CHAPTER 37

Anesthesia in Nonoperating Room Locations

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OVERVIEW

A large percentage of pediatric anesthesia practice takes place outside the traditional operating room (OR) environment. This practice presents unique challenges because of unfamiliar surroundings, lack of sufficient space, and ancillary personnel who are not familiar with anesthetic procedures and techniques. Furthermore, we are often scheduled in multiple locations throughout the institution on the same day. Therefore, equipment is transported and set up multiple times. This increases the risk of equipment-related problems.

Although the physical locations differ, the anesthesiologist who provides care outside the OR must abide by the same safety and monitoring standards that are followed inside the OR (Box 37-1). It is not necessary to always have an anesthesia machine at the off-site anesthetizing location. Its presence will depend on the comfort of the anesthesiologist and the anticipated use of inhalational anesthetic agents. When one anticipates the use of capnography, it is often easier to transport the entire anesthesia machine that stores the capnograph device. Children who are expected to present a difficult airway should undergo induction of general anesthesia and full airway management in the OR environment, where personnel and equipment are readily available. Once tracheal intubation is safely accomplished, the child is then transported, while anesthetized, to the procedural area.

There are numerous anesthetic techniques that are acceptable in off-site locations – the choice will primarily depend on the preference of the anesthesiologist and the type of procedure being performed. Children undergoing radiological procedures that are not painful are best managed by a hypnotic agent without analgesic properties, such as propofol or a barbiturate. Painful procedures are best managed using analgesics or inhalational anesthetics. It is possible to use high doses of a hypnotic agent during a painful procedure. However, for a severely painful procedure (e.g., bone marrow biopsy), few anesthetic agents will provide adequate analgesia and immobility without respiratory depression and the need for assisted ventilation (ketamine being a possible exception). Whatever the choice, the anesthesiologist should always have immediately available three syringes during and following each procedure: succinylcholine, atropine, and an induction agent of choice.

Transport of the child to the postanesthesia care unit (PACU) at the completion of the procedure is a consideration that should be addressed proactively. If there are recovery facilities in the anesthetizing area, emergence and tracheal extubation can occur at that location, and standard discharge criteria then apply. When the PACU is a considerable distance from the anesthetizing location, the anesthesiologist can choose to either: (1) keep the child anesthetized during transport, with emergence and extubation occurring in the PACU; or (2) transport a child who is emerging from anesthesia. Ultimately, the personal preference of the anesthesiologist is the most important determinant. Either way, it is essential to have at least a pulse oximeter, reliable oxygen source, and a positive-pressure ventilation device en route.

The cost efficiency of remote anesthesia presents an additional challenge. The daily schedule should reflect transport times between the anesthetizing location and the PACU, as well as between remote locations. The most common obstacle is delay, either because the remote

Box 37-1 American Society of Anesthesiologists Guidelines for Nonoperating Room Anesthetizing Locations[a]

These guidelines apply to all anesthesia care involving anesthesiology personnel for procedures intended to be performed in locations outside an operating room. These are minimal guidelines which may be exceeded at any time based on the judgment of the involved anesthesia personnel. These guidelines encourage quality patient care but observing them cannot guarantee any specific patient outcome. These guidelines are subject to revision from time to time, as warranted by the evolution of technology and practice.

- There should be, in each location, a reliable source of oxygen adequate for the length of the procedure. There should also be a backup supply. Prior to administering any anesthetic, the anesthesiologist should consider the capabilities, limitations, and accessibility of both the primary and backup oxygen sources. Oxygen piped from a central source, meeting applicable codes, is strongly encouraged. The backup system should include the equivalent of at least a full E cylinder.
- There should be, in each location, an adequate and reliable source of suction. Suction apparatus that meets operating room standards is strongly encouraged.
- In any location in which inhalation anesthetics are administered, there should be an adequate and reliable system for scavenging waste anesthetic gases.
- There should be in each location: (a) a self-inflating hand resuscitator bag capable of administering at least 90% oxygen as a means to deliver positive-pressure ventilation; (b) adequate anesthesia drugs, supplies, and equipment for the intended anesthesia care; and (c) adequate monitoring equipment to allow adherence to the "Standards for Basic Anesthetic Monitoring." In any location in which inhalation anesthesia is to be administered, there should be an anesthesia machine equivalent in function to that employed in operating rooms and maintained to current operating room standards.
- There should be, in each location, sufficient electrical outlets to satisfy anesthesia machine and monitoring equipment requirements, including clearly labeled outlets connected to an emergency power supply. In any anesthetizing location determined by the healthcare facility to be a "wet location" (e.g., for cystoscopy or arthroscopy or a birthing room in labor and delivery), either isolated electric power or electric circuits with ground fault circuit interrupters should be provided.
- There should be, in each location, provision for adequate illumination of the patient, anesthesia machine (when present), and monitoring equipment. In addition, a form of battery-powered illumination other than a laryngoscope should be immediately available.
- There should be, in each location, sufficient space to accommodate necessary equipment and personnel and to allow expeditious access to the patient, anesthesia machine (when present), and monitoring equipment.
- There should be immediately available, in each location, an emergency cart with a defibrillator, emergency drugs, and other equipment adequate to provide cardiopulmonary resuscitation.
- There should be immediately available, in each location, a reliable means of two-way communication to request assistance.
- For each location, all applicable building and safety codes and facility standards, where they exist, should be observed.

[a] Approved by the House of Delegates on October 19, 1994.

location is not properly prepared to begin on time or because of an unexpected delay during the previous case. When a significant delay occurs, the anesthesiologist must decide whether to move on to the following scheduled case, or delay the entire schedule. The solutions to these problems are to develop a fluid working relationship with the staff in each remote location, enabling them to understand the economic pressures, and to administer anesthesia in a cost-efficient manner with rapid induction and emergence times. An on-site recovery facility with staff trained in the recovery of anesthetized patients also enhances efficiency. Flexibility is essential on the part of the anesthesiologist but the anesthesiologist shouldn't expect staff in remote areas to be flexible as well. In fact, from their standpoint, the most important ingredient for success is consistency. At first these statements may seem paradoxical. However, with experience, the anesthesiologist will become familiar with the remote location's surroundings and staff and will develop a consistent procedure for taking care of their patients. This is especially true in the hematology/oncology or radiation oncology departments where the same patients require many procedures over time. Ideally, in any given institution a small cadre of anesthesiologists will make up the "off-site team" so that differences in preferences and techniques will be minimized and a trusting relationship can develop between members of the team and non-anesthesiology staff in these areas.

MAGNETIC RESONANCE IMAGING

The number of infants and small children requiring magnetic resonance imaging (MRI) has increased substantially

in recent years because MRI is superior to CT for demonstrating most central nervous system lesions (except acute subarachnoid hemorrhage, skull fractures, and various craniofacial and sinus-related disorders), without the risk of ionizing radiation or iodinated contrast agents. Increasing numbers of newborns and small infants are being referred for MRI because of sacral dimples, developmental delay, apnea, seizures, and stridor (for evaluation of a possible vascular ring). This has presented anesthesiologists with an enormous challenge, especially during times of staffing shortages and decreasing reimbursement from third-party payers for these services.

The overriding concern during MRI anesthesia is that the powerful magnetic field precludes the use of metallic devices in the area around the scanner, whether or not a scan is in progress. This includes virtually all our monitors and safety equipment, as well as credit cards, identification badges, and expensive pens. Thus, the challenge is to safely conduct general anesthesia from a distance.

The performance of general anesthesia on children for MRI has been facilitated by the availability of MRI-compatible anesthesia machines, MRI-compatible monitoring stations, and MRI-compatible electronic infusion pumps. Therefore, it is fairly easy to comply with all monitoring standards during anesthesia for MRI. The one exception is that a precordial stethoscope (plastic type) is useful only intermittently because of the noise from the scanner that interferes with auscultation. Temperature measurement is difficult inside the scanner and, because of the cool environment and the scanner fan, neonates and small infants are susceptible to hypothermia. These patients should be covered with several layers of blankets and the scanner fan should be turned off. Hypothermia can also be minimized by limiting the volume of administered intravenous fluids.

Most children anesthetized for MRI are outpatients, and are processed along with all other ambulatory surgical patients. There are no unique preoperative considerations. One of several different anesthetic techniques may be used. At The Children's Hospital of Philadelphia, children for MRI undergo induction of general anesthesia by sevoflurane inhalation in an area separate from the scanner, to optimize the use of ferromagnetic equipment that cannot be used in the immediate scanner vicinity. We utilize three separate MRI scanners, and thus it is most practical to maintain one anesthesia machine in a central anesthetic induction area. Maintenance of general anesthesia is most often accomplished using a continuous infusion of propofol at 200 μg/kg/min. This infusion dose is occasionally titrated upward, especially for neonates and small infants. With this technique, most children will not exhibit upper-airway obstruction during spontaneous ventilation. Adequate oxygenation is easily maintained using a nasal cannula with a capnograph attachment. Occasionally, when upper-airway obstruction occurs, insertion of a nasal or oral airway will provide a patent airway and relieve the rocking motion of the head and neck that interferes with acquisition of artifact-free images. Use of a laryngeal mask airway (LMA) or endotracheal intubation is infrequent, although preferred by some anesthesiologists. Intubated children who require scans of the head or neck will benefit from the use of an oral RAE tube, which is more convenient when using a head coil.

The most important anesthetic consideration is the avoidance of a tragic accident by a ferromagnetic object that, in the presence of a strong magnetic field, is transformed into a dangerous projectile missile that can easily injure the patient or nearby personnel. This includes all types of anesthesia equipment, oxygen tanks, IV poles, gurneys, etc. Anesthesiologists should ensure that all spare oxygen tanks in the MRI facility are made of aluminum. Each scanning facility must enforce strict safety precautions that limit the number and types of personnel within the scanner area, and a protocol should be established for detecting metallic objects that are transported into the scanner facility. Additional equipment hazards involve the use of MRI-compatible monitors, as burns have occurred when coiled electrocardiograph and pulse oximeter cables are allowed to rest on the patient's skin.

COMPUTERIZED TOMOGRAPHY

With improvements in CT scan technology, the need for sedation or anesthesia in children has decreased considerably. Multisection helical CT is three to five times faster than standard helical CT. Thus, more children are able to remain calm and lie still long enough to obtain good images. Yet, anesthesiologists are still called upon for children with severe anxiety, or significant medical disease. As opposed to MRI, there are far fewer anesthetic implications for the child who requires general anesthesia for a CT scan. Standard anesthesia machines and monitoring devices can be used in close proximity to the child. The anesthesiologist wears lead protection and may remain near the child during the scan, the duration of which is usually less than 20 minutes. The preoperative considerations and anesthetic technique options are the same as for MRI.

The recent literature has focused on two important issues with respect to sedation or general anesthesia for CT. The first is the timing of the administration of oral contrast prior to abdominal CT. This oral contrast is diatrizoate meglumine (Gastrografin, Gastroview, Hypaque, etc.), a water-soluble iodinated substance with an osmolality of 1900 mmol/L. From the radiologist's perspective, better diagnostic scans are obtained when the contrast is administered within an hour or so of the time of the scan.

Article To Know

Kanal E, Borgstede JP, Barkovich AJ et al:American College of Radiology White Paper on MR Safety.Am J Roentgenol 178: 1335–1347, 2002.

This important paper should be studied by all anesthesiologists who take part in MRI anesthesia. It is intended to be used as a template for MRI facilities when developing a safety program, in response to the growing number of reports of injuries from ferromagnetic objects inside the scanner area.

The authors of this paper (American College of Radiology Blue Ribbon Panel, which included a representative from the Anesthesia Patient Safety Foundation) begin to establish guidelines and standards for MRI facilities to maximize safety. These include important recommendations for:

- Establishing, implementing, and maintaining safety policies and procedures.
- Establishing separate safety zones in and around the scanner, that include restrictions on personnel allowed in each of these areas.
- Screening procedures for patients, staff, and possible ferromagnetic objects.
- A variety of other technical issues related to scanner safety.

Of note, the panel does not recommend metal detectors because of their inconsistent efficacy.

Case

A 4-year-old boy requires MRI of the brain to further elucidate a suspected brain tumor. His history includes intermittent headaches for 2 months, vomiting for 1 week, and occasional loss of balance. Two days prior, CT scanning using chloral hydrate sedation demonstrated a posterior fossa mass. He is otherwise healthy. His vital signs on admission to the day-surgery unit are: temperature 36.6°C, heart rate 120/min, respiratory rate 24/min, blood pressure 98/38 mmHg.

Is there anything else you would like to know before proceeding with general anesthesia?

My main concern in this child is his increased intracranial pressure, which is manifested clinically as headaches and vomiting. We can assume that the CT scan did not reveal evidence of impending herniation (e.g., midline shift of the brain), which would be unlikely in a posterior fossa mass. Since the child did not exhibit worsening of his condition following chloral hydrate sedation, I will assume that his increased intracranial pressure is not at a critically high level.

Is premedication indicated in this child?

I would consider premedication with an anxiolytic such as oral midazolam, but this will depend on his behavior at the time of the scan. Ideally, I would like to avoid premedication, because of the possible respiratory depressant effect that could worsen his increased intracranial pressure. I would have the child's parents accompany him into the MRI scanner (or induction area), and attempt to induce general anesthesia without much of a struggle using imagery techniques and magic tricks. The theoretical risk of a "stormy" induction in this setting is acutely increasing the intracranial pressure. On the other hand, if I think that this child will be difficult to calm, even in the presence of his parents and by using behavioral techniques, I would administer oral midazolam premedication.

How will you induce general anesthesia in this child?

Since this child has preexisting increased intracranial pressure, the technique of choice would be a modified rapid sequence induction, as described in Chapter 30. However, this child is arriving from home, and does not yet have existing intravenous access. I now have to choose between an inhalational induction by mask with placement of intravenous access after loss of consciousness, or placement of intravenous access while the child is awake. Personally, I'll choose the inhalation induction, knowing that not all pediatric anesthesiologists may agree with this approach. In this child, who appears to have marginally increased intracranial pressure, I don't feel there is any more of a risk of increasing it further by the effects of sevoflurane on the cerebral vasculature or the hypercapnia that might result from respiratory depression caused by the inhalational agent. If I observe a marked decrease in ventilatory effort after loss of consciousness, I will augment ventilation using a bag–mask technique. In addition, as long as the child has followed normal fasting guidelines (see Chapter 12), I don't believe he is at risk of having an increased amount of gastric contents that would predispose to pulmonary aspiration.

Placing an intravenous catheter in a conscious child will almost always result in a substantial amount of pain, crying, and restraint. Some argue that this process may cause greater increases in intracranial pressure than would be observed during an inhalational induction. Furthermore, those who prefer preanesthetic placement of the intravenous catheter presumably are doing so because they want to utilize the modified rapid sequence induction technique, perform endotracheal intubation, and

Case *Cont'd*

continue with controlled mechanical ventilation for the duration of the MRI. If I choose not to control ventilation, then the induction technique is irrelevant.

How will you maintain anesthesia?

As with induction, I must choose between a controlled ventilation technique following endotracheal intubation, or a spontaneously breathing technique in a nonintubated child using deep sedation with a propofol infusion. Some anesthesiologists feel it is most prudent to control ventilation to avoid increasing the intracranial pressure further. However, my preference is the spontaneous ventilation technique. The first response from the astute clinician would be that a spontaneous ventilation technique should not be used in any patient with increased intracranial pressure for fear of causing hypercapnia, increased cerebral blood flow, and thus, increasing intracranial pressure. However, the controlled ventilation technique can also be associated with dangerous increases in intracranial pressure from the sympathetic response generated during tracheal intubation and emergence. This child tolerated chloral hydrate sedation without any apparent worsening of his clinical status, and although I don't know for sure, I will assume that ventilatory parameters between chloral hydrate and propofol deep sedation are somewhat similar. If, on the other hand, this child demonstrated clear evidence of critically increased intracranial pressure (e.g., Cushing's triad, midline shift on the CT scan), a controlled-ventilation technique is indicated.

After obtaining several scans, the MRI technologist informs you that there is motion artifact caused by movement of the child's head during respiration, and they cannot proceed further. What will you do?

Movement of the child's head during respiration is almost always caused by partial upper-airway obstruction, which, other than interfering with adequate MRI, can cause hypercapnia and exacerbate increased intracranial pressure. One possible therapeutic maneuver is deepening the level of unconsciousness by administering a propofol bolus and then increasing the infusion dose. However, I don't want to depress consciousness to the point of further ventilatory depression. Therefore, I will initially attempt to alleviate the head motion by adjusting the head and neck position, usually in more extension, to increase patency of the upper airway. My next choice would be placement of an oral or nasal airway. This will alleviate any upper-airway obstruction in the majority of cases. In the event that these devices continue to be ineffective, I will insert an LMA, or perform endotracheal intubation as a last resort.

Approximately 10 minutes after alleviating the upper-airway obstruction with a nasal airway, the MRI technologist says alarmingly "Yipes! He's trying to crawl out of the scanner!" What will you do?

This is a common problem in MRI and almost always results from a lack of sufficient anesthesia because of technical errors. As the ongoing scan is aborted, I will go into the scanner room and immediately administer a bolus of propofol (approximately 2 mg/kg) as the MRI technologist simultaneously brings the MRI table out from the scanner. This bolus of propofol may cause apnea so my immediate attention will turn to ensuring adequate ventilation. Once the patient has lost consciousness, and after I have repositioned the head and neck, I will attempt to investigate the cause of the awakening. Most likely, it was a failure to deliver the propofol in a sufficient amount. This can be caused by an infiltrated or blocked intravenous site, an accidental disconnection of the intravenous tubing, a faulty infusion pump, or simply that I didn't remember to actuate the "Deliver" button on the infusion pump after the previous dose change. If one performs enough anesthetics for MRI, one or some of these mishaps will eventually occur.

However, anesthesiologists are concerned with this practice because it violates generally accepted fasting guidelines. The gastric emptying time of diatrizoate has not been evaluated but there is no ingredient (fat or protein) that should cause it to empty slower than a clear liquid. However, should pulmonary aspiration of this agent occur, its high osmolality renders it potentially toxic to the lung. Therefore, many pediatric anesthesiologists choose to perform rapid sequence induction of general anesthesia with tracheal intubation after contrast administration, instead of "deep sedation" without airway protection. Alternatively, the contrast material can be administered via an orogastric tube following routine administration of general anesthesia and endotracheal intubation.

The second issue concerns children with cancer undergoing chest CT for detection of primary or metastatic lesions. Radiologists are concerned that the development of atelectasis that accompanies induction of general anesthesia may mask underlying abnormalities (Fig. 37-1). Because of this, many radiologists request routine performance of tracheal intubation to provide positive-pressure ventilation prior to chest CT. A recent study demonstrated that the addition of 5 cmH_2O of positive end-expiratory pressure (PEEP) attenuated

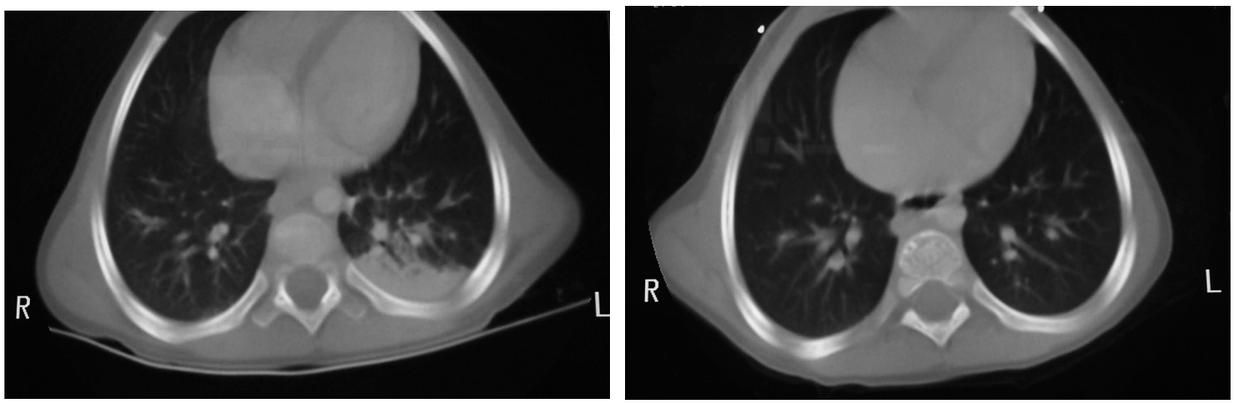

Figure 37-1 **A**, CT scan of the chest in a child prior to instituting positive pressure. Note the atelectasis at the base of the left lung, which may obscure an abnormality. **B**, CT scan of the chest of the same child following several positive-pressure breaths with several seconds of inspiratory hold to alleviate any existing atelectasis.

anesthesia-related atelectasis in children undergoing CT of the chest. An alternate method is to provide transient PEEP and positive-pressure ventilation using a bag–mask technique in unintubated children under deep sedation.

RADIATION THERAPY

Located in the bowels of the hospital, far from civilization, there exists no more daunting environment for the anesthesiologist than radiation oncology. There are several considerations that make this environment different from other remote locations. The first is the anesthetic considerations surrounding the patient's underlying illness; these are reviewed in Chapter 8. The second is that the child must lie completely motionless for a procedure that normally takes less than 10 minutes, with all personnel, including the anesthesiologist, outside the room. Typically, two video cameras are used: one is positioned to view the patient and the other to view the screen of the patient monitor, which displays values for oxyhemoglobin saturation, electrocardiography, capnography, and blood pressure. The anesthesiologist observes the patient on video monitors located immediately outside the treatment room (Fig. 37-2).

Figure 37-2 During a radiation treatment, the anesthesiologist views the patient and the monitor in an observation area immediately outside the treatment room.

Various successful anesthetic techniques exist. However, we have found that the most practical method for rapid induction and recovery of general anesthesia is a propofol-based technique, with the child breathing spontaneously. Supplemental oxygen is provided via a nasal cannula with a capnograph attachment. This can even be accomplished in most children who are required to lie prone for each treatment (Fig. 37-3). Propofol maintenance is provided by continuous infusion or intermittent boluses throughout the procedure. Once the adequacy of ventilation is confirmed, without airway obstruction or oxyhemoglobin desaturation, all staff immediately leave the room and observe the video monitors during the treatment. The tones of the pulse oximeter should be heard via a microphone inside the treatment room that is transmitted to speakers located in the observation area. Acceptable alternative airway methods include use of oral or nasal airways, LMA, or tracheal intubation, if necessary.

Logistical issues should be proactively addressed at the outset of the treatments, which are usually performed once or twice daily for 2–6 weeks. Most children have indwelling tunneled central venous catheters (e.g., Broviac). If not, every attempt is made at the first visit to place a long intravenous catheter that can remain for the duration of the treatment (i.e., PIC line). This enables the child to become anesthetized each day without the emotional trauma of a mask inhalation induction or the need for premedication. Parents should be counseled about proper fasting guidelines and encouraged to offer their child clear liquids on the morning of each treatment. Since it is quite a burden for the child (and parents!) to remain fasted each day, these treatments should be scheduled as early in the day as possible.

Figure 37-3 An anesthetized child is lying prone in a head molding with his chin resting on a soft cushion. Oxygen is provided via a nasal cannula attached to a capnograph to monitor ventilation.

Some anesthesiologists prefer to have these children awaken at the end of the treatment, whereas others will maintain propofol anesthesia until they arrive in the PACU to avoid awakening during transport.

ONCOLOGY CLINIC

The most common procedures that require general anesthesia in the oncology clinic are bone marrow biopsy and lumbar puncture for administration of intrathecal chemotherapy. These procedures are performed with the child lying prone or in the lateral position, depending on the preference of the practitioner performing the procedure. Most children who are currently receiving chemotherapy will have an indwelling central venous catheter, so oral premedication may not be necessary. Others may be undergoing routine surveillance following remission, so will have had their intravenous access removed.

Different anesthetic techniques can be successfully utilized for these procedures, which involve a brief, severe painful stimulus. Some anesthesiologists prefer a "deep sedation" technique using a combination of a benzodiazepine (e.g., midazolam) and an opioid (e.g., fentanyl). The use of remifentanil will facilitate a rapid recovery and discharge from the unit. This technique will rarely ensure complete loss of consciousness and immobility, and is preferred by some older children and adolescents. Postanesthetic emesis is common and may be a result of the opioid or intrathecal chemotherapy. Therefore, antiemetic prophylaxis is indicated.

Other anesthesiologists prefer to use a propofol-based general anesthetic technique. Clinic staff and parents tend to prefer this technique because the child is rendered unconscious. However, propofol is not an analgesic agent, and in most children it will cause central apnea at lower doses than are required for adequate analgesia and immobility during the procedure. Therefore, if one chooses a general anesthetic technique with propofol, and the practitioner performing the procedure requests immobility, the child will likely require assisted ventilation.

ENDOSCOPY SUITE

Esophagogastroduodenoscopy (EGD) and colonoscopy are commonly performed in children in a specially designated endoscopy suite, and require some form of sedation or general anesthesia. Common indications for EGD in children include evaluation of reflux disease, chronic abdominal pain, evaluation and treatment of esophageal varices in chronic liver disease (see Chapter 2), chronic nausea/vomiting, hematemesis, melena, peptic

ulcer disease, and weight loss, among others. Upper endoscopy is usually performed in the lateral position, while colonoscopy is usually performed with the child supine. The most important consideration for anesthesia during upper endoscopy is airway protection. Unless the child is an adolescent, and a sedative technique chosen, tracheal intubation is preferred for all children undergoing this procedure. The anesthetic technique reflects the fact that these procedures tend to end abruptly with little advance warning. Therefore, short-acting muscle relaxants (e.g., mivacurium) and maintenance of general anesthesia with desflurane are preferred. Opioids are rarely used because pain is not a prominent concern during and following upper endoscopy and their administration may delay awakening.

Common indications for colonoscopy in children include evaluation of chronic diarrhea, inflammatory bowel disease, and familial polyposis. Colonoscopy is more painful than it appears; opioids are often used as a component of the anesthetic technique. These children rarely require tracheal intubation unless they are susceptible to pulmonary aspiration of gastric contents due to preexisting medical conditions. Following induction of general anesthesia with sevoflurane, a propofol-based anesthetic technique is used most commonly, with opioid supplementation as needed. The length of the procedure varies depending on the number of biopsies required and the gastroenterologist's ability to reach the cecum, which can occasionally be quite challenging.

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