Chapter 16: Anesthesia for Otolaryngologic Procedures

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MYRINGOTOMY TUBES

FOCUS POINTS

1. Bilateral myringotomy tube placement is frequently a short case. Rapid turnover is usually expected.
2. Children presenting for bilateral myringotomy tube (BMT) placement may have an active or recent URTI. The risks and benefits of proceeding should be evaluated and discussed with the caregivers and surgeon.
3. Bilateral myringotomy tube placement is frequently done under inhalational anesthesia with mask ventilation. Peripheral IV access is not mandatory for otherwise healthy patients.
4. Nitrous oxide may be used to distend the tympanic membrane.
5. Children with trisomy 21 may have narrow ear canals, which increases the operative time. IV and laryngeal mask airway (LMA) placement may be appropriate.
6. Pain control may be achieved with nasal and IM medications supplemented by acetaminophen and/or ibuprofen.

INTRODUCTION

Ear, nose, and throat (ENT) surgery encompasses a wide variety of procedures, frequently short, taking as little as 5 minutes for uncomplicated myringotomy tubes. Given the brief nature of many pediatric ENT procedures, multiple surgeries are routinely scheduled in an operating room (OR), and a rapid turnover is often expected. ENT procedures carry a high incidence of airway complications, and a balance must be achieved between safety and efficiency. The anesthesia team must remain vigilant and be prepared to manage perioperative complications such as laryngospasm and bronchospasm. A factor that increases the risk of airway complications is that children presenting for ENT surgery are frequently experiencing or recovering from an upper respiratory tract infection (URTI). ENT procedures also vary in the amount of pain the patient may experience, from unstimulating brainstem auditory evoked response (BAER) evaluations to tonsillectomy and adenoidectomy surgeries. A wide variety of anesthesia techniques may be safely utilized for ENT procedures; however, there is no one “recipe” for each case and an anesthetic plan must be individualized to each patient and procedure.

As with any anesthetic, preoperative evaluation and physical examination should be performed, and any comorbid conditions should be medically optimized prior to proceeding with elective surgery. Preparation of the anesthesia workstation should include rescue medications and emergency airway management equipment.

Case

A 14-month-old girl presents for BMTs, 6 days after being diagnosed with acute otitis media, and has been taking antibiotics as prescribed by her pediatrician. The patient had been referred to an ENT surgeon for BMT placement after being treated for multiple episodes of acute otitis media in the preceding months. Discussion with the patient’s family reveals that she was born at term and is otherwise healthy. The parents state that she has had multiple “ear infections” over the past several months, and it seems like she is “always fighting one.” Physical exam reveals a playful, well-developed

14-month-old child with dried mucus in her bilateral nares. Cardiac and pulmonary auscultation are unremarkable and her vital signs are age-appropriate.

Background

Indications

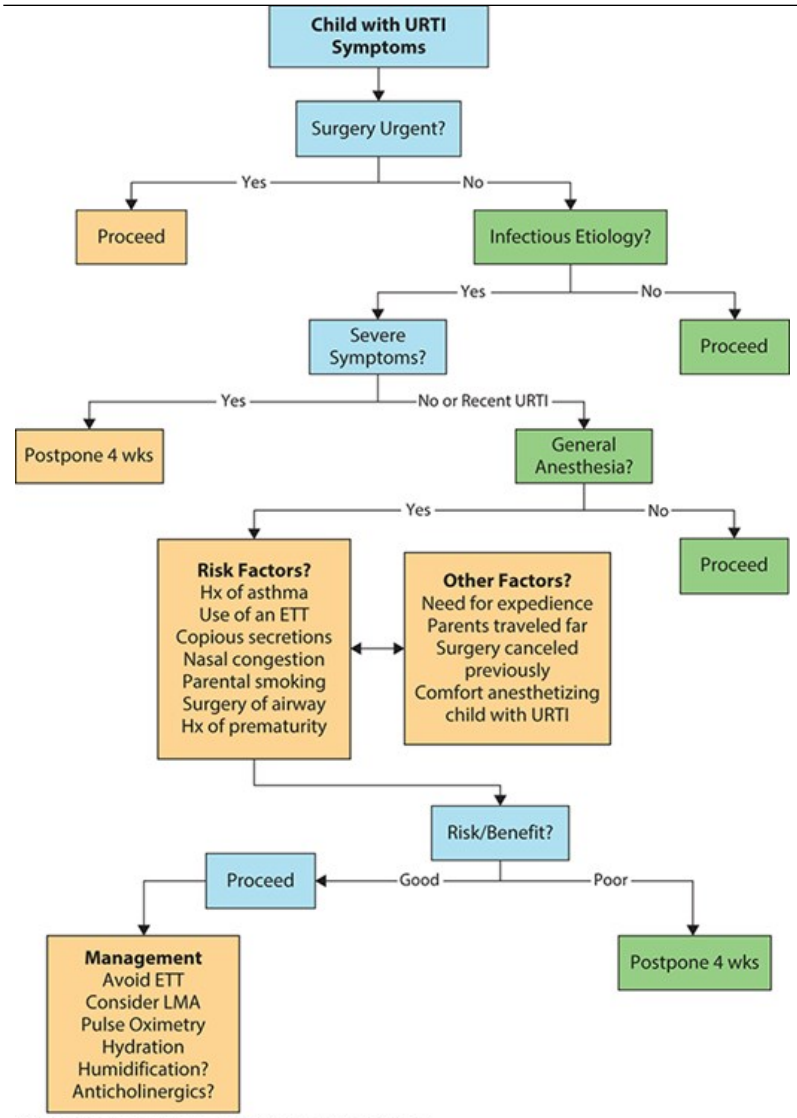
Bilateral myringotomy tube placement is one of the most common surgical procedures performed in the United States. It may be performed for indications such as recurrent acute otitis media or chronic ear effusions.

Patient Considerations

Children presenting for bilateral myringotomy tube placement frequently present with an active case of acute otitis media or have recovered from such an infection within the past month. While all patients should be evaluated and medically optimized prior to proceeding with an anesthetic, it is also common for patients to present having recently experienced a URTI. Recent URTI increases the risk of laryngospasm, bronchospasm, and oxygen desaturation. A discussion of risks and benefits of proceeding should be held between the surgeon and the patient's parents or guardian. If it is unlikely that the patient will experience complete URTI recovery prior to onset of another URTI, consideration should be given to proceeding while taking actions to minimize the risk of airway reactivity intraoperatively.[1,2] Tait and Malviya have proposed an algorithm for assessment and management of a child with a URTI, which may be useful in determining whether to proceed with an anesthetic (Figure 16-1).

Figure 16-1

Algorithm for assessment and management of a child with URTI. (Reproduced with permission, from Tait AR, Malviya S. Anesthesia for the Child with an Upper Respiratory Tract Infection: Still a Dilemma? *Anesthesia & Analgesia.* 2005;100(1), 59-65. https://journals.lww.com/anesthesia-analgesia.)



Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

Specific consideration should also be given to the patient's comorbid conditions. Children with trisomy 21 may have atlantoaxial instability, and care should be taken when manipulating the patient's head for surgical exposure. Some surgeons and anesthesiologists opt to brace the patient's head in place while tilting the entire surgical table to facilitate exposure. Additionally, children with trisomy 21 commonly have narrow ear canals, leading to a technically difficult procedure. If a prolonged procedure is expected, consideration should be given to obtaining intravenous access and placing a LMA.[3]

Anesthetic Management

While it is common to defer IV access during this brief procedure, IV access equipment should be readily available.

Children less than 10 months of age are unlikely to experience separation anxiety and do not routinely require anxiolysis. Above this age, preoperative anxiolysis may be achieved using a variety of means. Distraction is an effective means of managing some children. The use of toys, videos, or pretend-plays, such as having the child breathe into the mask to "blow up the balloon," may be enough to ensure a smooth induction. Alternatively, consideration may be given to having a parent present at induction. The benefit to the child should be weighed against the risk of the parent becoming distressed or disruptive during induction of anesthesia. Parents should be briefed on the physical signs of the excitement stage and reassured that these signs are normal for the child's age. Sedative medications may also be employed. Oral midazolam (0.3–0.5 mg/kg) is appropriate for anxious or combative children but may result in delayed emergence and an extended PACU stay following a brief procedure.[4]

Standard American Society of Anesthesiologists (ASA) monitors should be utilized. An inhalational induction with a mixture of nitrous oxide, oxygen, and gradually increased sevoflurane is the most commonly used combination, although preoperative IV placement and IV induction may be considered for larger children. After the child passes through the excitement stage (Table 16-1), the patient may be maintained with sevoflurane volatile anesthetic administered via a facemask. The surgeon may request the use of nitrous oxide to cause the tympanic membranes to bulge, allowing for easier tympanostomy. The procedure is most commonly performed in the supine position with the bed unturned. Tympanostomy requires a still surgical field; if mask ventilation is difficult or there is a need to switch hands, clear communication with the surgeon is required to avoid accidental movement of the field as the surgeon incises the tympanic membrane. There are no procedure-specific hemodynamic or physiologic goals and blood loss is usually negligible.

Table 16-1

Classic Stages and Planes of Inhalational Anesthesia

- **Stage 1** is defined as the time between the normal waking state and the loss of consciousness (**hypnosis**) caused by an anesthetic agent. There is also mild **analgesia** in stage 1 anesthesia.
- **Stage 2** is associated with loss of awareness and recall (**amnesia**). Stage 2 is associated with the undesired effects of cardiovascular instability, excitation, dysconjugate ocular movements, and emesis.
- **Stage 3** is defined as surgical anesthesia, a state during which **movement in response to pain is suppressed**. Various planes of anesthesia were described by Guedel* based on additional physiological signs:
  - **Plane 1** is associated with deep respiration, coordinated thoracic and diaphragmatic muscular activity, and pupillary constriction.
  - **Plane 2** is associated with diminished respiration, as well as fixed midline and dilated pupils.
  - **Plane 3** is associated with continued diaphragmatic movement, diminished thoracic movement, and further pupillary dilation.
  - **Plane 4** is associated with thoracic immobility and diminished diaphragmatic movement.
- **Stage 4** is associated with cessation of spontaneous respiration and medullary cardiac reflexes and may lead to death.

*Guedel A. *Inhalation Anaesthesia: A Fundamental Guide*. New York: Macmillan; 1937.

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Postoperative pain may be managed using a number of options. Administration of fentanyl (1–2 mcg/kg) via a nasal atomizer is common. Additionally, intramuscular (IM) injections of morphine (0.1 mg/kg) and/or ketorolac (0.5 mg/kg) may be used. Oral acetaminophen (10–15 mg/kg) or ibuprofen (10 mg/kg) may be given preoperatively or in the recovery room. Most patients do not have postoperative pain significant enough to require IV narcotics in the post-anesthesia care unit (PACU). Older children, or those with a history of postoperative nausea and vomiting (PONV), may benefit from post-induction peripheral IV placement and the administration of PONV prophylactic medications such as dexamethasone (0.3–0.5 mg/kg) and ondansetron (0.1–0.15 mg/kg).

Appropriately selected patients may be taken to the PACU in a deep plane of anesthesia while breathing spontaneously. Recovery room staff must be familiar with the management of an emerging patient, and be trained in the identification and management of airway obstruction if emergence is to occur in the PACU. Patients experiencing signs of increased airway reactivity or airway obstruction should be emerged from anesthesia under care of an anesthesia provider skilled in airway management with emergency airway equipment readily available.

Common complications during BMT placement are primarily airway related, such as upper airway obstruction, bronchospasm, and laryngospasm. Upper airway obstruction may be secondary to large, obstructing tonsils, abnormal airway anatomy, or excessive soft tissue secondary to obesity. Jaw thrust and oral airway placement are first-line management techniques, although placement of an LMA or endotracheal tube (ETT) may be necessary. Partial laryngospasm may present with signs such as stridor and neck retraction, while complete laryngospasm may present with absent air movement with or without signs of respiratory effort. This most commonly occurs during the second stage of anesthesia when airway reflexes are the most disinhibited. Continuous positive airway pressure (CPAP) delivered via facemask is frequently enough to break laryngospasm and is considered first-line. Care should be taken to avoid high CPAP pressures as gastric insufflation may occur with continuous pressures greater than 12-cm H_2O.[5]

Intramuscular succinylcholine (2–4 mg/kg) may be given to break laryngospasm if it is unresponsive to nonpharmacologic management. Given the high parasympathetic tone in young children, it is common to co-administer IM atropine (0.02 mg/kg) if IM succinylcholine is given. If IV access is present, IV succinylcholine (0.25–1 mg/kg) may be administered. An IV bolus of an induction agent such as propofol (1–2 mg/kg) may also break laryngospasm; however, this requires enough induction agent to move the nearly emerged patient to a deeper plane of anesthesia and will require the patient to reenter stage 2 of anesthesia, with a possible recurrence of laryngospasm as he emerges a second time.[6]

Bronchospasm should also be considered on the differential when the patient experiences airway obstruction. It may be identified by a "shark fin" appearance of the end-tidal carbon dioxide ($EtCO_2$) waveform. Auscultation of the chest may demonstrate wheezing or absent air entry in the setting of severe bronchospasm. A recent URTI increases the predisposition to airway reactivity including both bronchospasm and laryngospasm. Avoiding airway instrumentation may decrease these risks.[1] Bronchospasm may be treated with deepening the inhaled anesthetic and administration of inhaled albuterol if air movement is not significantly impaired. Severe bronchospasm may impair the delivery of volatile anesthetic and inhaled albuterol. In this situation, a bolus of IV epinephrine (0.5–1 mcg/kg) is appropriate and may be repeated until symptoms improve.[7]

Emergence delirium is common with short procedures involving a rapid emergence from anesthesia. This disassociated state may present as an incoherent, screaming, and thrashing child who refuses to make eye contact. Movement is non-purposeful but may be violent. In addition to causing distress among caregivers, violent thrashing may result in the child inadvertently injuring himself or dislodging IV lines.[8] Allowing the patient to recover from a deep plane of anesthesia in PACU decreases this incidence. Intraoperative IV placement and prophylactic IV dexmedetomidine (0.5 mcg/kg bolus) should be considered for high-risk patients. Nasal fentanyl has been shown to effectively treat emergence delirium in patients without peripheral IV access.[8–10]

Our Case

The child is brought to the OR and standard ASA monitors are placed. A mask induction is performed using nitrous oxide and progressively increased sevoflurane. Upon achieving an adequate depth of anesthesia, fentanyl (1 mcg/kg) is administered nasally using an atomizer and ketorolac (0.5 mg/kg) is administered intramuscularly to the left deltoid. An oral airway is placed, and the airway is maintained with mask ventilation throughout the procedure. Upon completion of the procedure, the patient is placed in the left lateral decubitus position. She is then taken to the recovery room in a deep plane of anesthesia while breathing spontaneously, where she emerges from her anesthetic without issue. Her recovery stay is uneventful, and she is discharged after receiving oral acetaminophen and tolerating a popsicle.

BRAINSTEM AUDITORY EVOKED RESPONSE (BAER)

FOCUS POINTS

1. BAER evaluation is performed in patients with suspected hearing impairment.
2. An ear examination under anesthesia (EUA) and BMT may precede the BAER study.
3. BAER evaluation is not painful, and the lack of stimulation may lead to relative hypotension.
4. Patients with recent meningitis or recurrent ear infections may display URTI symptoms with increased airway reactivity during the BAER study.
5. While volatile anesthesia does not affect the quality of the study, OR noise can have a negative impact on the results.

Case

A 3-year-old boy presents for a BAER evaluation under general anesthesia. He has a past medical history significant for being unvaccinated and he experienced haemophilus influenzae type B meningitis approximately 6 weeks ago with full symptom resolution 4 weeks prior to presentation. A BAER evaluation has been ordered due to concerns of hearing loss secondary to meningitis. Preoperative vital signs are appropriate for the patient's age and physical exam demonstrates an anxious child who appears fearful of medical staff but is otherwise unremarkable. The parents say that the child

developed a fear of medical staff during his hospital stay.

Background

Indications

A BAER evaluation is a common study when there is concern for hearing impairment. Patients presenting for BAER have frequently failed an initial hearing screen or may have suffered a neurological insult, such as meningitis, that is suspected to have damaged the patient's hearing. BAER may also be performed to accurately assess hearing impairment in anticipation of cochlear implant placement.[11]

Patient Considerations

Patients presenting for BAER evaluation under general anesthesia are unable to participate in traditional hearing exams. This may be due to young age or other intellectual disabilities. Of note, patients presenting for BAER evaluation following meningitis may have active or recent URTI symptoms which can increase airway reactivity. BAER is frequently combined with an ear EUA. If an effusion is noted at the time of ear EUA, myringotomy tubes may be placed prior to the exam to ensure the accuracy of the results.

Anesthetic Management

If needed, anxiolytic premedication may be given without impacting the quality of the study.

Anesthesia may be induced with volatile anesthetic followed by peripheral IV placement. The airway can be maintained using a LMA for most patients. Anesthesia may be maintained with volatile anesthetic without impacting the quality of the study. Alternatively, total intravenous anesthesia (TIVA) with propofol infusion may be administered with either a natural airway or an LMA.

Of note, auditory-evoked responses are less susceptible to the effects of volatile anesthesia when compared to sensory or motor-evoked responses. Electrode placement may be stimulating, but the procedure itself has minimal postoperative pain. PONV and emergence delirium prophylaxis should be considered in appropriate patients.

As with most procedures, standard ASA monitors should be employed during the anesthetic. While BAER evaluation results are resistant to the effects of volatile anesthesia, noises in the OR can impact the quality of the study. Monitor volume should be minimized, and the OR should remain quiet while the procedure is in progress. As the procedure is not painful, relative hypotension may occur due to deep anesthesia. This frequently resolves with IV fluid administration and a decreased depth of anesthesia. Blood products are generally not indicated. Upon completion of the study, appropriate patients may be extubated and taken to PACU in a deep plane of anesthesia. Most patients are discharged to home the same day as the procedure.

Our Case

Given the patient's anxiety, oral midazolam (0.5 mg/kg) is administered and the patient is observed until effective anxiolysis is achieved (about 10–20 minutes). The patient is brought to the OR and anesthesia is induced using nitrous oxide and slowly increasing concentrations of sevoflurane. A peripheral IV is obtained and an LMA is placed successfully. Monitor volume is decreased to minimal levels, and the audiologist performs the BAER evaluation. Relative hypotension is noted during the case, but this resolves with IV fluid administration and decreased inspired sevoflurane concentrations. Upon completion of the exam, the patient's LMA is removed under deep anesthesia with spontaneous ventilation and the patient is taken to the recovery room where he emerges uneventfully.

TONSILLECTOMY AND ADENOIDECTOMY

FOCUS POINTS

1. Tonsillectomy and adenoidectomy (T&A) surgery is frequently a short case with a rapid turnover expected.
2. Children with recurrent tonsillitis may have recently recovered from a URTI and are at increased risk of airway reactivity.
3. Children with severe obstructive sleep apnea (OSA) are prone to postoperative airway obstruction and are very susceptible to the respiratory suppressant effects of narcotic medications. Adjuvant analgesics should be maximized in this population. If utilized, long-acting narcotics should be dosed with caution.
4. Any airway surgery involving electrocautery or laser carries a risk of airway fire.
5. Deep extubation helps prevent coughing and may decrease bronchospasm during emergence and emergence delirium postoperatively. It should be avoided in patients with moderate to severe OSA and in those with difficult mask ventilation or intubation.

Case

A 4-year-old girl with history of loud snoring presents for T&A surgery. Overnight polysomnography demonstrated an apnea hypopnea index (AHI) of 25 with a minimum oxygen saturation (SpO_2) of 74%. Discussion with the patient's family reveals that she was born at term and is otherwise healthy.

They affirm that the child snores loudly on a nightly basis. She has been observed having apneic episodes which resolve spontaneously, and the family observes that she regularly experiences daytime somnolence. Airway examination reveals grade 4 "kissing" tonsils. Physical exam reveals a well-developed 4-year-old. Cardiac and pulmonary auscultations are unremarkable, and her vital signs are age appropriate.

Background

Indications

Tonsillectomy and adenoidectomy is one of the most common surgical procedures performed on children. It may be performed as a treatment for recurrent tonsillitis or for the management of obstructive sleep apnea (OSA) in children. Children presenting for T&A due to recurrent tonsillitis may have recently experienced a URTI, which entails an increase in airway reactivity. Children presenting for T&A due to obstructive sleep apnea have increased incidence of airway obstruction during mask ventilation and often demonstrate increased sensitivity to the respiratory suppressant effects of narcotic medications. If performed, a polysomnography study allows quantification and stratification of this risk:

	Apnea Hypopnea Index (AHI)	Oxygen Saturation (%)
Mild OSA	2–5	88–92
Moderate OSA	5–10	80–88
Severe OSA	>10	<80

Children with severe OSA are at particular risk of postoperative airway obstruction and apnea. It is policy at many centers to observe children with severe OSA or children under the age of 2 years overnight prior to discharge home.[12–15]

Anesthetic Management

Preoperative anxiolysis may be managed as described in the myringotomy tubes section; however, sedative premedications should be used with caution in children with severe OSA. Standard ASA monitors should be used. IV induction or inhalational induction followed by peripheral IV placement may be performed as clinically indicated. Endotracheal intubation is commonly performed with a cuffed endotracheal tube (either straight

or RAE) taped midline down the chin. Care should be taken to ensure that the endotracheal tube follows this midline course in the mouth and does not deviate to the side as retractor placement may then lead to unintentional extubation.

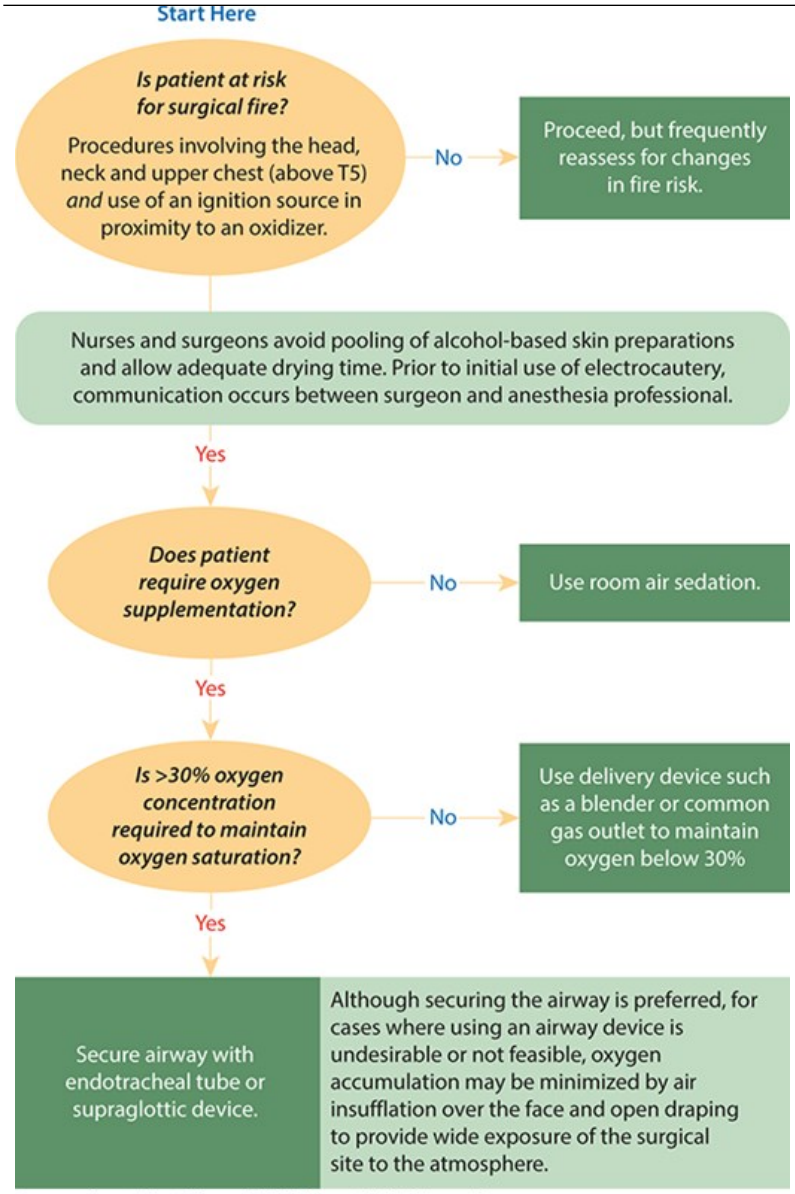
Anesthesia may be maintained with volatile anesthesia; however, nitrous oxide should be used with caution and the FiO_2 should be kept below 30%, as both gases support oxidation which increases the risk of airway fire. Airway fire is a potential hazard of any oral surgery involving electrocautery or laser. The “Fire Triad” describes the three sources required to allow a fire:

1. An oxidizing agent: Both oxygen and nitrous oxide may serve as oxidizing agents allowing the propagation of an OR fire.
2. An ignition source: Surgical electrocautery or laser can ignite an OR fire.
3. A fuel source: Endotracheal tubes, pledgets, and surgical drapes may all act as fuel for an OR fire.

The anesthesia team should notify the surgical team of the FiO_2 in use prior to the activation of electrocautery or a laser in proximity to the airway. A “surgical fire” checklist (Figure 16-2) should be discussed with the OR team prior to starting such a case.

Figure 16-2

Operating room fire prevention algorithm. (Reproduced with permission, from Anesthesia Patient Safety Foundation. 2014. www.apsf.org. Copyright © Anesthesia Patient Safety Foundation. All rights reserved.)



Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

Airway fire is an emergency and should be managed with swift action. The surgeon should flood the field with saline or water, gas flow should be immediately disconnected, and the endotracheal tube should be immediately removed. Termination of gas flow may be accomplished by disconnecting the anesthesia circuit from the anesthesia machine ensuring that a “blowtorch” effect is avoided as the trachea is extubated. Once the fire has been extinguished, the airway should be reintubated and evaluated with fiberoptic bronchoscope to ensure that the trauma of the burn does not result in complete airway obstruction.[16]

During T&A procedures, the patient is frequently positioned supine with the table rotated 90 degrees. To allow surgical exposure, the patient is then placed in suspension for the procedure. There are no procedure-specific hemodynamic goals for T&A surgery. Blood loss is usually minimal during T&A surgery; however, patients with known coagulopathies should be evaluated and optimized in consultation with a hematologist prior to T&A surgery.

It is common to give intraoperative dexamethasone (0.2–0.5 mg/kg), although doses vary significantly by institution and surgeon. The steroid serves to decrease airway edema following surgery while simultaneously acting as an antiemetic. T&A surgery has a high incidence of PONV. Opioid pain medications, volatile anesthetics, and swallowed blood all increase the risk of nausea and vomiting. Additionally, surgical stimulation of the glossopharyngeal nerve acts as a potent stimulus of nausea and vomiting. Ondansetron (0.1–0.15 mg/kg) is frequently given in combination with

dexamethasone to minimize PONV.[17]

Narcotic pain medications are a mainstay of intraoperative pain control, but should be used with caution in children with severe OSA. While children presenting for T&A for the management of recurrent tonsillitis may benefit from long-acting narcotics such as morphine (0.1 mg/kg) or hydromorphone (0.02 mg/kg), children with severe obstructive sleep apnea may be at risk for prolonged apnea and airway obstruction following administration of those drugs. In addition to short-acting narcotics such as fentanyl (1–2 mcg/kg), a multimodal pain medication regimen should be employed. Acetaminophen (10–15 mg/kg oral or IV), surgical administration of local anesthetic, and ketorolac (0.5 mg/kg), if not surgically contraindicated, are some of the more commonly utilized adjuvants. IV dexmedetomidine (0.5 mcg/kg bolus) decreases opioid requirements but may also delay emergence and extubation. Consideration should be given to reserving dexmedetomidine administration for selected cases.

Tonsillectomy does not immediately cure the patient of OSA symptoms. Edema at the surgical site may duplicate or surpass the degree of obstruction caused by the enlarged tonsils. Additionally, surgical alleviation of the chronic airway obstruction does not immediately reduce the increased sensitivity to narcotics caused by chronic CO_2 retention.

The brief nature of T&A surgery, along with the associated pain, makes emergence delirium very common. Deep extubation for appropriately selected patients, along with boluses of IV dexmedetomidine (0.5 mcg/kg) or propofol (1 mg/kg at the end of the procedure), is the mainstay of emergence delirium prophylaxis. IV dexmedetomidine (0.5–1 mcg/kg) may also be utilized as a rescue agent in PACU if emergence delirium is suspected.[8–10]

The decision to extubate deep versus after complete emergence from anesthesia should be based on several factors. Patients with difficult mask ventilation or intubation should not be extubated deep, as rescue of the airway may be challenging. Consideration should be given to performing an awake extubation on children with documented moderate to severe OSA. Children at risk for bronchospasm, such as those suffering from a recent or active URTI, asthma, or bronchopulmonary dysplasia, may benefit from deep extubation. If there is high concern for a post-extubation airway event in a child that would benefit from deep extubation, consideration should be given to a deep extubation followed by emergence from anesthesia in the OR with mask ventilation.

Children undergoing T&A surgery should be observed in the PACU until they have recovered from the acute effects of general anesthesia. During this time, they should be observed for signs of acute postoperative tonsillar bleeding. Pain medication should be titrated to patient comfort and the child observed for signs of airway obstruction and apnea. Children should also be evaluated for tolerance of oral liquid intake prior to discharge home. Children under the age of 2 and those suffering from severe OSA should be admitted for observation and apnea monitoring overnight.[12–15]

Tonsillectomy and adenoidectomy surgery has a large number of potentially serious complications. In addition to laryngospasm and bronchospasm, which are discussed in greater detail earlier in this chapter, post-extubation stridor is a concern. The proximity of the surgical site to the airway increases the risk of edema impairing air movement following extubation. Smaller children are more likely to experience stridor related to airway edema. The Hagen-Poiseuille equation describes how the resistance to flow in the airway is inversely proportional to the radius of the airway raised to the fourth power. The implication is that a small decrease in the airway radius raises resistance to flow exponentially. IV dexamethasone may limit airway edema when given prophylactically but takes time to effect (minimum 1–2 hours). Nebulized racemic epinephrine causes local vasoconstriction, making it an excellent rescue medication if airway edema causes symptomatic stridor.[5]

Surgical encroachment on the airway is a common pitfall of T&A surgeries. When the patient is placed in suspension, the endotracheal tube may become kinked or dislodged. Evaluation of a sudden change in ventilation or loss of ETO_2 should entail a systematic evaluation beginning with the patient and leading to the anesthesia machine. Concerns should be immediately communicated to the surgeon and prompt action taken once the source of the problem is identified.

Our Case

The child is brought to the OR and standard ASA monitors are placed. A mask induction is performed using nitrous oxide and progressively increasing sevoflurane. The patient is noted to be obstructing as mask ventilation is attempted. Placement of an oral airway alleviates the obstruction, and a peripheral IV is placed. Fentanyl (1 mcg/kg) and propofol (3 mg/kg) are administered intravenously and the airway is secured with a 4.5 oral endotracheal tube which is taped midline down the patient's chin. The table is then rotated 90 degrees and the surgeon places the patient in suspension for the procedure. Local anesthetic is injected to the surgical site prior to completion. Dexamethasone (0.25 mg/kg) and ondansetron (0.1 mg/kg) are then administered intravenously. Upon completion of the surgery, the volatile anesthetic is discontinued, and the patient is placed on 100%

oxygen. Following several minutes of controlled ventilation, the patient emerges from anesthesia and is extubated. She then proceeds to scream and thrash wildly. During this time, she fails to make eye contact with the OR staff and does not verbalize any identifiable words. Dexmedetomidine (0.5 mcg/kg) is given as an IV bolus and the patient calms. She is taken to PACU on supplemental oxygen via facemask and SpO_2 monitoring. Upon arrival to PACU, she is snoring gently. During her recovery, she receives two doses of fentanyl (0.5 mcg/kg per dose) and oral acetaminophen (15 mg/kg). She is admitted to the hospital for observation and is discharged to home the following morning following an uneventful night.

DIRECT LARYNGOSCOPY/RIGID BRONCHOSCOPY

FOCUS POINTS

1. Direct laryngoscopy/bronchoscopy may entail anything from a brief diagnostic evaluation to a lengthy surgical intervention on the airway.
2. The “shared airway” requires constant and clear communication with the surgical team.
3. Direct laryngoscopy/rigid bronchoscopy is a very stimulating procedure, but postoperative pain is frequently minimal. The anesthetic plan should account for periods of brief, intense stimulation followed by abrupt absence of stimulation.
4. Procedures involving laser treatment of the airway require careful balance of the risk of airway fire with adequate oxygenation of the patient.
5. Beware of postoperative edema and airway obstruction in these cases.

Case

A 3-year-old boy presents for direct laryngoscopy and bronchoscopy to evaluate and treat subglottic stenosis. The patient has a medical history of prematurity, having been born at 27 weeks’ gestation. He had a 12-week stay in the neonatal intensive care unit, spending the first eight weeks after birth on mechanical ventilation via an endotracheal tube. The patient was diagnosed with bronchopulmonary dysplasia and discharged on oxygen via nasal cannula. He was weaned off of oxygen in the subsequent months. The patient’s parents note that he seems to have less airway reactivity as he has grown, but they are concerned about persistent stridor. Physical exam reveals a well-developed 3-year-old. Cardiac and pulmonary auscultation are unremarkable, but auscultation over the patient’s neck reveals biphasic stridor.

Background

Indications

Direct laryngoscopy and bronchoscopy may be performed for a variety of indications. It may be used for diagnostic evaluation of the airway to diagnose laryngotracheomalacia, subglottic stenosis, and vascular rings, or to identify a tracheoesophageal fistula. Surgical interventions may also be performed during direct laryngoscopy/bronchoscopy. These interventions include supraglottoplasty for laryngomalacia, laser treatment of subglottic stenosis or papilloma, injection of laryngeal cleft, and/or removal of an airway foreign body.[5,12,18]

Patient Considerations

Patients presenting for direct laryngoscopy and bronchoscopy may have a high degree of airway obstruction at baseline. A detailed history of obstructive symptoms should be obtained prior to induction of general anesthesia. Additionally, patients frequently have comorbid conditions such as bronchopulmonary dysplasia. This increases airway reactivity and decreases the patient’s tolerance of apnea.

Anesthetic Management

Induction of anesthesia should be performed in a way that maintains spontaneous ventilation. A mask induction with volatile anesthetic followed by peripheral IV placement frequently accomplishes this goal. Direct laryngoscopy/bronchoscopy procedures are frequently performed without endotracheal intubation and an open airway that is shared with the surgeon. The surgeon or anesthetist, prior to relinquishing the airway, will typically

apply local anesthetic to the vocal cords using a laryngotracheal atomizer to help minimize the risk of laryngospasm. Direct laryngoscopy and bronchoscopy are both very stimulating. Anesthetic depth should be deep enough to prevent laryngospasm and bronchospasm, while accounting for the possibility that removal of stimulation may lead to apnea caused by the depth of anesthesia without the mitigating influence of stimulation.

There are many safe and effective options for maintenance of anesthesia, most relying on a combination of medications. As the surgeon evaluates the airway, volatile anesthesia may be insufflated through the rigid bronchoscope. Alternatively, a 4.0 to 5.0 uncuffed endotracheal tube placed into the posterior pharynx can be used to passively deliver oxygen and volatile anesthetic. As the airway is open to the room, consistent delivery of volatile anesthetic may be difficult to achieve, and intravenous anesthetic agents may be needed to supplement. Intravenous infusions of propofol, dexmedetomidine, or remifentanil may be titrated to reach an adequate depth of anesthesia. Boluses of ketamine, dexmedetomidine, and fentanyl have also been utilized effectively. Caution should be used when bolusing opioids, as this may trigger apnea. Boluses or infusions of dexmedetomidine have the added benefit of minimizing emergence delirium. Steroids such as dexamethasone should be considered to minimize airway edema and postoperative nausea and vomiting prophylaxis may be accomplished by administering ondansetron.

Standard ASA monitors should be utilized during direct laryngoscopy/bronchoscopy. End-tidal CO_2 monitoring may be unreliable with an open airway, and alternative means must be used to ensure adequate oxygenation and ventilation. Adequate ventilation can be confirmed by observation of chest rise or by use of a precordial stethoscope. Pulse oximetry may be used to verify adequacy of oxygenation.

As may be inferred by the nature of the surgery, airway obstruction is the most commonly encountered complication of direct laryngoscopy/bronchoscopy. Laryngospasm may occur due to light anesthesia or surgical manipulation of the vocal cords. An adequate depth of anesthesia and surgical topicalization of the vocal cords may help prevent this. Treatment of laryngospasm should involve deepening the anesthetic and positive pressure via mask ventilation if needed. Muscle relaxation may be considered in refractory cases, but this prevents the spontaneous ventilation required to facilitate the surgery.[5,12,18]

Bronchospasm during direct laryngoscopy and bronchoscopy arises most commonly in children predisposed to airway reactivity, such as those with asthma, bronchopulmonary dysplasia (BPD), or a recent URTI. Surgical stimulation in the setting of light anesthesia may precipitate bronchospasm. Prevention of bronchospasm relies on optimization of conditions that predispose to it. Asthma and BPD should be well controlled prior to proceeding with elective surgery, and elective airway procedures should be delayed several weeks following the resolution of URTI symptoms. Bronchospasm may be challenging to treat in the setting of a shared airway. Use of inhaled bronchodilators such as albuterol is likely to be ineffective and should not delay the use of bolus IV epinephrine (0.5–1 mcg/kg) to treat bronchospasm.[7]

Direct surgical intervention on the airway increases the risk of edema impairing air movement during or after the procedure. Smaller children are more likely to experience stridor related to airway edema. The Hagen-Poiseuille equation dictates that the resistance to flow in the airway is inversely proportional to the radius raised to the fourth power. The implication is that a small decrease in the airway radius raises resistance to air flow exponentially. IV dexamethasone may limit airway edema when given prophylactically. Nebulized racemic epinephrine causes local vasoconstriction, making it an excellent rescue medication if airway edema causes symptomatic stridor. Patients should be observed for recurrence of stridor after racemic epinephrine administration. Inhaled helium-oxygen (Heliox) when available has less resistance to air-flow through edematous areas of the trachea and may be required as a supportive measure until airway edema resolves.[5,12]

Direct laryngoscopy/bronchoscopy entails uncommon stressors to the patient's physiology. Effective ventilation may be decreased as the patient hypoventilates during the procedure. Apneic oxygenation using passively insufflated 100% oxygen may serve to delay desaturation; however, removal of carbon dioxide is impaired during this process, and $PaCO_2$ will continue to rise until effective ventilation is restored. Decreased PaO_2 and increased $PaCO_2$ both serve to increase pulmonary vascular resistance. Children with existing pulmonary hypertension may experience a pulmonary hypertensive crisis in the setting of these physiologic derangements. The anesthetic plan should aim to minimize decreases in PaO_2 and increases in $PaCO_2$.

The nature of a "shared airway" anesthetic requires constant communication with the surgical team. As the surgeon is manipulating the airway, it is the responsibility of the anesthetic team to facilitate the operative intervention while balancing this against the physiologic stresses the surgery entails. As the patient becomes hypoxic and hypercarbic, it is the responsibility of the anesthesia team to notify the surgeon when surgical intervention must be paused to allow mask ventilation or temporary intubation to restore oxygenation and ventilation.

Airway surgical interventions may involve the use of a laser. In these situations, inspired oxygen and nitrous oxide concentrations should be minimized to decrease the risk of an airway fire (see the section “Tonsillectomy and Adenoidectomy”).

Concern for postoperative airway obstruction should dictate the plans for postoperative disposition. Patients undergoing diagnostic bronchoscopy may be eligible for same-day surgery and discharge to home following their procedure, whereas prolonged procedures, and those with surgical intervention that may result in significant postoperative edema (such as supraglottoplasty), may require admission to the pediatric intensive care unit (PICU) for observation.

Our Case

The patient is taken to the OR and standard ASA monitors are placed. Anesthesia is induced with nitrous oxide and sevoflurane. The patient is transitioned to 100% oxygen and sevoflurane. Spontaneous ventilation is maintained. A peripheral IV is obtained with some difficulty, as the patient is noted to have significant scarring at previous IV sites. A propofol infusion is started at 100 mcg/kg/min. Dexmedetomidine (0.5 mcg/kg) is administered, along with dexamethasone (0.5 mg/kg). Once the patient achieves a stable plane of anesthesia, the bed is turned 90 degrees and the surgeon assumes mask ventilation. As the surgeon begins evaluating the airway, an uncuffed endotracheal tube is placed in the side of the mouth and oxygen and sevoflurane are insufflated into the open airway using 5 L/min fresh gas flows. End-tidal carbon dioxide ($EtCO_2$) is not reliably captured at this time, so ventilation and oxygenation are confirmed by visualization of open vocal cords during bronchoscopy, chest movement, and SpO_2 monitoring. The surgeon notes subglottic stenosis and decides to perform a laser excision of the scar tissue. The FiO_2 is decreased to 25% and the surgeon begins resection. Several times during the resection, the patient’s SpO_2 falls into the mid-80s. Laser excision is paused, and the patient is assisted with mask ventilation and 100% FiO_2 until return of optimal oxygen saturation. The FiO_2 is then lowered and the resection resumed. This process is repeated several times before completion of the procedure. At that time, the patient is placed on 100% FiO_2 and emerged from anesthesia in the OR. He is taken to the recovery room where he is noted to have worsening stridor. Nebulized racemic epinephrine is administered and the patient is observed in the recovery room for 2 hours following resolution of the stridor. The patient is then admitted overnight for observation prior to discharge home.

AIRWAY FOREIGN BODY

FOCUS POINTS

1. The “shared airway” requires constant and clear communication with the surgical team.
2. Foreign bodies can traumatize the local airway and lead to persistent obstruction at the site of the foreign body.
3. Foreign bodies that have been in place for prolonged periods may lead to accumulation of purulent material that can contaminate the contralateral lung upon foreign body removal.
4. Direct laryngoscopy/bronchoscopy is a very stimulating procedure, but postoperative pain is frequently minimal. The anesthetic plan should account for periods of brief, intense stimulation followed by abrupt absence of stimulation.
5. Beware of postoperative edema and airway obstruction.

Case

An 18-month-old girl presents to the OR for emergent removal of an airway foreign body. Three hours prior, her parents noted that she was running with what appeared to be an almond in her mouth when she tripped and fell. After falling, the child immediately began to have increased work of breathing and was found to be wheezing audibly. The patient was taken to the emergency department, where a chest radiograph demonstrated a foreign body in the right mainstem bronchus with hyperinflation of the right lung. The patient has no significant medical or surgical history. The child was eating almonds at the time of the incident and has been NPO since then. Cardiac auscultation is unremarkable. Pulmonary auscultation demonstrates decreased air movement and wheezing on the right side. The patient appears tachypneic with increased work of breathing. Vital signs

are significant for tachypnea and tachycardia with an oxygen saturation of 91% on pulse oximetry on room air. A 22-g peripheral IV is in place in the patient's right hand.

Background

An airway foreign body is typically the result of aspiration of food or other household items. Aspirated items may be found in the trachea, mainstem, or distal bronchi. In addition to mechanical obstruction, airway foreign bodies may cause physical or chemical trauma to the airway epithelium. Sharp or jagged objects may puncture the airway, and foods with oils, such as unroasted nuts, may cause significant inflammation and edema at the site. Sharp or irregularly shaped foreign bodies may also wedge themselves in the airway, making extraction particularly challenging.

While patients with stable respiratory symptoms may be observed and delayed to allow an appropriate NPO status, airway foreign body removals are frequently emergent. Large, obstructing objects can impair oxygenation and ventilation and serve as a "ball valve," trapping air and leading to hyperinflation of the affected lung and subsequent barotrauma. Urgent removal may be necessitated to prevent patient decompensation. Unfortunately, these patients frequently do not meet NPO criteria, which creates a dilemma for the anesthesia team.

Airway foreign body extraction frequently requires rigid bronchoscopy which cannot be accomplished with an endotracheal tube in situ. While most emergency surgeries on non-NPO patients allow for a rapid sequence induction (RSI), emergent airway foreign body removal frequently does not allow for rapid securing of the airway via endotracheal intubation. The risks and benefits of proceeding must be discussed and understood by the anesthesia team, surgeon, and patient's guardian. Fatal gastric content aspiration events have not been reported during airway foreign body removal, while progression of partial airway obstruction to total airway obstruction and acute decompensation of the patient has been reported. If all parties agree that the benefits of proceeding outweigh the risks, this discussion should be documented in the patient's medical record and the removal performed emergently.[12,18–22]

Anesthetic Management

A preoperative discussion should occur between the anesthesia team and the surgeon. This should include discussion of the surgical plan and an agreement on how this may best be facilitated by the anesthesia team. While endotracheal intubation may be optimal for protection against aspiration contents, this may prevent successful extraction of the foreign body and an open airway approach may be required. In this situation, emergency and contingency plans should be discussed, and any necessary equipment prepared. Suction should be readily available and the anesthesia team or surgeon should be prepared to rapidly secure the airway should reflux of gastric contents occur.

While the anesthetic management of a shared-airway procedure is discussed in the section "Direct Laryngoscopy/Rigid Bronchoscopy," this section will highlight the differences and considerations unique to airway foreign body removal.

When preparing for rigid bronchoscopy to facilitate airway foreign body removal, induction of anesthesia should be titrated to ensure maintenance of spontaneous respiration. An inhalational induction may be performed; however, the use of nitrous oxide should be limited, as nitrous oxide may accumulate behind the foreign body and worsen air trapping. Anesthesia maintenance may be accomplished using the same techniques described in the section "Direct Laryngoscopy/Rigid Bronchoscopy."

To facilitate removal of the foreign body, the surgeon may manipulate the head and neck to create a straight line from the oropharynx to the foreign body and allow easier extraction with rigid bronchoscopy. If the foreign body is wedged or in a distal bronchus, the extraction may be prolonged. Prolonged or traumatic extractions increase the risk of airway edema and subsequent airway obstruction.

Several complications are more common during airway foreign body removal. When NPO time has not been adequate, anesthesia personnel should constantly observe for reflux of gastric contents, and be prepared to immediately suction and secure the airway if any gastric contents are identified. Upon successful extraction of the foreign body, the airway may then be intubated and the patient extubated after fully emerging from anesthesia.

As the surgeon performs the extraction, total airway obstruction may occur if the foreign body lodges in the trachea and cannot be quickly removed. If ventilation becomes impossible and the foreign body cannot be immediately extracted, the surgeon should push the foreign body back down into a distal airway allowing ventilation of the contralateral lung.[21]

If air trapping is severe, or if the foreign body has punctured the airway, pneumothorax may occur. Preoperative anesthesia planning should include a

discussion of how a possible pneumothorax will be decompressed intraoperatively. Foreign bodies may also cause tracheoesophageal fistulae via mechanical pressure, puncture, or caustic trauma. On rare occasions, a foreign body may erode into the adjacent pulmonary vasculature, resulting in catastrophic hemorrhage and exsanguination.

Finally, a prolonged obstruction of distal airways may cause pneumonia and allow the accumulation of purulent material distal to the obstruction. Upon removal of the foreign body, this purulent material may contaminate the contralateral lung and significantly impair oxygenation/ventilation.[22]

Patients with significant airway edema, gastric content aspiration, or pneumothorax may require observation in the PICU postoperatively, and severe cases may warrant postoperative ventilation. Generous steroid administration (dexamethasone 0.5 mg/kg) may help prevent post-extraction airway edema.

Our Case

Following a detailed discussion of the risks, benefits, and alternatives to proceeding emergently, the patient is given IV midazolam (0.1 mg/kg) and taken to the OR. A mask induction is performed using 100% oxygen and gradually increasing concentrations of sevoflurane. A propofol infusion is started through the existing Peripheral IV, and the patient reaches a stable plane of anesthesia. The bed is rotated 90 degrees, and the surgeon assumes control of the airway. IV dexamethasone (0.5 mg/kg) is administered prior to the start of the procedure. The surgeon performs a brief direct laryngoscopy and topically anesthetizes the vocal cords using lidocaine. The patient's heart rate is noted to increase during laryngoscopy and the patient's breathing becomes erratic. An IV bolus of dexmedetomidine (0.5 mcg/kg) is administered, and the patient returns to a stable plane of anesthesia. The patient is briefly masked, and the surgeon then places the patient in suspension. The anesthesia circuit is attached to the ventilating port of the rigid bronchoscope and the surgeon begins the procedure. One-hundred percent oxygen and sevoflurane are administered via the bronchoscope as the surgeon examines the airway. An end-tidal CO_2 waveform is visible on the anesthesia monitor. Chest rise is observed, and the vocal cords are seen to be patent on the bronchoscope's video feed. Oxygen saturation via pulse oximetry measures 100%. Using the rigid bronchoscope, the surgeon identifies the almond in the right mainstem bronchus. The surgeon attempts to remove the foreign body using forceps but the almond slips from her grasp as it passes the carina. At this point, the end-tidal CO_2 waveform is lost, and the patient begins to desaturate. The surgeon immediately uses the bronchoscope to push the foreign body back into the right mainstem bronchus, resulting in return of adequate oxygenation and ventilation leading to the stabilization of the patient's vital signs. The subsequent attempt to remove the foreign body is successful. A post-extraction evaluation of the airway demonstrates edema at the site of the foreign body but no residual foreign body fragments or purulent material. Control of the patient's airway is returned to the anesthesia team, sevoflurane and propofol delivery are terminated, and the patient is emerged from general anesthesia in the OR and taken to the recovery room in stable condition. The patient is observed in a monitored bed overnight prior to being discharged to home the following day.

TRACHEOSTOMY

FOCUS POINTS

1. Surgical dissection with electrocautery necessitates lowering the FiO_2 to prevent airway fire.
2. Patients presenting for tracheostomy frequently have pulmonary hypertension. Hypoxia and hypercarbia may exacerbate this leading to a pulmonary hypertensive crisis.
3. Pulmonary hypertensive crisis may require inhaled nitric oxide to treat.
4. As the surgeon enters the airway, clear communication is essential to ensure a safe transition from ventilation through an endotracheal tube to ventilation through the new tracheostomy.
5. Adequate sedation should be utilized postoperatively to minimize risk of tracheostomy dislodgement.
6. In an emergency, reintubate from above.

Case

A 2-year-old, former 26-week-premature male infant is scheduled to come to the OR for tracheostomy. In addition to prematurity, the patient has a medical history significant for bronchopulmonary dysplasia (BPD) and a small ventricular septal defect (VSD), which the patient's cardiologist has been observing. The patient contracted respiratory syncytial virus (RSV) and experienced respiratory distress, requiring intubation and mechanical ventilation 3 weeks prior. The patient has failed to wean from the vent multiple times, and has been scheduled for a tracheostomy to facilitate long-term mechanical ventilation. An echocardiogram performed in the PICU demonstrated a small VSD with bidirectional flow across it, as well as evidence of moderate-to-severe pulmonary hypertension. Vital signs have been stable without vasopressor support, and ventilation parameters have remained stable for several days. Physical exam shows an underweight toddler who is sedated on mechanical ventilation. Cardiac auscultation demonstrates a grade 3 holosystolic murmur. Pulmonary auscultation demonstrates coarse breath sounds in the setting of mechanical ventilation. The patient is receiving intravenous fentanyl and midazolam infusions for sedation via a peripherally inserted central venous catheter line.

Background

Indications

Tracheostomy may be indicated for prolonged intubation with failure to extubate, chronic ventilator requirement secondary to neuromuscular disease or injury, and refractory airway obstruction, such as those seen in patients with some craniofacial syndromes. Tracheostomy may also be performed emergently in the setting of failed intubation with difficult mask ventilation or severe facial trauma.[12]

Patient Considerations

The indication for the tracheostomy frequently dictates the anesthetic course. Patients presenting for tracheostomy may have severe pulmonary disease with associated pulmonary hypertension, or they may have obstructive sleep apnea symptoms. The anesthetic plan should be tailored to account for the patient's comorbid conditions.

Severe lung disease is frequently associated with pulmonary hypertension secondary to chronic hypoxic pulmonary vasoconstriction, leading to pulmonary vasculature remodeling. Patients with severe pulmonary disease and pulmonary hypertension are less likely to tolerate the low inspired oxygen concentrations and the interrupted ventilation required for tracheostomy placement. In patients with pulmonary hypertension, the presence of an intracardiac shunt determines the observable signs of a pulmonary hypertensive crisis. A patient with a baseline intracardiac left-to-right or bidirectional shunt may demonstrate reversal of flow through the shunt as pulmonary vascular resistance rises. The new right-to-left shunt may be identified as systemic oxygen desaturation on pulse oximetry. This "pop-off" mechanism prevents increased pressure being transmitted to the right heart and may prevent the right heart from failing while maintaining forward-flow through the systemic circulation. If no shunt exists, acute right heart failure and hemodynamic collapse may be the presenting signs of a pulmonary hypertensive crisis.

Anesthetic Management

As with any anesthetic, preoperative evaluation and physical exam should be performed and any comorbid conditions should be medically optimized prior to proceeding with elective surgery. Preparation of the anesthesia workstation should include rescue medications and emergency airway management equipment. If the patient has a known difficult airway, difficult airway management equipment should be present in the OR to allow management of a lost airway during the procedure. Patients presenting for tracheostomy are frequently already intubated and require transport from the PICU to the OR. Full transport monitoring, including end-tidal CO_2, should be employed and adequate assistance should be available to help manage any emergencies that arise during transport. Emergency airway equipment should accompany the patient and a plan for managing airway loss during transport should be considered. An emergency airway plan may involve reintubation, temporary placement of an LMA, or mask ventilation of the patient until the patient can be reintubated in a controlled environment.

Consideration should be given to administration of a nondepolarizing muscle relaxant prior to transport or prior to surgical incision. IV narcotics and supplemental volatile anesthetic may be used to attenuate the physiologic stress of the surgery. Patients receiving sedative or opioid medications in the PICU over prolonged periods may demonstrate tolerance and require increased doses of these medications intraoperatively.

Standard ASA monitors, including capnography, should be used during transport and the surgical procedure. Invasive monitors such as arterial blood

pressure or CVP monitoring may be indicated if the patient's comorbid conditions dictate their use. Blood products are not routinely required for tracheostomy, but may be indicated if the patient has anemia or coagulopathy at baseline. Inhaled nitric oxide should be available for patients with preexisting pulmonary hypertension, as the stress of tracheostomy placement may precipitate a pulmonary hypertensive crisis.

Anesthesia may be induced with volatile anesthetic delivered through the patient's existing endotracheal tube. This may be supplemented by nondepolarizing muscle relaxants, benzodiazepine, opioids, and other sedative/hypnotic agents. Maintenance of anesthesia should avoid nitrous oxide as this increases the risk of airway fire.

The patient will be positioned supine for the procedure with a shoulder-roll in place to extend the neck and optimize surgical exposure. Inspired oxygen concentration should be limited during surgical dissection to limit the risk of airway fire. Close communication with the surgical team is essential throughout the procedure. As the surgeon enters the airway, the endotracheal tube will be retracted so the tip is proximal to the tracheal incision. A large air leak will develop at this time, and achieving adequate tidal volume ventilation may be challenging. The surgeon will then place the tracheostomy tube and the anesthesia circuit will be handed over the drapes and connected to the tracheostomy tube by the surgeon. A flexible "accordion" extension attached to the anesthesia circuit may be used to decrease the tension on the new tracheostomy. Ventilation should be immediately resumed, and confirmation of end-tidal CO_2 should be communicated to the surgeon prior to proceeding. If ventilation cannot be established via the new tracheostomy, oral endotracheal reintubation should be emergently performed as emergent tracheostomy replacement can result in intubation of a false passage.

Following completion of the surgical procedure, the patient should be returned to the PICU. Dislodgement of a fresh tracheostomy may be fatal; therefore, generous sedation with muscle relaxation is indicated.

Tracheostomy placement may involve several complications that the anesthesia team should be prepared to manage. Hypoxia may occur due to inadequate oxygen delivery during dissection, or it may be related to existing pulmonary disease. Patients with an underlying pulmonary infectious process that lead to chronic ventilator dependence may have residual airway hyperreactivity, and are more likely to experience bronchospasm. Hypoxia and hypercarbia increase pulmonary vascular resistance which may worsen pulmonary hypertension and trigger a pulmonary hypertensive crisis. Intraoperatively, this may require inhaled nitric oxide to treat. Airway loss during the procedure or during transport is a potentially fatal event. Attempting to blindly replace a fresh tracheostomy may result in intubation of a false passage and fiberoptic guidance is unlikely to be successful in the presence of bleeding. In the setting of dislodgement of a recently placed tracheostomy, oral endotracheal intubation should be urgently performed.[12]

Our Case

The patient is evaluated in the PICU and given a bolus of rocuronium (1 mg/kg) in preparation for transport. The patient is then transported to the OR with AMBU bag assist on full ASA monitors including capnography. Upon arrival to the OR, the patient is transferred to the anesthesia machine ventilator and connected to the standard ASA monitors, also on the anesthesia machine. Inhaled nitric oxide had been ordered and is connected to the anesthesia circuit. The patient's sedation infusions are continued, and sevoflurane is administered via the existing endotracheal tube. The inspired oxygen concentration is decreased to 30% and the patient's oxygen saturation via pulse oximetry stabilizes at 96%.

The patient is prepped and draped, and a surgical time-out is performed. The patient receives a bolus of fentanyl (1 mcg/kg) and the procedure begins. As the surgeon prepares to enter the trachea, the inspired oxygen concentration (FiO_2) is reduced to 21%. The surgeon enters the trachea and notes the endotracheal tube cuff distal to the tracheotomy. The endotracheal tube is retracted until the end of the tube is proximal to the surgical site. A large air leak is noted at this time, and the patient begins to desaturate. The surgeon places the tracheostomy tube and the anesthesia ventilator circuit is transferred from the endotracheal tube to the new tracheostomy. Ventilation is resumed and end-tidal CO_2 is noted to be present with tidal volumes similar to those achieved through the oral endotracheal tube. Oxygen saturation nadired at 82% but has failed to recover following return of ventilation despite increasing the FiO_2 to 100%, and despite adequate ventilation noted upon auscultation of breath sounds. At this point, a diagnosis of pulmonary hypertensive crisis with right-to-left shunting across the patient's VSD is considered. Inhaled nitric oxide is initiated at 20 ppm, and oxygen saturation returns to baseline shortly thereafter. The procedure finishes uneventfully. Prior to transport, an additional bolus of rocuronium (1 mg/kg) is administered and the patient is returned to the PICU using full monitors including capnography. The patient remains stable and the nitric oxide is successfully weaned off that evening.

REFERENCES

1. Tait AR, Malviya S. Anesthesia for the child with an upper respiratory tract infection: still a dilemma? *Anesth Analg.* 2005;100(1):59–65. [PubMed: 15616052]

2. Tait A, Malviya S, Voepel-Lewis T, Munro HM, Seiwert M, Pandit UA. Risk factors for perioperative adverse respiratory events in children with upper respiratory tract infections. *Anesthesiology*. 2001;95(2):299–306. [PubMed: 11506098]

3. Rosenfeld RM, Schwartz SR, Pynnonen MA et al. Clinical practice guideline: tympanostomy tubes in children. *Otolaryngol Head Neck Surg.* 2013;149(1 suppl):S1–S35. [PubMed: 23818543]

4. Sola C, Lefauconnier A, Bringuier S, Raux O, Capdevila X, Dadure C. Childhood preoperative anxiolysis: is sedation and distraction better than either alone? A prospective randomized study. *Pediatr Anesth.* 2017;27(8):827–834.

5. Holzman R. Airway management. In: Davis PJ, Cladis FP eds. *Smith's Anesthesia for Infants and Children*. 8th ed. Philadelphia, PA: Elsevier; 2011:344–364.

6. Larson PC. Laryngospasm–the best treatment. *Anesthesiology*. 1998;89(5):1293–1294. [PubMed: 9822036]

7. Woods BD, Sladen RN. Perioperative considerations for the patient with asthma and bronchospasm. *Brit J Anaesth.* 2009;103(suppl 1):i57–i65.

8. Malarbi S, Stargatt R, Howard K, Davidson A. Characterizing the behavior of children emerging with delirium from general anesthesia. *Pediatr Anesth.* 2011;21(9):942–950.

9. Rosen HD, Mervitz D, Cravero JP. Pediatric emergence delirium: Canadian pediatric anesthesiologists experience. *Pediatr Anesth.* 2015;26(2):207–212.

10. Zhu M, Wang H, Zhu A, Niu K, Wang G. Meta-analysis of dexmedetomidine on emergence agitation and recovery profiles in children after sevoflurane anesthesia: different administration and different dosage. *Plos One*. 2015;10(4):e0123728.

11. Litman R, Cohen D, Sclabassi R et al. Monitoring. In: Davis PJ, Cladis FP eds. *Smith's Anesthesia for Infants and Children*. 8th ed. Philadelphia, PA: Elsevier; 2011:341–342.

12. Landsman I, Werkhaven J, Motoyama E. Anesthesia for pediatric otorhinolaryngologic surgery. In: Davis PJ, Cladis FP eds. *Smith's Anesthesia for Infants and Children*. 8th ed. Philadelphia, PA: Elsevier; 2011:786–820.

13. Clinical practice guideline: diagnosis and management of childhood obstructive sleep apnea syndrome. *Pediatrics*. 2002;109(4):704–712. [PubMed: 11927718]

14. Brown K, Laferrière A, Lakheeram I, Moss IR. Recurrent hypoxemia in children is associated with increased analgesic sensitivity to opiates. *Anesthesiology*. 2006;105(4):665–669. [PubMed: 17006062]

15. Schechter MS. Technical report: diagnosis and management of childhood obstructive sleep apnea syndrome. *Pediatrics*. 2002;109(4):e69. [PubMed: 11927742]

16. Apfelbaum JL, Caplan RA, Barker SJ et al. Practice advisory for the prevention and management of operating room fires. *Anesthesiology*. 2013;118(2):271–290. [PubMed: 23287706]

17. Development and validation of a risk score to predict the probability of postoperative vomiting in pediatric patients: the VPOP score. *Pediatr Anesth.* 2015;25(3):330–330.

18. Nicolai T. Pediatric bronchoscopy. *Pediatr Pulmonol.* 2001;31(2):150–164. [PubMed: 11180692]

19. Mani N, Soma M, Massey S, Albert D, Bailey CM. Removal of inhaled foreign bodies—middle of the night or the next morning? *Int J Pediatr Otorhinolaryngol.* 2009;73(8):1085–1089. [PubMed: 19477532]

20. Fidkowski CW, Zheng H, Firth PG. The anesthetic considerations of tracheobronchial foreign bodies in children: a literature review of 12,979 cases. *Anesth Analg.* 2010;111:1016. [PubMed: 20802055]

21. Kendigelen P. The anaesthetic consideration of tracheobronchial foreign body aspiration in children. *J Thorac Dis.* 2016;8(12):3803–3807. [PubMed: 28149580]

22. Tomaske M, Gerber AC, Weiss M. Anesthesia and periinterventional morbidity of rigid bronchoscopy for tracheobronchial foreign body diagnosis and removal. *Pediatr Anesthes.* 2006;16(2):123–129.