) in case one clots or proves to be ineffective. The otolaryngologist should be present and tracheostomy equipment immediately available should a surgical airway become necessary.

The patient is considered to have a full stomach, even if they have not recently eaten, because of swallowed blood.

This presents a dilemma for the anesthesiologist who may be concerned that visualization of the larynx and intubation may be difficult. An awake fiberoptic intubation may be an option in the older patient but it is not a feasible option in the young agitated child. Also, the presence of blood in the airway may make visualization with the flexible bronchoscope difficult, if not impossible. Thus, a rapid sequence induction is usually performed. However, in the situation where there is significant concern about the airway, a smooth mask inhalation induction with cricoid pressure can be performed with the patient in the right lateral decubitus position with the head down (tonsillar position) with suction immediately available. The tonsillar position minimizes aspiration risk by promoting the pooling of blood in the orapharynx.

The choice of IV induction agent will depend on the volume status. Etomidate or ketamine may be used if there is ongoing concern about volume status and hemodynamic stability. Alternatively, propofol may be used but in a decreased dose. Muscle relaxation can be achieved with either succinylcholine or rocuronium. However, the duration of action of rocuronium at the dose recommended for rapid sequence induction (1.2 mg/kg) will likely exceed the length of the procedure. Furthermore, in situations where the airway is of major concern, succinylcholine, with its rapid onset and short duration of action, may be preferable, despite the concern of its use in the pediatric population.

Volume status should be continually assessed in the face of ongoing bleeding and managed appropriately with isotonic fluids. The hematocrit, degree of hemodynamic stability, and the status of hemostasis will dictate the need for a blood transfusion. Replacement of coagulation factors is rarely necessary. However, if a previously undiagnosed coagulopathy is discovered, the appropriate therapy should be initiated and a hematology consult obtained.

All other intraoperative and postoperative concerns are the same as described above for tonsillectomy.

Airway and Esophageal Foreign Body

Introduction

Foreign body aspiration into the airway occurs most commonly in children less than 4 years of age [99], but is rare before age one, when a child develops a significant degree of mobility and the ability to manipulate small objects. A history of a witnessed episode of choking and/or coughing may be elicited, but the absence of such a history does not rule out the presence of an airway foreign body. Small foreign bodies may be small enough to pass silently through the larynx and impact in the distal bronchi, with signs and symptoms not developing for days or weeks. Diagnosis may be quite challenging, but a heightened index of suspicion must be raised when asymmetric breath sounds, persistent cough, new onset wheezing in the absence of reactive airway disease, or CXR evidence of air trapping and/or segmental collapse.

Occlusive pharyngeal foreign bodies that obstruct the larynx and result in complete airway obstruction are true life-threatening emergencies that rarely make it to the operating room. Accidental asphyxia from items such as grapes, hot dogs, or fruit skins can result in death within minutes and are best managed by widespread familiarity with emergency procedures such as the Heimlich maneuver. Aspirated airway foreign bodies, on the other hand, are rarely emergencies, and may present in subtle ways, as mentioned above. Therefore, operative intervention should not be undertaken until the circumstances are optimized and the appropriate otolaryngologist and anesthesiologist are available, even if it means delaying the procedure [100]. Furthermore, all necessary equipment should be available and tested prior to the induction of anesthesia.

Children, who present with agitation, wheezing, and/or cyanosis, are true surgical emergencies and should be taken to the OR as soon as possible. The aspiration of watch and hearing aid batteries are especially notorious since they can induce a corrosive reaction that can result in complete transmural injury in as little as an hour [101]. Sharp objects, such as open safety pins, are also typically considered emergencies, although in some cases these can present months after the initial aspiration (Fig. 20.4).

At the other extreme, patients with a chronic airway foreign body, especially if suspected to be organic in nature, may have significant granulation tissue surrounding the object but a stable airway. Such patients will benefit from 24 to 48 h of systemic steroid therapy prior to endoscopy, which will minimize bleeding and make extraction easier. Nuts and seeds are the most common objects aspirated by children. Most nuts are oily and may cause a localized inflammatory reaction. They can also be difficult to extract during bronchoscopy, as they may break apart during manipulation. Foreign bodies more commonly lodge in the right main bronchus and less frequently in the larynx and trachea. Coins are the most common esophageal foreign body. Less common are plastic or metal parts of toys.

Preoperative Assessment and Optimization

The degree of airway obstruction and/or respiratory distress should be assessed and will guide the timeline of surgical management. Children with foreign bodies lodged in the supraglottic region will present with inspiratory stridor, dyspnea, cough, and possibly cyanosis. Children with foreign bodies lodged in the glottis or subglottis will present with

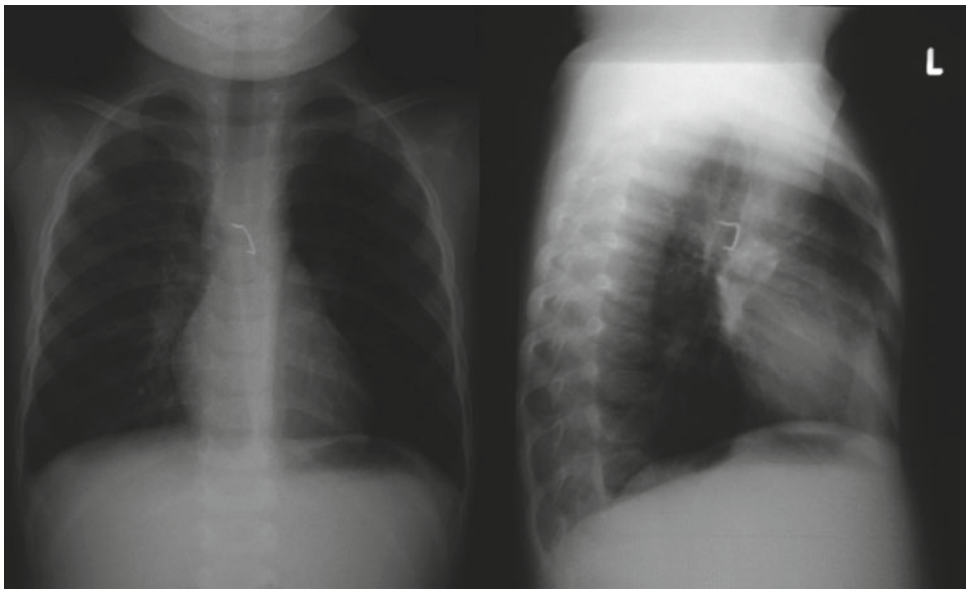

Fig. 20.4 PA and lateral chest X-ray of a child who had aspirated a carpet staple several months prior to presentation. Symptoms included a lingering cough and failure to thrive, but no significant stridor or respiratory distress. At bronchoscopy, the foreign body was found to be lodged at the carina, surrounded by a large mass of granulation tissue

biphasic stridor, cough, and hoarseness. Foreign bodies in the intrathoracic airways will demonstrate expiratory stridor that is more pronounced on collapse of the airway during exhalation. A foreign body that passes the subglottis will almost always pass the carina and lodge in the mainstem bronchus or possibly more distally depending on the size of the object. This condition will result in asymmetric wheezing, more pronounced on the involved side. However, a chronic foreign body resulting in atelectasis or consolidation may alternatively produce diminished breath sounds on the involved side. Room air oxygen saturation will be helpful in determining the severity of the respiratory compromise. Premedication in most cases should not be administered to these children, especially if respiratory compromise is apparent. However, anxiety due to respiratory compromise should be expected and managed with a calm demeanor and parental presence throughout the process.

Although routine preoperative studies are not indicated, a CXR should be obtained in stable patients with suspected foreign body aspiration. Although many foreign bodies are not radiopaque, the CXR may be helpful in determining the location of the foreign body by evidence of secondary changes. Unilateral air trapping or hyperinflation would suggest the presence of a foreign body on that side. Additionally, atelectasis on the effected side distal to the foreign body, an infiltrate on the effected side, or mediastinal shift may be seen.

If the patient has recently eaten, surgery should be postponed only if the patient is stable and delaying surgery would not place the patient at increased risk for worsening of respiratory function or even complete obstruction. Removal of foreign bodies lodged in the hypopharynx should be considered an urgent procedure. A foreign body in this position poses a hazard of dislodging, particularly if the patient is gagging and coughing, and entering the larynx completely occluding the airway. While the majority of tracheobronchial foreign bodies are not emergencies and standard nil per os (NPO) guidelines may be observed, certain foreign bodies warrant immediate surgical intervention, even in the face of a full stomach, as outlined above (Fig. 20.5).

Intraoperative Management

Communication between the anesthesiologist and otolaryngologist is critical to the safe and successful care of these patients. The anesthetic plan, particularly management of the airway, should be discussed and agreed upon prior to the start of the case.

Either an inhalation or IV induction is appropriate. However, IV access should be obtained pre-induction in the compromised child, even if an inhalation induction is planned. The administration of an antisialagogue, glycopyrrolate (0.01 mg/kg), or atropine (0.01–0.02 mg/kg) should be considered to decrease secretions that may impair the otolaryngologist view. Dexamethasone should be administered to decrease airway edema.

If proceeding in a patient determined to have a full stomach, the anesthesiologist must weigh the risk of pulmonary aspiration of gastric contents against the risk of losing a patent airway if a rapid sequence induction is performed.

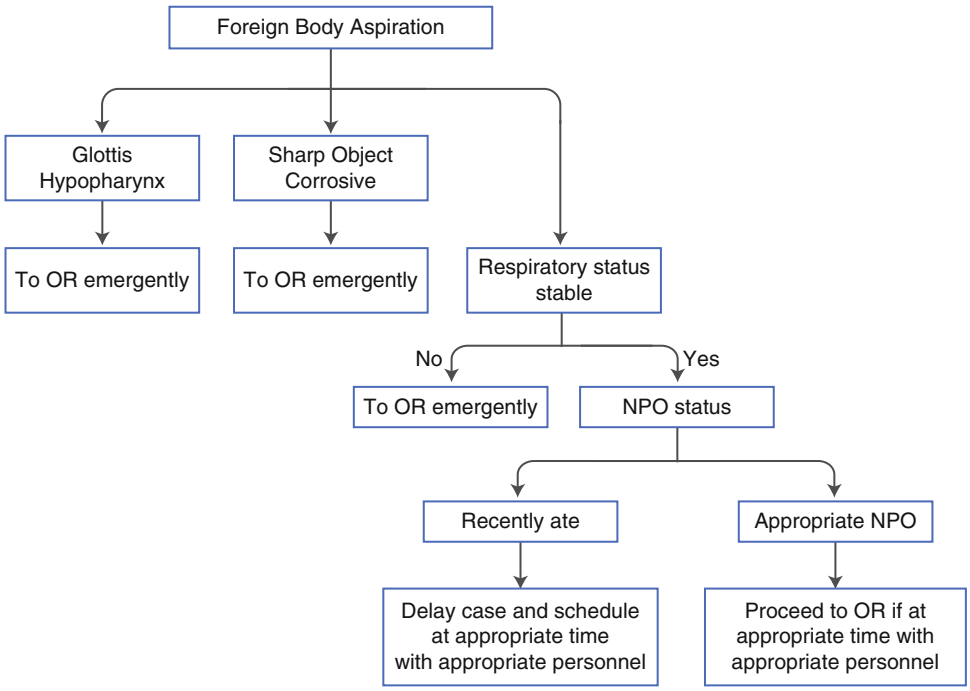

Fig. 20.5 Approach to the patient with foreign body aspiration

It should be remembered that even in the patient with a full stomach, removal of a foreign body from the respiratory system precludes placement of an ETT and the airway will be unprotected until the otolaryngologist introduces the rigid bronchoscope. Suctioning of the stomach after induction but prior to inserting the bronchoscope may be helpful in decreasing the risk of gastric aspiration. Tracheal intubation is possible when esophageal foreign bodies are present. However, cricoid pressure during rapid sequence induction may be contraindicated if the foreign body is at the level of the cricopharyngus. Of note, the ETT may become compressed by the esophagoscope and can be detected by close monitoring of the peak airway pressure and the presence and quality of the $ETCO_2$ waveform.

The anesthetic management of patients undergoing bronchoscopy for foreign body removal is controversial as to whether to maintain spontaneous ventilation or to control ventilation [102]. There is a theoretical concern that controlled ventilation and positive pressure may push the foreign object deeper into the small airways making retrieval more difficult or creating a greater obstruction through a "ball-valve" effect. Conversely, spontaneous ventilation may prove inadequate to maintain adequate oxygenation or ventilation and increases the risk of unexpected movement or coughing causing airway trauma or rupture. Although both methods of ventilation are acceptable, studies have shown that the need for conversion from spontaneous to controlled ventilation occurs frequently [86, 103]. The reverse, conversion from controlled to spontaneous, has not been reported. The ultimate decision will be based on the preference of the anesthesiologist and otolaryngologist, the medical condition of the patient, and the nature of the foreign body aspiration.

If spontaneous ventilation is maintained, topical anesthesia of the vocal cords may help to decrease stimulation by insertion of the bronchoscope. Lidocaine is commonly used and the dose should not exceed 2–3 mL/kg to avoid toxicity since absorption via mucosal surfaces may approach that of IV administration. This can be administered either by a prefilled laryngo-tracheal-anesthesia (LTA) device or by using a syringe with an attached angiocatheter. In the latter case, it is important to ensure that the catheter is tightly fixed to the syringe by Luer-lock or tape, to decrease the risk of catheter dislodgement into the airway. During controlled ventilation, muscle relaxation should be administered to ensure immobility of the patient.

There is no preferred method of general anesthesia maintenance for these cases. In all cases, nitrous oxide should be avoided because of the presence of air trapping in the lungs and the likely presence of decreased oxygenation. The anesthesia circuit can be attached to the rigid bronchoscope (Fig. 20.6) with a standard 15 mm ventilatory side port that allows for the administration of a potent inhalation agent. However, since ventilation may vary during the procedure, particularly if spontaneous, the depth of anesthesia may be inconsistent, requiring an IV agent as an adjunct to ensure an adequate depth of anesthesia. If an unsheathed optical forceps is used in place of a ventilating bronchoscope (which is occasionally a useful technique in very small airways), total intravenous anesthesia (TIVA) will be necessary. This can be accomplished in a number of ways and no particular method

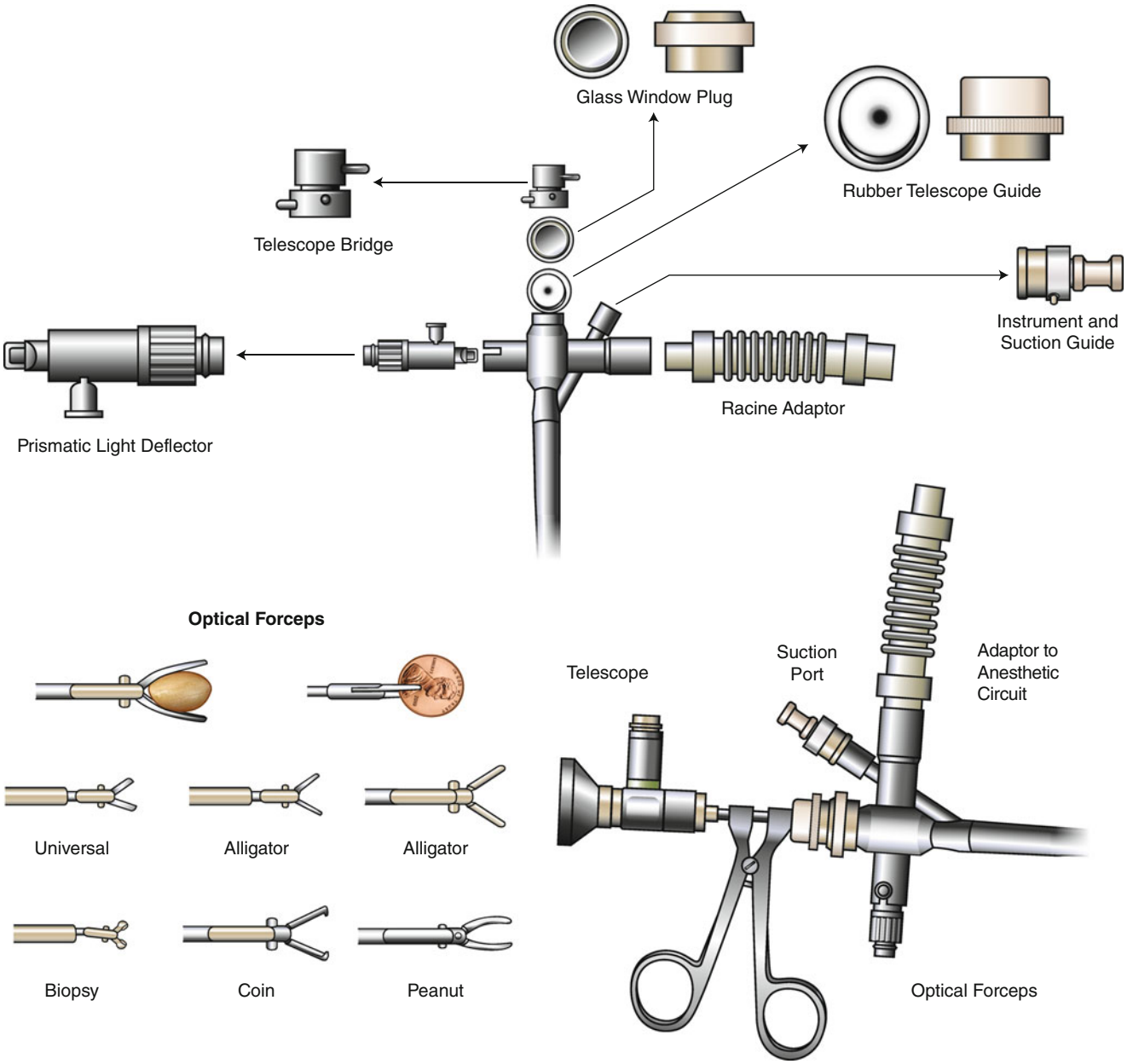

Fig. 20.6 Ventilating bronchoscope with accessories for the use of optical forceps. Modified with permission from KARL STORZ Endoscopy America

has been shown to be superior compared to another. Commonly used agents are propofol and remifentanil. The advantage of these agents is that they are short-acting and, therefore, will not contribute to respiratory compromise postoperatively.

Problems encountered during ventilation via the bronchoscope include: (1) dislodgement of the anesthesia circuit, (2) increased work of breathing through the narrower lumen of the bronchoscope in the spontaneously breathing patient, (3) leak around the bronchoscope especially when removing foreign bodies from the proximal airway, and (4) one-lung ventilation of the compromised lung when the bronchoscope is advanced into the effected lung. The latter will result in oxygen desaturation and elevated CO_2. Periods of oxygen desaturation and ineffective ventilation may need to be tolerated briefly to allow the otolaryngologist time to retrieve and remove the foreign body. During this period, it is crucial that effective communication between the otolaryngologist and anesthesiologist is ongoing. The video feed commonly available with modern bronchoscopy equipment greatly facilitates this communication, allowing all members of the team to see exactly where the bronchoscope is in the airway at all times.

It is strongly recommended that all anesthesiologists become familiar with bronchoscopic images so that during bronchoscopy the otolaryngologist's progress can be closely followed.

During the procedure, the otolaryngologist may need to withdraw the bronchoscope into the trachea in order to allow for adequate oxygenation and ventilation. Once these parameters improve, the otolaryngologist can reintroduce the bronchoscope. Depending on the underlying pulmonary compromise, this may need to be repeated multiple times. Occluding the patient's nose and mouth can minimize tidal volume and anesthetic leakage around the bronchoscope.

When working high in the airway, as is the case during the rare tracheal foreign body (Fig. 20.7), significant leakage from the circuit may occur through side holes located in the end of a typical ventilating bronchoscope, which may be above the level of the glottis. To prevent this problem, a tracheoscope may be used, which is identical to a ventilating bronchoscope but without the side holes near the tip (Fig. 20.8). If such a device is not available, the holes can be occluded by wrapping the distal portion of the bronchoscope with an occlusive plastic dressing (e.g., Tegaderm™), but care must be taken to prevent such items from being left in the airway. During removal of a fragmented foreign body, the bronchoscope may be removed and reinserted with each fragment removed. This may necessitate mask ventilation with 100% oxygen in between each reinsertion.

Large foreign bodies in the bronchus may be dropped during removal in the trachea or larynx causing complete airway obstruction. If prompt removal of the foreign body is not possible, the otolaryngologist should push it back into one of the mainstem bronchi in which it was originally impacted, so that ventilation of at least one lung can resume. If the foreign body advances into the "good lung", airway edema in the other lung can further compromise the patient's pulmonary function.

Intraoperative hypoxia, hypercarbia, and laryngospasm may be avoided by maintaining an adequate depth of anesthesia and ensuring adequate oxygenation and ventilation. An inadequate depth of anesthesia and stimulation of the airway may lead to arrhythmias. Inhalation agents, by

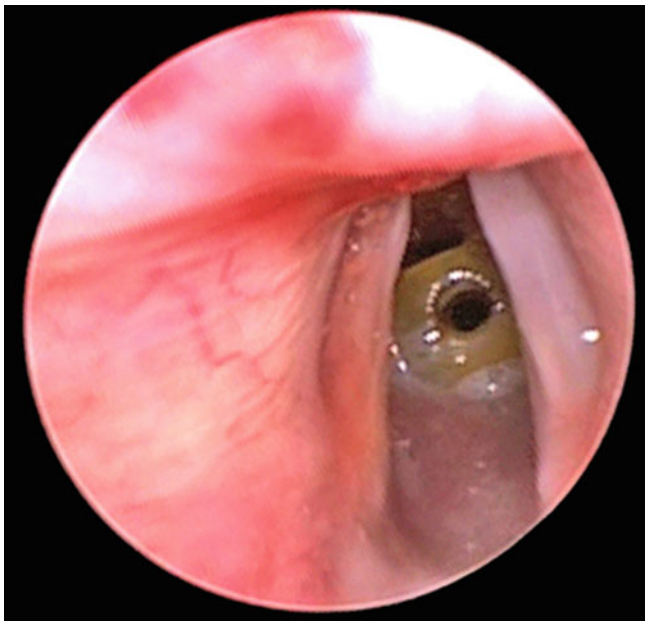

Fig. 20.7 A high tracheal foreign body (a plastic bead) in the subglottic area. Ventilation using a standard ventilating bronchoscope with side ports may be impossible due to the proximal gas leak. A tracheoscope may be helpful in this situation, or temporary occlusion of the side ports with an adhesive wrapper if a tracheoscope is not available

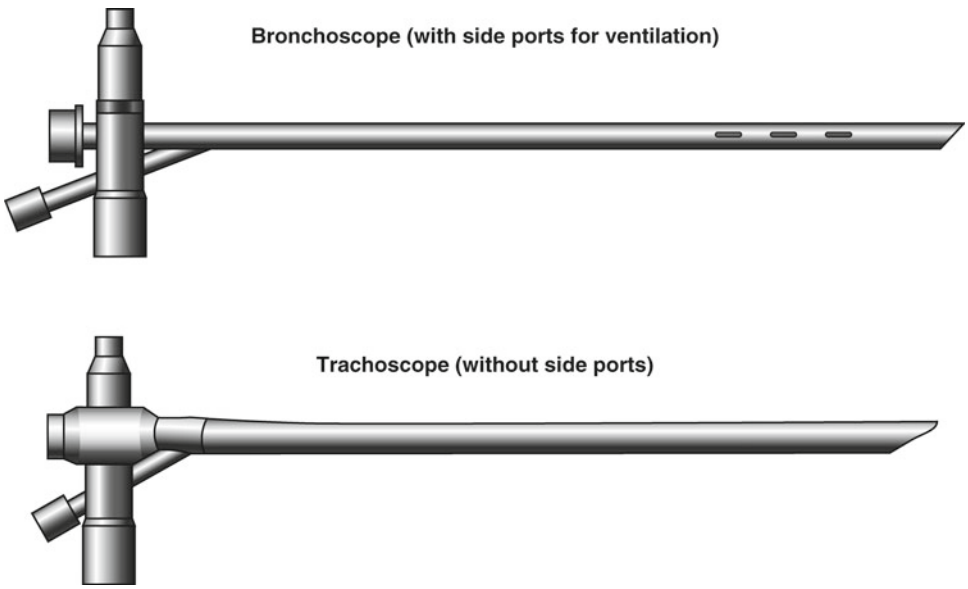

Fig. 20.8 Comparison of a ventilating bronchoscope with distal side ports and a tracheoscope that does not have side ports. These ports are useful in case of occlusion of the end of the endoscope, however when working high in the trachea they will cause an air leak into the pharynx resulting in ineffectual ventilation of the airway

sensitizing the myocardium to catecholamines, contribute to the development of arrhythmias as well. This was seen more often with halothane than sevoflurane.

Pneumothorax, although rare, is a life-threatening complication and should be considered anytime there is an acute change in pulmonary and/or cardiovascular parameters. If suspected, placing a needle in the suspected side may be life saving and should not be delayed while waiting for CXR confirmation. Needle aspiration is performed in the 2nd intercostal space at the midclavicular line entering above the 3rd rib to avoid damaging the neurovascular bundle located below the 2nd rib. After sterilely preparing the area, a 14–18 gauge angiocatheter attached to a 5 or 10 mL syringe is advanced in a downward angle until a loss of resistance or a "pop" is felt. Advance the catheter over the needle into the pleural space and replace the syringe with a three-way stopcock and 50 mL syringe to aspirate air. This should be replaced with a chest tube if necessary.

After completion of the procedure, extubation of the trachea may be considered if significant respiratory compromise was not present preoperatively and is not expected postoperatively. Reversal of muscle relaxation should be assured. Once adequate ventilation, oxygenation, and muscle relaxation are demonstrated, extubation of the trachea may take place.

If intubation was not performed for the procedure, the anesthesiologist may opt to awaken the patient utilizing mask ventilation if pulmonary function is adequate and significant airway edema and inflammation is not expected. If there is any concern, the trachea should be intubated until that time when the patient has completely emerged from general anesthesia and extubation criteria have been met. At times, significant respiratory compromise may be present at the end of the procedure secondary to edema and inflammation of the airways either present preoperatively or exacerbated during difficult removal of the foreign body. In these instances, postoperative intubation and ventilation should be considered and the patient transferred to the intensive care unit. This allows time for lung expansion and resolution of any airway edema and inflammation.

Postoperative Management

The respiratory status, both preoperative and postoperative, and the difficulty in removal of the foreign body will be determining factors in the postoperative disposition of the patient. For uncomplicated cases, the patient may be discharged home the same day. Depending on the type of foreign body and the duration of impaction, an inflammatory response may persist well beyond the time of removal. For those with respiratory compromise, admission to the hospital, and possibly the intensive care unit, will be necessary.

Table 20.12 Indications for tracheostomy in the infant

1. Prolonged mechanical ventilation
(a) Bronchopulmonary dysplasia
(b) Central hypoventilation
2. Airway obstruction
(a) Craniofacial abnormalities
(b) Congenital or acquired subglottic stenosis
(c) Severe tracheomalacia
(d) Bilateral vocal cord paralysis
3. Pulmonary toilet in children with severe neurological or pulmonary disease

Neonatal Tracheostomy

Introduction

Indications for tracheostomy in the infant are outlined in Table 20.12. The most common diagnosis requiring tracheostomy in the neonatal population is inability to wean from mechanical ventilation usually secondary to bronchopulmonary dysplasia (BPD) in the preterm infant. Upper airway obstruction comprises the other major group of patients requiring tracheostomy. Presenting symptoms in the patient who is not already intubated are persistent hypoxia, hypercarbia, or airway obstruction.

In most instances, this procedure is usually performed electively with the patient already intubated. However, the patient who presents with airway compromise and is not intubated poses a significant challenge for the anesthesiologist.

Preoperative Assessment and Optimization

Preoperative assessment will be focused on evaluation of the airway and comorbidities. In patients who are already intubated, the indication for tracheostomy and the ease of prior intubations should be ascertained. In preterm infants, the course in the neonatal intensive care unit should be reviewed with special attention focused on the pulmonary, cardiac, and neurologic status of the patient. Patients with craniofacial abnormalities often have associated cardiac congenital anomalies that require preoperative evaluation.

Patients with craniofacial abnormalities who are not already intubated pose an additional challenge to the anesthesiologist. Besides the preoperative assessment outlined above, evaluation of the airway is of paramount importance in order to formulate an appropriate anesthetic plan that would not place the patient in jeopardy for complete airway obstruction leading to hypoxia prior to the establishment of an artificial airway. The airway evaluation should include a

determination of whether airway patency can be maintained by facemask once general anesthesia is induced and the ease of visualization of the larynx by standard laryngoscopy. Additional airway adjuncts should be available and prepared including oral and nasal airways of various sizes, LMAs of various sizes, a flexible pediatric bronchoscope, and a pediatric videolaryngoscope. Occasionally, a rigid pediatric bronchoscope may be necessary as well.

Premedication with a sedative is contraindicated due to possible development of airway obstruction and hypoxia. Certainly, respiratory depressants should be avoided in the already respiratory compromised patient. Administration of an antisialagogue, glycopyrrolate or atropine, may be beneficial to decrease airway secretions. The additional anticholinergic property of these medications may offer protection against bradycardia secondary to hypoxia if airway obstruction should develop.

Intraoperative Management

Based on the preoperative evaluation of the airway, all necessary airway equipment should be prepared accordingly even if the patient arrives to the operating room with their trachea already intubated. If a difficult airway is anticipated, another experienced anesthesiologist should be present until the airway is safely secured. The otolaryngologist should be present from the start of the case, as well, prepared to either pass a bronchoscope or perform an emergency surgical airway if necessary.

If the patient arrives to the operating room tracheally intubated, placement of the ETT should be confirmed by the presence of bilateral breath sounds and $ETCO_2$ because the ETT may have become dislodged or advanced during patient transport. If an IV is present, it should be checked for functionality. The technique for the induction of general anesthesia will be dictated by the presence of comorbidities.

For the patient who is not tracheally intubated, an inhalation induction is preferred. The goal is to maintain spontaneous ventilation until the anesthesiologist confirms that a patent airway can be maintained, manual ventilation is possible, and/or intubation of the trachea successful. In the compromised airway or identified difficult airway, IV access should be obtained prior to induction so that emergency medications can be administered as needed. An anticholinergic/antisialagogue medication should be administered prior to induction for reasons stated above. The addition of positive end expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) may help in stenting the airway open and facilitate assisted ventilation. Patients with micrognathia (e.g., Pierre Robin anomalad) may be helped by placement of a nasal airway. If mask ventilation proves to be difficult, placement of an LMA may relieve the obstruction and allow for adequate ventilation and oxygenation [104, 105].

Intubation in the presumed difficult airway should be performed without muscle relaxation so that if the attempts are unsuccessful, the patient can resume spontaneous ventilation. If muscle relaxation is deemed necessary for optimal intubation conditions, a short-acting medication, such as succinylcholine, should be administered if not contraindicated.

If intubation using a standard laryngoscope is unsuccessful, then other intubation devices should be tried as long as adequate oxygenation and ventilation are maintained. Whether a fiberoptic scope or videolaryngoscope is used is unimportant. The anesthesiologist should use the device with which they are most familiar. In the event that intubation is not possible with these other devices, tracheotomy may be performed with an LMA in place or by facemask as long as adequate oxygenation and ventilation can be achieved [106].

When selecting the size of the ETT, the presence of abnormal airway narrowing should be taken into account. The use of a stylette should be entertained to optimize intubation conditions.

Once the airway is secured, maintenance of general anesthesia will be dictated by the presence of comorbidities; 100% oxygen should be administered in the event that the airway is lost at any time during the procedure. The use of muscle relaxation is at the preference of the anesthesiologist. Those who do not use muscle relaxants believe that if the ETT should become dislodged or ventilation becomes compromised (i.e., when the trachea is entered by the otolaryngologist) oxygenation will be maintained by the spontaneously breathing patient. Those who use muscle relaxants believe that the ETT is less likely to dislodge if the patient does not move. It is also important for the patient to be immobile during critical points in the surgery such as when the otolaryngologist enters the trachea.

Positioning consists of a shoulder roll that extends the neck to provide adequate surgical access. The chin will be pulled up by strategic placement of a tape sling to maintain extension and to stabilize the soft tissue over the trachea. Head extension withdraws the ETT from the airway and care must be taken to prevent a premature extubation.

The use of opioids is at the discretion of the anesthesiologist. Local infiltration by the otolaryngologist with a local anesthetic containing epinephrine is performed prior to the start of the procedure and will provide adequate analgesia postoperatively. The use of epinephrine rarely causes cardiovascular compromise when injected locally, however, if there is any concern epinephrine may be omitted.

Prior to entering the trachea, the otolaryngologist must alert the anesthesiologist. If a cuffed ETT is used, the cuff should be deflated to avoid being damaged during this part of the procedure. When the otolaryngologist enters the trachea, a large leak will develop causing a loss of tidal volume possibly compromising oxygenation and ventilation. It is during this time that communication between the otolaryngologist and anesthesiologist is of paramount importance. If oxygenation

and ventilation become significantly compromised, it may be necessary for the otolaryngologist to stop and occlude the opening made in the trachea. This maneuver may be necessary multiple times until the tracheotomy tube is ready to be inserted. Non-absorbable Prolene or nylon stay sutures (4–0 in infants, 3–0 in older children) are placed on either side of the tracheal opening to stabilize the trachea for cannulation. Postoperatively and prior to establishment of the tracheal tract, these stay sutures may be life-saving in the event that the tracheotomy tube becomes dislodged and re-insertion of an airway device becomes necessary. The stay sutures should be clearly marked right or left so that pulling on the sutures in the proper direction results in opening of the tracheotomy site. Absorbable sutures are used to adapt the skin to the tracheotomy site, maturing the tract, making the surgical airway more stable and minimizing the possibility of passing a tube into a false passage.

Just prior to insertion of the tracheotomy tube, the ETT, if present, is withdrawn to just above the tracheal window but still within the trachea. This allows for re-advancement of the ETT beyond the tracheal window in the event of difficult tracheal cannulation. The ETT is not completely removed until correct positioning of the tracheotomy tube is confirmed by attaching the anesthesia circuit and auscultating for bilateral breath sounds and confirming the presence of $ETCO_2$. It should be noted that ventilation through the tracheotomy tube might be compromised by the presence of the ETT, as it allows for easy shunting of gas out of the airway. Therefore, when checking ventilation through the tracheotomy tube, the ETT should be occluded but not withdrawn. Once positioning of the tracheotomy tube and integrity of the cuff, if present, is confirmed and the otolaryngologist agrees, the ETT is completely withdrawn.

Intraoperative complications include airway fire (discribed in detail later in chapter), the development of subcutaneous emphysema, pneumothorax, pneumomediastinum, bleeding, recurrent laryngeal nerve injury, and passage of the tracheotomy tube into a “false passage” in the soft tissues outside of the airway. Subcutaneous emphysema is diagnosed by the presence of crepitus in the neck and shoulders and should prompt investigation into the correct positioning of the tracheotomy tube. Tube position can be quickly ascertained by passage of a flexible bronchoscope (2.5 mm outer diametet) through the lumen that will immediately determine tracheostomy tube location and position. Acute deterioration in the pulmonary or cardiac status of the patient, if not related to malpositioning of the tracheotomy tube, may be secondary to pneumothorax or pneumomediastinum. Bleeding from soft tissue, thyroid vessels, or vascular anomalies may obscure the otolaryngologist’s view.

Postoperative Management

At the end of the procedure, the patient is transferred to the intensive care unit. Either mechanical or spontaneous ventilation is continued and humidified air or oxygen provided. Suctioning of the tracheotomy tube by experienced personnel is important to prevent clogging by blood clots or secretions. Due to the small tracheal tube lumen size, any obstruction can significantly impede oxygenation and ventilation. Extreme care should be taken not to dislodge a newly placed tracheotomy tube. The stay sutures should be readily accessible and clearly marked in case of tracheotomy tube dislodgement. A backup tracheotomy tube and appropriate sized ETTs should be available at the bedside should any problems arise whether it is secondary to lumen obstruction or dislodgement.

Recurrent Respiratory Papilloma

Introduction

Recurrent respiratory papillomas (RRP) in infants are usually caused by exposure to human papilloma virus present in the birth canal. However, cases of neonatal RRP have been reported even after cesarean delivery. They can be found at any site in the upper aerodigestive tract, but they are most common, and most potentially dangerous, in the laryngotracheal complex. Presenting symptoms consist of stridor and hoarseness. Rapid growth of the papillomas results in progressive airway obstruction and some of these patients present emergently to the operating room. Because the papillomas cannot be eradicated surgically, these children frequently return to surgery for debulking at intervals, with the timing being dictated by the rapidity of papilloma regrowth. The goal of surgical resection is to maintain a safe airway without causing permanent damage to the larynx. Although there are some adjuvant medical treatments that might prevent spread of the virus or diminish the rate of recurrence, the primary management of RRP at this point remains surgical [107].

In the past, laser surgery was the most common method used for RRP debulking. The benefit of laser surgery is that the beam can be focused on a very small area for precise tissue excision and hemostasis. However, the use of a laser in the airway is complicated and potentially dangerous, as plastic ETTs are flammable and not safe in this application. Furthermore, even in skilled hands there is a potential for permanent scarring and residual vocal problems [108]. While still used in some cases of papilloma (more commonly in adults treated in an office setting), the microdebrider has for practical purposes replaced the laser in the treatment of pediatric RRP in our practice. This device allows for precise, rapid excision of papilloma tissue around a small ETT with minimal injury to the surrounding structures of the larynx. Despite this improved technique, however, laryngeal injury is still possible [109]. Therefore, it should be clear that the goal of any such resection is not complete elimination of gross disease, but rather maintenance of a safe airway while awaiting the remission of viral expression with time.

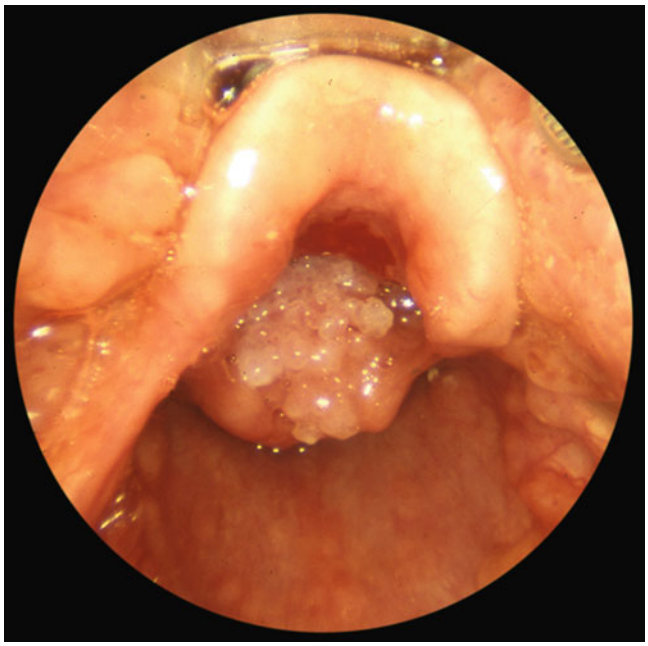

Fig. 20.9 Glottic opening obscured by overgrowth of laryngeal papilloma

Preoperative Assessment and Optimization

Preoperative assessment is directed at assessing the degree of airway obstruction and respiratory compromise. Difficult mask ventilation and tracheal intubation should be anticipated and prepared for if significant disease is present. However, if the child is moving air well while awake, even in the setting of marked papilloma obstruction at the glottis, a small ETT can often still be used. While no airway should ever be taken for granted, as long as equipment and personnel are standing by for an emergency surgical airway, the appearance of the glottis alone should not preclude a gentle attempt at orotracheal intubation (Fig. 20.9).

Keeping the child calm is important since agitated breathing may exacerbate the symptoms of airway obstruction. Premedication, if used, should be done cautiously and judiciously. The risk of causing further or total airway obstruction in the sedated child should be weighed against the benefit of decreasing anxiety in a patient who may be psychologically affected by the frequent repeated visits to the operating room. It would be prudent to withhold premedication in the patient presenting emergently for progressive airway obstruction and provide sedation for the child presenting for maintenance therapy. If premedication is undertaken, it should be done in a monitored setting with emergency airway equipment immediately available.

Intraoperative Management

While lasers are rarely used in our practice at the time of this writing in the management of RRP, we will outline our approach to their use in case the reader encounters such a situation. When laser surgery is planned, precautions need to be taken to avoid harming the patient and operating room personnel by inadvertent contact with the laser beam. Signs stating that laser is being used should be placed on all doors to the operating room. Since the laser beam can damage the cornea or retina, all operating room personnel should wear appropriate eye goggles and the patient's eyes should be taped shut and covered with saline soaked eye pads or metal shields. The head and neck of the patient should be covered by saline soaked towels to prevent laser injury or fire. Appropriate high-density masks should be worn by all operating room personnel in close contact to the smoke plume emanating from the airway. The smoke plumes contain fine particulate (0.1–0.8 mcm) matter that may contain viral particles [110]. Regular operating room masks cannot protect against such small particles.

The risk of fire is a particular concern with the use of lasers, with airway fires being the most serious complication. Surgical drapes are flammable, and are unnecessary for this procedure, so should not be used. The patient's head and neck should be shielded with saline soaked towels, as mentioned above. The laser should always be switched off or in stand-by mode when not in use by the surgeon. Airway fires are caused by the laser beam contacting flammable material in the airway such as polyvinyl chloride ETTs or cotton pledgets. Therefore, during laser surgery of the airway, a specialized ETT should be used that will not catch on fire if contacted by the laser beam. Red rubber tubes wrapped with reflective aluminum have been used in the past, but such a coating may easily fail. Furthermore, the aluminum wrap can be applied only up to the cuff leaving the area below the vocal cords vulnerable to fire. Commercially available laser-safe tubes that have metal exteriors are more commonly used. However, their use in small infants or patients with narrowed airways is limited because of the larger outer diameter of laser-safe tubes when compared with the same sized PVC tube. The larger sized tubes come with two cuffs so that if the laser beam damages the proximal cuff, the second cuff will remain inflated and protect the airway. The cuffs should be filled with a normal saline solution not air. In this way, if the laser beam ruptures the proximal cuff, the spray of saline solution may extinguish early combustion, thereby, preventing an airway fire [111]. In some cases, the ETT can be dispensed with altogether during RRP excision by relying on apneic technique with intermittent intubation between brief laser sessions. This is challenging, however, for both the otolaryngologist and the anesthesiologist, and should not be the method of choice since better alternatives exist.

Because oxygen increases the combustibility of flammable materials, the inspired concentration of oxygen should be kept at less than 30%, as long as adequate oxygenation of the patient is maintained. Nitrous oxide should be avoided as well since it can support combustion at 450 °C [95].

Although airway fires are rare, the operating room team should be ready to manage it expeditiously. The mnemonic of the 4Es should be executed as quickly as possible in order to limit the damage [112]. All combustible material should be EXTRACTED from the airway, the source of oxygen should be ELIMINATED, all fires should be EXTINGUISHED with normal saline, and any damage caused by the fire should be EVALUATED. If the ETT is on fire, it should be immediately removed and the airway secured as soon as it is possible with a new ETT.

During induction of general anesthesia, the otolaryngologist should be present and ready to advance a bronchoscope or perform an emergency surgical airway if necessary. Induction of general anesthesia is usually performed by facemask with sevoflurane and oxygen with or without nitrous oxide. If nitrous oxide is used, it should be discontinued as soon as an adequate plane of anesthesia is attained. In the severely obstructed patient, consideration should be given to obtaining IV access prior to induction. Otherwise, IV access is obtained after an adequate depth of anesthesia is achieved. Spontaneous ventilation is maintained until the anesthesiologist can prove that they can assist or manually ventilate without difficulty. Dexamethasone and a muscle relaxant should be administered at this time. Muscle relaxation is important to provide a still surgical field so that the otolaryngologist will be able to precisely excise the papillomas without interference from laryngeal motion. An antisialagogue may be administered at this time as well.

On occasion, the airway obstruction from overgrowth of the papillomas is so great that induction of anesthesia becomes hazardous and tracheal intubation almost impossible because the glottic opening is totally obscured. Because these patients frequently return for repeated debulking, the decision may be made to perform a tracheotomy to allow for safer management of these patients during future anesthetics. Although the mechanism of distal papilloma spread into the trachea is not clear, tracheotomy has classically been associated with exacerbation of this risk. This may be due to postoperative mucosal changes, or simply the fact that tracheotomy is done in patients with the most aggressive disease. In any case, heroic measures to avoid a tracheotomy, such as very frequent debulking sessions, are themselves risky in patients with marginal airways. It does not seem prudent to withhold this operation solely based on unproven fears of distal spread [113].

Management of the airway can be achieved in multiple ways, the method chosen based on the preference of the anesthesiologist and otolaryngologist and the need for surgical access to papillomas that may be obscured by the ETT. The three methods available are placement of an ETT for the entire procedure, intermittent apnea with removal of the ETT during use of the laser, and jet ventilation (Table 20.13).

Table 20.13 Comparison of techniques for airway management during papilloma surgery of the airway

ETT and controlled ventilation	Intermittent apnea	Jet ventilation
Specialized ETT to avoid airway fire if using laser	No specialized ETT needed	No specialized ETT needed
Inhalation, TIVA, or combination	TIVA	TIVA
<30% oxygen, avoid nitrous oxide if using laser	Intermittent intubation with oxygenation and hyperventilation	Provide controlled ventilation throughout, <30% oxygen if using laser
Obscures anterior and posterior commissures	Unobstructed surgical field	Unobstructed surgical field
Small ETT sizes may not be appropriate for small infants and narrowed airways	Increased $ETCO_2$	Complications: Pneumothorax Pneumomediastinum Air trapping Stomach distension; risk of regurgitation Possible distal spread of viral particles

ETT endotracheal tube, *TIVA* total intravenous anesthesia, *$ETCO_2$* end-tidal carbon dioxide

Placement of an ETT ensures a secure airway and allows for ventilation throughout the procedure. It also protects the airway from particulate debris from entering the airway. However, the ETT may obscure visualization by the otolaryngologist of the anterior and posterior commissures. Maintenance of general anesthesia can be accomplished either by inhalation, TIVA, or a combination of both. No one technique has been proven to be superior.

Intermittent apnea with removal of the ETT [114] allows for greater access to the papillomas present in the posterior commissure. Another advantage to this method is that the risk of an airway fire is greatly reduced since there is no flammable object (ETT) in the airway and oxygen is not insufflated during the laser treatment. A polyvinyl chloride ETT may be used for intubation. Initially, the trachea is intubated while the otolaryngologist is positioning the patient and equipment. During this time, the patient should be on 100% oxygen and hyperventilated in preparation for apnea. Once the otolaryngologist is ready to laser, the oxygen should be turned off and the ETT removed. The otolaryngologist under direct vision performs re-intubation during laryngeal suspension when there is a decrease in oxygen saturation. $ETCO_2$ will rise during the apneic period but is usually well tolerated. TIVA will be necessary to maintain an adequate level of anesthesia since there will be significant periods of time when the inhalation agent will be discontinued.

Jet ventilation is another alternative to airway management. In our practice, we do not utilize this technique for RRP

management in children. However, this discussion is included for the sake of completeness, as it is occasionally used in some circumstances. In children, a metal injector attached to a Venturi apparatus is placed 1–2 cm above the glottic opening. Oxygen concentrations should be kept at <30%. Care should be taken to keep the driving pressure less than 15 psi and to allow enough time for expiration (2–4 s) to occur. This method has the advantage of providing ventilation and oxygenation without the presence of a flammable object thus reducing the risk of an airway fire. The risks of this approach include air trapping and barotrauma in an obstructed airway, as well as the potential for distal dissemination of papilloma virus. Stomach distension may occur increasing the risk of regurgitation and pulmonary aspiration.

When the procedure is completed, emergence can occur with or without tracheal intubation. If the ETT was in place the entire procedure, the patient should be awakened with the ETT in place. Reversal of muscle relaxation should be assured and the ETT removed when the patient is awake and meets extubation criteria. If intermittent apnea or jet ventilation was used, it is acceptable to have the patient emerge from general anesthesia with a facemask. However, if significant respiratory compromise was present preoperatively, it would be wise to awaken the patient with an ETT in place.

Postoperative Management

Many of these cases are done on an ambulatory basis, particularly the regularly scheduled maintenance procedures. If there is no respiratory compromise noted in the PACU, these patients can be discharged home. However, the patient who presented emergently with airway compromise or who continues to have signs of airway obstruction in the PACU may require admission to a monitored setting for further management. In a small subset of patients, a return to the operating room for further debulking may be necessary. In these patients, adequate debulking of the papillomas may have been compromised by the presence of the ETT during the laser treatment. If further surgery is necessary, one of the alternative methods described above may be necessary to provide optimal visualization for the otolaryngologist.

Postoperative pain is not a major issue in these patients and can easily be managed with acetaminophen.

Acute Upper Airway Infections

Introduction

Some acute infections of the upper airway may require operative intervention in addition to medical therapy. These are often problems in the pediatric population, given a smaller airway's increased susceptibility to compromise with edema or inflammatory debris. Some of these (e.g., epiglottitis) have all but vanished due to vaccinations and herd immunity [115, 116]. The most common of these, croup (laryngotracheobronchitis), rarely requires an artificial airway or other surgical management.

Epiglottitis usually occurs in children 2–7 years of age and is most commonly caused by Haemophilus influenzae. The child with epiglottitis will present with symptoms of upper airway obstruction consisting of inspiratory stridor, tachypnea, and retractions. The presence of stridor is concerning in that complete airway obstruction may be pending. The child will prefer to be sitting with their chin up and mouth open and supporting themselves on their hands (tripod position). The inability to handle secretions and difficulty swallowing will result in drooling.

Croup usually occurs in children 6 months to 3 years of age and is viral in origin. Presenting symptoms are a barking cough, inspiratory stridor, and hoarseness. Medical management consists of cool mist, oxygen as needed, and steroids [117]. Although cool mist is used often, the literature does not support its usefulness [118]. Biphasic stridor represents severe airway compromise as do chest retractions and cyanosis in room air. Nebulized epinephrine may be useful in relieving the obstruction and repeat dosing may be necessary.

Bacterial tracheitis involves the accumulation of inspissated mucus in the upper airway. This may require the techniques of foreign body extraction to keep the tracheobronchial tree clear while antibiotic therapy is used to manage the underlying disease.

In each of these cases, however, it is important to remember that airway compromise may develop rapidly in a patient who is also suffering from a systemic infection, making efficient coordinated efforts between the otolaryngology and anesthesia teams crucial for success.

Preoperative Assessment and Optimization

Just as with other cases involving a tenuous airway, children with croup, epiglottitis, or other such infectious airway problems should be kept as calm as possible during the time prior to securing the airway as anxiety or panic can precipitate deterioration in the airway status. Preoperative evaluation is directed at the degree of airway compromise. Radiographic examination of these patients should be entertained only in the stable patient. In epiglottitis, a lateral soft tissue neck film shows a large round epiglottis ("thumb sign"). In croup, an anteroposterior soft tissue neck film shows narrowing of the subglottic area ("steeple sign"). If there is any doubt regarding the stability of the airway, radiographic examination should not be performed nor is it necessary.

Supplemental oxygen should be administered as needed and IV access attempted in the stable patient for fluid and

antibiotic administration. IV access will also be helpful in the event that the airway becomes unstable and intervention is needed emergently. Otherwise, these children should be brought emergently to the OR suite for definitive intervention with the appropriate personnel and equipment available.

While in the past clinicians have been cautioned about airway inspection in cases of epiglottitis (for fear of precipitating further airway compromise), the information gained by awake flexible laryngoscopy can be invaluable when considering the need for a tracheotomy under local anesthesia. A *skilled* otolaryngologist or anesthesiologist should be able to see the hypopharynx and larynx with a minimum of direct airway trauma using a small flexible endoscope, and in such cases the benefits outweigh the risks. However, this should not be done by someone inexperienced in this technique in children with compromised and tenuous airways.

Once the decision has been made to secure the airway in the operating room, it is the responsibility of the otolaryngologist and anesthesiologist to ensure that all necessary equipment is immediately available before the induction of anesthesia. This includes the full range of ventilating bronchoscopes, as well as a tracheotomy set that has been opened and prepared for emergent use.

Intraoperative Management

In cases of epiglottitis, it may not be possible to visualize the glottic airway due to edema and cellulitis of the epiglottis and other supraglottic structures. Patients with impending asphyxia should undergo tracheotomy under local anesthesia, or even a cricothyrotomy if the situation is truly dire. However, if the patient is breathing spontaneously and moving air, there may yet be a transoral pathway to the trachea. This would be preferable to a surgical airway, as attempts at an awake tracheotomy in a struggling child could convert a partial obstruction into a complete one. Even if tracheotomy is ultimately necessary, it is far safer to secure the airway first by orotracheal intubation if possible.

An inhalation induction is preferable with the goal of maintaining spontaneous ventilation until the airway has been safely secured. Topical anesthesia delivered directly to the larynx prior to instrumentation once the patient is adequately anesthetized may be beneficial. Visualization of the glottis may be difficult in epiglottitis secondary to the enlarged epiglottis and care should be taken not to traumatize the epiglottis further by manipulation of the laryngoscope blade. A styletted ETT a half size smaller than predicted should optimize the chances of successful intubation.

The key in epiglottitis is not to blindly attempt intubation that may result in worsening of airway compromise from hematoma or exacerbation of existing edema. The ventilating bronchoscope would be more appropriate in this situation, allowing the optical element at the tip to be manipulated precisely past the supraglottic pathology to the (presumably normal) glottis and tracheobronchial tree. Once the airway has been secured in this manner and ventilation confirmed, tracheotomy may be done over the bronchoscope. Attempts at replacing the bronchoscope with an endotracheal tube using the Seldinger technique would inappropriately risk loss of the airway and exacerbating the existing airway compromise. However, it is important that good positioning of the scope be maintained throughout the tracheotomy, in the center of the lumen and above the carina. This would be the responsibility of a second endoscopist. Unlike an endotracheal tube, which may be safely secured by tape once proper placement is ensured, a rigid steel bronchoscope can potentially cause life-threatening trauma to the tracheobronchial tree if it is displaced distally or driven against the tracheal wall while being used to ventilate the patient.

If the airway is secured with an ETT, the patient is transferred to the intensive care unit for further management. Either orotracheal or nasotracheal intubation is appropriate and will be dictated by the preference of the critical care team. In some instances, tracheotomy is performed electively after ETT intubation.

Patients with croup may require endotracheal intubation in severe cases. However, due to the acute inflammation in the subglottis, such patients are particularly prone to injury from the ETT [119]. It is best to avoid the need for intubation in the first place if possible (through the use of steroids, racemic epinephrine or heliox). If intubation is required, the smallest tube which will allow for adequate ventilation should be used, and extubation should be done as soon as clinically feasible. Since in cases of croup, visualization of the glottis is not typically a problem, consideration should be given to nasotracheal intubation. By fixing the endotracheal tube at the nares instead of the oral commissure, motion of the ETT (with associated axial shearing trauma of the subglottic mucosa) may be minimized, reducing the risk of airway injury. Tracheotomy through an inflamed tracheal airway (i.e., croup) is also associated with an increased risk for long-term complications such as stenosis, and should be used sparingly if at all. This was recognized as early as the nineteenth century [120].

In cases of bacterial tracheitis, the anesthetic and endoscopic techniques of foreign body extraction would apply, with the appropriate modifications for working high in the airway (as described above).

Postoperative Management

When such cases are brought to the operating room, it is usually to secure the airway. Therefore, postoperative management will be primarily by the critical care team, who will determine the timing of extubation following standard clinical guidelines.

Conclusion

The pediatric patient has different physiologic characteristics and anatomical aspects of the upper aerodigestive tracts that require special equipment, training and experience on the part of both the otolaryngologist and the anesthesiologist. These small airways are prone to rapid luminal compromise from either the underlying disease processes or from inexpert attempts at manipulation and intubation. In addition, infants and young children are much more susceptible to rapid oxygen desaturation than are older patients, making the margin for error even smaller. We have described our methods for sharing the pediatric airway, and our preferred approach to the perioperative management of children and their families. As with all areas of otolaryngology and anesthesiology, careful planning and effective communication between team members before the patient even arrives in the operating room will optimize outcomes and minimize complications.

Appendix A

General Anesthesia and Your Child

For most parents, the thought of their child undergoing general anesthesia is by far the most frightening part of any planned surgery. This is understandable, since anesthesia is unfamiliar to most families. Furthermore, the media occasionally reports on a terrifying story of a life-threatening problem associated with a surgical anesthetic. In reality, though, modern anesthesia is extremely safe. It is only because it is so safe—with millions of uncomplicated anesthetics administered every year—that such problems are considered news at all. Here are answers to some commonly asked questions.

Why Can't You Do the procedure Under Local Anesthesia?

For most young children, it is simply not possible to safely perform a surgical procedure without complete (general) anesthesia. Although this may be possible for dental procedures in older patients, it would be far from appropriate for the common operations in my practice.

The administration of local anesthesia itself is often painful and terrifying to a child, as would be the need for restraint. For example, during the placement of ear tubes, even the smallest degree of motion could result in permanent damage to the ear. It simply isn't worth the risk.

Can You Just Use the Smallest Amount of Anesthesia Possible, or Just Some Sedation?

This can actually be more dangerous than general anesthesia. Again, for some clinical situations (such as painless but frightening procedures like a CAT scan), it can be useful. But in a young child with a small airway, the chance of breathing problems is greater if the airway isn't under the anesthesiologist's continual control.

In fact, the period requiring the greatest amount of attention is when the patient is "light," or only slightly anesthetized, during the start or finish of the procedure.

The best analogy is that of flying in an airplane. Most accidents occur during takeoff and landing, when the plane is close to the ground. Similarly, the start and end of anesthesia (induction and emergence) are the most difficult parts of the anesthetic, when the level of anesthesia is lightest. Asking an anesthesiologist to use a small amount of anesthesia (a very common request) would be like asking the pilot to keep the altitude to a minimum by flying just above the treetops!

Who Will Give My Child Anesthesia? Can I Meet That Doctor Ahead of Time?

Your child's anesthetic will be given by a fully trained and experienced attending anesthesiologist, who may have one or more assistants. In almost every case, this doctor will be a specialist in pediatric anesthesiology. In rare situations (usually related to scheduling issues) a general anesthesiologist will be working with me, but in no case will this change the safety of the anesthetic. I would never work with anyone that I did not trust completely.

You will meet this doctor in the hospital just before the surgery, but if you would like to speak to one of the pediatric anesthesiologists ahead of time, you can call the anesthesia office (my staff will give you their number).

I Heard About a Case Where Someone Died Under Anesthesia. Is That Possible?

While this is possible, and has happened, it is extremely rare, especially for healthy children. The overwhelming majority of deaths during surgery involve elderly and/or extremely sick patients undergoing major operations. Millions of people have general anesthesia every year without any difficulty. The actual risk of a fatal event under anesthesia (for an otherwise healthy child) is about 1 in 300,000. To put that number into perspective, the risk of death from an unexpected reaction to penicillin is about 1 in 80,000. The risk of a fatal

automobile accident while riding in a car (in the USA, over a 1 year period) is about 1 in 6,500! Remember, these are extremely rare events, so that when something like that does happen, it makes the news.

What If My Child Is Allergic to Anesthesia? Can You Test for That?

There really is no anesthesia allergy, but there is a very rare condition in which people have a bad reaction to certain anesthetic agents. This is a congenital muscle disease (malignant hyperthermia), which causes a patient to be unstable under anesthesia. Every anesthesiologist knows about this and how to react if this scenario occurs. However, there is no reason to test for this ahead of time (by muscle biopsy) in the absence of anything else that might suggest that the disease is present.

Can I Be There When My Child Goes to Sleep?

My main concern is, of course, the safety of your child. However, I also understand that the stress of surgery (both on the patient and the parent!) can be reduced by your presence in the operating room. In general, one parent is allowed into the operating room while the child goes to sleep.

However, there are some limitations to this general policy. The anesthesiologist is the one who makes the ultimate determination about who is allowed in the operating room. Parents are not allowed in the operating room for patients who are under 9 months of age, or who have certain medical conditions—you should speak to the anesthesiologist about your own child's individual case.

If you yourself feel unsure about how you will react, it is better if you are not there. Seeing a parent having a strong emotional reaction is not reassuring to the child, and may actually be worse than having to go through the procedure alone. And it goes without saying that having a parent faint is not only frightening to the child, but also would result in the need to direct medical attention away from the patient!

Can I Stay During the Procedure?

The only reason for a parent to be in the operating room is to help their child feel better as they go off to sleep. This is not for the parent's benefit. Parents are not allowed in the operating room during the surgery itself, even if they are physicians. This is potentially disruptive. Once again, your child's safety is my primary concern.

Can I Be There When My Child Wakes Up?

This is another very common request. While I do all that I can to make sure that you are separated from your child for the shortest amount of time possible, allowances have to be made for safety. Emergence from anesthesia often requires a good deal of work on the part of the anesthesiologist, and your child need to regain a certain level of consciousness before it is safe to leave the monitors and equipment in the operating room.

While most children are to some degree awake by the time you are reunited with them, they are slowly emerging from a very deep sleep, and usually don't remember much until later on in the recovery period. I know that it is hard to be separated from them when they are going through a stressful experience. I always do my best to keep that time as short as possible.

Why Is My Child Crying in the Recovery Room?

Unlike adults, most children do cry in the recovery room, especially if they are very young or have had a painful procedure (such as a tonsillectomy). This is not because children feel more pain than adults, or get less pain medication. It is because there are many things in this environment that cause stress, and children tend to cry in stressful situations.

In addition to the pain of surgery (which will be treated with a variety of medications), children are often disoriented, frightened, nauseated, hungry, and dehydrated after surgery. All of these things can add to stress. However, children usually feel better within 30 min or so, once they have woken up more fully and have had something to eat or drink.

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