Anesthesia and Sedation for Procedures in Radiology

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Standards of Practice and Quality Assurance
The practice standards adopted by the American Society of Anesthesiologists in 1986 for basic intra-operative monitoring apply as well to extramural locations. Practice standards and guidelines promulgated by the American Academy of Pediatrics (1,2) are exceeded by established practice standards in anesthesiology.(3) Significant variances may exist when non-anesthesiologists sedate.(4) Practice Standards for Non-Anesthetizing Locations were adopted by the American Society of Anesthesiologists in 1994.(5)

Scheduling and Preparation of Patients
Appropriate planning for an anesthetic begins with a familiarity with the procedure. The requesting service orders the procedure and then leaves the logistics of scheduling to the extramural service. The referring physician should not schedule the procedure because he may not realize the subtle logistics of the procedure or its duration. Radiologists, in particular, recognize that involvement with anesthesia will lengthen their total time commitment to a patient and potentially limit the number of procedures accomplished in a day.(6,7) A well coordinated system to screen patients on the day of procedure is important. Experienced personnel, usually a certified nurse practitioner (CRNP), should be designated to take initial vital signs, review recent medical history, begin IVs if necessary and familiarize the family with the upcoming anesthesia procedure.

It is not always possible for an anesthesiologist to provide sedation and anesthesia for all children when there is a large volume of cases. A structured nursing sedation program can provide safe and effective sedation. As recommended by the JCAHO, the Department of Anesthesia at each facility should work with the Department of Radiology and Nursing to develop and oversee a sedation program (8-12). In actuality, the program begins with the triaging of patients prior to scheduling the procedure. A radiology nurse screens the patient by reviewing the past and current medical history and gathering any relevant laboratory or clinical studies. She then contacts the family for clarification if needed. After this review, the nurse will, in the majority of cases, be able to make an appropriate referral for either general anesthesia or procedural sedation. To ensure consistent decision making, the Departments of Anesthesia and Radiology should develop a set of guidelines and "Red Flags" (Table 1) to help in this triaging process. If there are any questions or additional medical history or studies that need clarification, the nurse and anesthesiologist confer before making the final decision regarding general anesthesia or procedural sedation.

Is gastroesophageal reflux a contraindication to procedural sedation? Because gastoesophageal regurgitation is common in infants, a detailed clinical history should be taken with regard to the incidence and timing of the regurgitation. If the reflux is predictable, (i.e. only associated with mealtimes or soon thereafter) children are usually approved for procedural sedation. NPO guidelines are adjusted to minimize the risk of reflux. For example, if the baby refluxes within 2 hours of solid feeds, but never after 3 hours, then the NPO guidelines for this infant may be extended to 6 hours for solids.

Specific Extramural Sites
Radiology
Computerized Tomography (CT) Scan

CT differentiates between high density (calcium, iron, bone, contrast-enhanced vascular and cerebrospinal fluid (CSF) spaces) and low density (oxygen, nitrogen, carbon in air, fat, CSF, muscle, white matter, gray matter, and water-containing lesions) structures. Because the scan time is quick, CT may be preferable for patients who are medically unstable and in need of rapid diagnosis, for example, the child being evaluated for abuse, an intracranial hemorrhage or abdominal or thoracic mass. Other indications for emergency CT scans may include encephalopathy and a change in neurological status. In these situations, full stomach and increased intracranial pressure (ICP) issues usually necessitate a rapid sequence induction with tracheal intubation. Head CT scan is often the preferred study in emergency situations where head trauma is involved.(13)

The actual scanning sequences are short and can range from 10-40 seconds. These short scan times enable many children to complete a CT scan without any sedation, especially with parental presence and distraction techniques. When an anesthesiologist is involved, it is often for airway or failed sedation issues or for a medically complicated patient. An important aspect of some CT scans is to visualize the sinuses, ears, inner auditory canal, and temporomandibular bones and to evaluate for choanal atresia or craniofacial abnormalities. These scans may require direct coronal imaging with extreme head extension (off the end of the table between a 40 to 70 angle) or absolute immobility for 3-Dimensional reconstruction.

Any patient who is at risk for cervical instability should be properly screened prior to neck extension. Children with Down syndrome are at risk for atlantoaxial instability. The incidence of instability varies from 12% to 32%.(13) Many children with Down syndrome require cervical spine radiographs prior to entering grade school or participating in Special Olympics. Usually, the parents are well aware of the radiological findings. The cervical spine films, however, do not indicate whether or not the child is at risk for dislocation.(14) Rather, those children who exhibit neurological signs or symptoms such as abnormal gait, increased clumsiness, fatigue with ambulation or a new preference for sitting games, are at risk. In infants, developmental milestones (crawling, sitting up, reaching for objects, etc) should be examined. Physical signs may include clonus, hyperreflexia, quadriparesis, neurogenic bladder, hemiparesis, ataxia, and sensory loss. The asymptomatic Down syndrome child with radiologic evidence of instability may be approved for procedural sedation. However, unnecessary neck movement should be avoided. It is important to recognize that any child who displays neurologic signs or symptoms should not be sedated by either a nurse or an anesthesiologist until neurosurgical or orthopedic consultation is obtained.

Radiologists employ gastrografin when evaluating abdominal masses. Gastrografin diluted to a concentration of 1.5% is usually considered a clear liquid. However, the volume that is administered orally is not insignificant: newborns less than 1 month of age receive 60 to 90 mL, infants between 1 month and 1 year of age may receive up to 240 mL and children between the ages of 1 and 5 years receive between 240 to 360 mL. Because sedation or anesthesia should usually be accomplished within a window of 1-2 hours after ingestion of the contrast, most "elective" NPO guidelines would be violated. Yet radiologists insist that the scan must be completed while the Gastrografin is still in the gastrointestinal tract. There are no published data involving optimal induction or sedation techniques as they relate to aspiration risk in these circumstances. Full strength (3%) Gastrografin is hyperosmolar and hypertonic. All Gastrografin should be diluted to an isosmolar and isotonic 1.5% concentration of neutral pH. There is one case report of 1.5% Gastrografin aspiration in a child(15)with no adverse sequelae; therefore, the risk of using a 1.5% concentration of Gastrografin seems low.(16)

Embolization procedures
Interventional techniques include nonvascular and vascular intervention.(17) In vascular interventions, embolization and sclerotherapy have become important techniques for treating vascular malformations, aneurysms, fistulas, hemorrhage, and accomplishing renal ablation. Percutaneous transluminal angioplasty and fibrinolytic therapy are gaining popularity in pediatric institutions. Even in the smallest babies, great success is being reported, and the important contribution that adequate sedation and analgesia can make to ultimate outcome has been recognized.(18) The basic indications for embolization are occlusion of vascular malformations, management of uncontrollable hemorrhage, medical renal ablation and presurgical embolization of hypervascular masses.

Vascular malformations are congenital aberrant connections between blood vessels. Vascular malformations may be composed of lymphatic, arterial, and venous connections. These lesions, although present at birth, are often discrete and not clearly visible. As the child grows, the vascular malformation may expand rapidly, growing with the child. This rapid proliferative phase may occur in response to hormonal changes (pregnancy, puberty), trauma, or other stimuli.(19) Vascular malformations may be high-flow or low-flow lesions, depending on which vessels are involved. High-flow lesions include arteriovenous fistulas, some large hemangiomas, and arteriovenous malformations. Particularly with large lesions, high-output cardiac failure and congestive heart failure with the potential for pulmonary edema should be anticipated and sought out in the medical history and physical exam. Low-flow lesions consist of venous, intramuscular venous, and lymphatic malformations. Surgical resection of symptomatic vascular malformations may be hazardous as well as unsuccessful: any vascular element not resected may enlarge and cause further problems. For this reason, invasive angiography and embolization is becoming an alternative to surgical resection.

When embolizing vascular malformations, radiologists often strive to cut off not only the feeding vessels but also the central confluence (nidus). It is at the nidus that much of the arterial shunting occurs. Embolic agents include stainless steel mini-coils, absorbable gelatin pledgets and powder, detachable silicone balloons, polyvinyl alcohol foam, cyanoacrylate glue, and ethanol. The choice of agent depends on the clinical situation and the size of the blood vessel. When permanent occlusion is the goal, polyvinyl alcohol foam and ethanol are often employed. Both occlude at the level of the arterioles and capillaries. Medium to small-sized arteries may be occluded with coils, which are the equivalent of surgical ligation. Particularly in trauma situations, when only temporary (days) occlusion is the goal, absorbable gelatin pledgets or powder are used.(20)

Large hemangiomas may be associated with the coagulopathy of Kasabach-Merritt syndrome. In this condition, the hemangioma traps and destroys platelets and other coagulation factors, resulting in thrombocytopenia and an increased risk of bleeding. As the hemangioma involutes, the coagulation status improves.(21) A condition described as systemic intravascular coagulation (SIC) can occur after the embolization of extensive vascular malformations. This condition is marked by an elevated prothrombin time (PT) with a decrease in coagulation factors and platelets.

Absolute ethanol is injected in vascular malformations to promote sclerosis. Ethanol may produce a coagulum of blood and cause endothelial necrosis.(22) Sclerotherapy or embolization with absolute (99.9%) ethanol increases the risk of developing a post-procedure coagulopathy(8,9) marked by positive d-dimers, elevated PT and decreased platelets. Ethanol causes thrombosis because it injures the vascular endothelium. Ethanol also denatures blood proteins. Extensive ethanol injections can cause hematuria and urinary catheters should be inserted to monitor urine output, diuresis, and hematuria. Especially with children scheduled for day surgery, liberal fluid replacement will ensure that the hematuria clears prior to discharge. Ethanol can cause neuropathy and tissue necrosis if not injected selectively. Using selective catheterization and direct percutaneous puncture, care is taken not to expose normal blood vessels to the ethanol. In addition to the risk of hematuria, ethanol also can produce significant serum alcohol levels. Mason and others notes that up to 1 mL/kg of ethanol can be administered and that serum ethanol levels have been greater than the intoxication level of .08 mg/dL.(23) Patients with high serum ethanol levels are either sedated or extremely agitated, depending on their particular response to intoxication.

Embolization or balloon occlusion of arterial venous malformations, vascular tumors, intracranial aneurysms and fistulae carries considerable risk of catastrophic results. Such risks include a sudden intracranial hemorrhage, acute cerebral ischemia, or catheter or balloon migration. If sedated, the patient may require urgent airway management. Very long cases require a urinary catheter, especially if contrast material is utilized.

Cerebral angiography requires motionlessness as well as exquisite control of ventilation. Anesthetic technique, both in choice of agent as well as control of arterial CO_2 tension, may affect cerebral blood flow and hence the quality of the scan. Cerebral angiography in children may be performed for the diagnosis or follow-up of Moya Moya disease and these children should have anesthetic techniques that minimize the risk of transient ischemic attacks (TIA) and stroke during the procedure.(24) Other considerations include controlled hypercarbia to promote vasodilation and facilitate access and visualization of the vasculature for the radiologist. In the event of vasospasm or difficult access of small, torturous vessels, locally administered (through the catheter) nitroglycerin in small doses (25-50 mcg) may facilitate visualization and access. Occlusion of the venous portion of the AVM without complete occlusion of the arterial inflow vessels could result in acute swelling and bleeding. Vascularity reduction through occlusion of major feeder vessels is the goal of embolizing large AVMs prior to planned surgical excision. This may be accomplished as a staged procedure over several days, involving repeat anesthetics or sedation sessions.

Angiographic imaging may be enhanced through the use of glucagon. Glucagon is efficacious for digital substraction angiography, visceral angiography and selective arterial injection in the viscera. Glucagon, when needed, is administered in divided doses of 0.25 mg to a maximum of 1.0 mg intravenously. Risks include glucagon-induced hyperglycemia, vomiting (particularly when given rapidly), gastric hypotonia, and provocation signs of pheochromocytoma.(25-27) Children who receive glucagons should be routinely administered prophylactic antiemetics.

The ability to intermittently assess neurological function and mental status is invaluable during embolization procedures but may not be practical in children because of fear, pain and movement. General anesthesia permits easier control of blood pressure and ventilation and eliminates concern about patient movement. For children, general anesthesia is often preferred when performing high-risk procedures that require immobility and periods of breath holding. Pre-procedural assessment should include any history of seizures, bleeding, treatment with anticonsulvants or anticoagulants, neurological symptoms and evaluation of intracranial pressure status. It is important to determine if the patient has had any transient ischemic attacks or evidence of cerebrovascular occlusion. Vasodilator agents (calcium channel blockers) and/or nitrate derivatives may need to be administered after embolization. Because many patients are anticoagulated during the procedure, a preoperative coagulation profile should be obtained. A variety of anticoagulants may have to be on hand as well to prophylax thrombosis.(28)

The potential morbidity associated with embolization is not negligible. Arteriovenous malformations (AVMs) involving the head and neck frequently require cannulation of the external carotid artery branches and the thyrocervical trunk. All patients scheduled for embolization should be typed and cross matched for blood. Those patients who undergo embolizations of AVMs of the head and neck are at risk for stroke, cranial nerve palsies, skin necrosis, blindness, infection, and pulmonary embolism.(29) It is important to document full return of neurologic status after the patient is extubated.

Ultrasound-directed Procedures

Needle biopsies and drainage procedures are directed with ultrasound guidance for diagnostic examination (kidney, liver, lung, muscle, unknown mass, unknown fluid). Percutaneous drainage of abscesses, cysts, pancreatic pseudocysts and other fluid-containing structures can often be accomplished with ultrasound guidance. Ultrasound is useful for placement of difficult central catheters (CVL) and peripherally inserted central catheters. The requirement for general anesthesia versus procedural sedation for ultrasound-guided procedures depends in part on the duration of the procedure, the location involved, the risks associated with the procedure and any procedural requirements. The need for controlled ventilation with breath holding may mandate an endotracheal tube and general anesthesia. Associated secondary effects of the end-organ disease must be kept in mind in the overall anesthetic care plan.

Magnetic resonance imaging (MRI)

MRI is employed for the evaluation of CNS neoplasms, nonhemorrhagic trauma, and vascular and hemorrhagic lesions.(30) Brain MRIs are frequently performed to evaluate developmental delay, behavioral disorders, seizures, failure to thrive, apnea/cyanosis, hypotonia, and mitochondrial / metabolic disorders." Magnetic resonance angiography (MRA) is especially helpful in evaluating vascular flow and can often replace invasive angiography in follow-up evaluations of vascular malformations, interventional therapy, or radiotherapy.(31,32) MRA imaging does not involve the injection of any intravascular contrast and thereby avoids any risk of contrast reaction.

The most common cause of image degradation when performing MRI scans in children is patient movement. Techniques for monitoring anesthetized or critically ill patients during magnetic resonance imaging have been described in several excellent papers.(33-35) It is important to decide at the outset whether the anesthesia support should be sited within the magnetic field or outside of it as this will determine the configuration and composition of the equipment. Equipment sited outside the magnetic field (e.g. outside of the 30-50 Gauss line) can consist of standard equipment with long monitoring leads, and ventilation and gas aspiration tubing. The risks are related to disconnection and impaired direct contact monitoring. When sited close to the magnet, the anesthesia machine and its components must be non-ferrous, with power supplied by filtered sources. All battery-operated equipment must be securely fixed in position and not moved during the examination because the homogeneity of the magnetic field will be affected and the diagnostic images degraded. Most intravenous needles and catheters with metallic hubs are composed of high-grade stainless steel, which is not ferromagnetic. Infusion pumps can be sited outside of the magnetic field as the pump itself may malfunction under the influence of the strong magnetic field. When sited outside the magnetic field, extra length tubing of small bore is required for infusion. Intravenous or inhalation general anesthesia may be used effectively; there is some suggestion that the MRI signal may be altered under the influence of general inhalation anesthetics. Sedation can be problematic in the MR environment when so little of the patient is directly visible. MRI-compatible stethoscopes and flashlights are also helpful. Intubating in the MRI scanner can be accomplished without investing in MRI-compatible laryngoscopes. The only component of the laryngoscope that is not MRI-compatible is the battery in the handle, however, lithium containing batteries are MRI compatible. Beware that some batteries labeled as "lithium" may be tainted with a ferrous-containing substance. To identify this situation, the anesthesiologist should carefully bring the battery into the MRI scanner to confirm compatibility. Non-ferrous laryngoscopes should be clearly identified to minimize the risk of a projectile injury in the scanner.

Anesthetic management of children in the MRI suite is highly dependent on availability of MRI, compatible monitors, anesthesia gas machines, and proximity of the anesthetic provider to the patient and MRI unit. Anesthetic management also depends on the availability of support personnel, the personal style and comfort level of the anesthesiologist, and, of course, the patient's particular medical history. Requiring a general anesthetic in order to complete a noninvasive procedure is often a frightening concept for parents. Parents do not realize that although there is no pain or discomfort involved in the procedure, the child may still need a general anesthetic in order to remain motionless for the scan. It is the rare child who is able to remain motionless after oral midazolam or intramuscular ketamine. One technique for general anesthesia is to perform an inhalation induction followed by placement of a laryngeal mask airway (LMA). During the scan the patient maintains spontaneous ventilation. Lidocaine gel (2%) on the LMA cuff is a useful adjunct, in that the lidocaine gel can decrease the incidence of sore throat(36) and retching.(37) A retrospective study of 200 patients demonstrated the usefulness of this approach.(38) In children with upper respiratory infections, there was a lower incidence of mild bronchospasm, laryngospasm, breath-holding, and major oxygen desaturation (less than 90%) in the group with LMAs compared to the group with endotracheal anesthesia.(39) In the MRI suite temperature monitoring can be accomplished by liquid crystal display (skin temperature).

Anesthesiologists must be aware of many personal items taken for granted - clipboards, pens, watches, scissors, clamps, credit cards, eyeglasses, paper clips, etc. Laryngoscopes and blades are not ferromagnetic but the batteries contained within the handle are. As an alternative, a plastic laryngoscope can be powered by a single, paper-covered nonmagnetic 3V lithium battery, or a DC light source.(33-35) Conventional ECG monitoring is not possible because as the lead wires traverse the magnetic fields, image degradation occurs; ECG by telemetry is often chosen. Non-ferrous pulse oximeters are available, and in some circumstances, fiberoptically-cabled pulse oximeters may be shielded by aluminum foil to minimize magnetic field degradation. Burns have resulted from pulse oximetry monitoring in the MRI.(40,41) Any wire in the magnet bore that is a sizable portion of a wavelength may absorb a considerable amount of energy from the transmitting coil and large voltages may build up on the surface of the wire with no discharge path other than free space. If the wire is poorly insulated or partly exposed, the voltage may discharge through space into the skin, causing significant local burns. Precordial stethoscopes made of non-ferrous materials are acceptable, but the amount of noise generated during radiofrequency pulsing and the length of tubing required renders auscultation ineffective. The use of infrared transmission of breath and heart sounds with a special microphone has been described.(42)

There are, however, focal heating concerns with respect to monitoring equipment in the MRI scanner. For example, ECG leads must not have frayed or exposed wires. Any coils or loops in a conductor can cause tissue burns. There are case reports of first, second, and third degree burns after MRI.(40) In order to prevent patient injury, care must be used to avoid creating a conductive loop between the patient and a conductor (ECG monitoring/gating leads, plethysmographic gating wire, and fingertip attachment). During the scan no exposed wires or conductors can touch the patient's skin and no imaging coil can be left unconnected to the magnet.

The American College of Radiology has established guidelines to avoid mishaps in the MRI environment.(43) Special care should be taken to distinguish ferrous from non-ferrous oxygen tanks. There are morbidities and mortalities, which have occurred from the accidental introduction of a ferrous cylinder into the MRI environment.(44)

Additional MRI safety issues include implanted objects (i.e., cardiac pacemakers), ferromagnetic attraction creating "missiles," noise, biological effects of the magnetic field, thermal effects, equipment issues, and claustrophobia. Some stainless steel may contain ferritic, austenitic, and martensitic components.(45-47) Martensitic alloys contain fractions of a crystal phase known as martensite, which has a body-centered cubic structure, is prone to stress corrosion failure and is ferromagnetic. Austenite is formed in the hardening process of low carbon and alloyed steels, and has ferromagnetic properties. Iron, nickel, and cobalt are also ferromagnetic. For this reason, the components of any implanted device should be carefully researched prior to entering the magnet. Stainless steel or surgical stainless objects interacting with an external magnetic field may produce translational (attractive) and rotational (torque) forces. Intracranial aneurysm clips, cochlear and stapedial implants, shrapnel, intraorbital metallic bodies, and prosthetic limbs may move and potentially dislodge. Some eye makeup and tattoos may contain metallic dyes and therefore cause ocular, periorbital and skin irritation.(48,49) Some tissue expanders employed in reconstructive surgery have a magnetic port to help identify the location for intermittent injections of saline.(50) Personal experience has also demonstrated that Bivona® tracheostomy tubes may also pose a risk in the MRI environment. Although not listed on the package insert, there is ferrous material within the Bivona tracheostomy tube itself. This may not only produce rotational and translational motion but may also prove a thermal hazard.

The magnetic field may affect the electrocardiogram. The changes in the T-wave are not due to biologic effects of the magnetic field but rather to super-imposed induced voltages. This effect of the magnetic field on the T-wave is not related to cardiac depolarization, since no changes to the P, Q, R, or S wave have ever been observed in patients exposed to fields up to 2T. There are no reports of MRI affecting heart rate(51) ECG recording,(52) cardiac contractility,(53) or blood pressure.(54) One study, however, found that humans exposed to a 2T magnet for 10 minutes developed a 17% increase in the cardiac cycle length (CCL). The CCL reverted to pre-exposure length within 10 minutes of removing the patient from the magnetic field.(55) The implications of this finding are unclear. This change in CCL in patients with normal hearts may be of no consequence. The implications of this finding for patients with fragile dysrhythmias or sick sinus syndrome, however, have yet to be determined.

Projectiles are a hazard in the MRI suite. In the presence of an external magnetic field, a ferromagnetic object can develop its own magnetic field. The attractive forces that are created between the intrinsic and extrinsic magnetic fields can propel the ferromagnetic object towards the MRI scanner. Placing a magnet outside the MRI scanner is a helpful way to test any objects as to their attraction to a magnet. This may avoid potential disasters in the MRI scanner. Some objects that have been attracted to the MRI magnet include a metal fan, pulse oximeter, shrapnel, wheelchair, cigarette lighter, stethoscope, pager, hearing aid, vacuum cleaner, calculator, hair pin, oxygen tank, prosthetic limb, pencil, insulin infusion pump, keys, watches, and steel-tipped/heeled shoes.(56) Large objects may have so much attractive force with the MRI scanner that quenching the magnet may be the only way to release the object, once attached to the scanner. Quenching the magnet is not without risk as it fills the scanner with noxious helium gas, mandates extensive follow-up technical support to restart the magnet and requires a minimum of 48 hours to regenerate the magnetic field.

Some patients experience claustrophobia and have difficulty cooperating during the study. Anxiety reactions (57) have been estimated to occur in 4 to 30% of patients. (58)Patients with extreme skeletal abnormalities such as advanced scoliosis or flexion contractures may be unable to lie motionless or supine for the duration of the scan.. These patients may require general anesthesia for positioning and comfort.

Nuclear Medicine

Nuclear medicine is one of the oldest functional imaging disciplines. These scans are useful for identification of epileptic foci in refractory epilepsy, evaluation of cerebrovascular (Moya Moya) disease and the evaluation of cognitive and behavior disorders.(59) Anesthesiologists become involved when the child's medical history suggests that procedural sedation would not be appropriate. In order to complete these scans, the child must remain motionless for at least 1 hour.

The two most common nuclear medicine studies that require the administration of an anesthetic are single photon emission computed tomography (SPECT) scans and positron emission tomography (PET) scans. SPECT scans use single photon gamma emitting radioisotopes and rotating gamma cameras to produce three-dimensional brain images. SPECT scans involve the use of radiolabeled technetium-99m (half-life, 6 hours), which has a high rate of first-pass extraction as well as intracellular trapping in proportion to regional cerebral blood flow.(60) This scan is ideal when seeking seizure foci, which are associated with alterations in regional cerebral blood flow and metabolism. This scan often precedes surgical resection of the identified focus. The technetium radionuclide is ideal because it remains intracellular and can be visualized on scan hours after a seizure has occurred. Ideally, the child should be scanned within 1 to 6 hours of the seizure. The radionuclides are physiologically harmless and nonallergenic. Caretakers, however, should wear gloves to minimize contact with radiation containing secretions.

PET scans use positron emission tomography and radionuclide tracers of metabolic activity, such as oxygen or glucose metabolism(61,62). Unlike SPECT scans, PET scans should be performed during the seizure itself. Because of the short half-life of the glucose tracer (110 minutes), the scan is best completed during the seizure or within 1 hour thereafter.

Radiation Oncology

Radiation therapy for children uses ionizing photons to destroy lymphomas, acute leukemias, Wilm's tumor, retinoblastomas and tumors of the central nervous system. Repeat sessions are typical, requiring reliable motionlessness in order to precisely aim the beam at malignant cells while sparing healthy cells and remote monitoring with a child in isolation. A planning session in a simulator is often scheduled prior to the initiation of radiation therapy so that fields to be irradiated can be plotted and marked.

Radiation therapy is usually very brief, non-painful, and may be approached with a variety of plans for rendering the patient temporarily motionless. The key issue is the anesthesiologist's limited access to the patient. Remote video monitoring as well as ECG and pulse oximeter use is crucial. Two or in some locations three video cameras are used to look at the monitors, the chest, and the face of the patient. A central venous line in young children undergoing a long course of radiation therapy helps immensely. It is important to remember that babies undergoing radiation therapy following a prolonged fast are at risk for hypoglycemia; delayed awakening or tremulousness should prompt a Dextrostix determination.

Clinic and Office Procedures

Endoscopic Retrograde Cholangio Pancreatography (ERCP)

The inability to independently maintain ventilatory function and to respond purposefully increases the risk involved with deep sedation. It has been recommended that deep sedation and general anesthesia be performed by an anesthesiologist.(63-68) Furthermore, if the majority of these cases could be done in the endoscopy suite rather than the operating room, then multiple advantages can be realized – increased OR utilization for surgical procedures and improved efficiency and turnover in scheduling in the smaller and more manageable endoscopy suite. Children with more complex medical problems, anticipated airway difficulties, morbid obesity or behavioral problems can undergo their procedure in the operating room. Regardless of the site of the procedure, all patients scheduled for endoscopy should be evaluated prior to the procedure to confirm that they are appropriate candidates. In addition, the anesthetic technique depends on the procedure, the patient and the skill of the endoscopist as well as the limitations and capabilities of the endoscopy suite (for example, total intravenous anesthesia techniques in the absence of appropriate scavenging). It is important to recognize that the majority of ERCP procedures in children require prone positioning. For this reason, most anesthesiologists prefer endotracheal intubation.

Gastrointestinal endoscopy has become a routine part of patient care and as such it constitutes the bulk of procedures performed by a pediatric gastroenterologist.(69) Depending upon the patient and the type of procedure contemplated (therapeutic vs. diagnostic), children may require no, minimal to moderately deep sedation or general anesthesia.

Safety Issues for Patients and Their Anesthesiologists

As anesthesiologists find themselves participating in the care of patients requiring increasingly sophisticated imaging technology, it is appropriate to examine the risks for patients and staff exposed to the types of high energies and contrast agents used.

Use of intravascular contrast media

In a comprehensive review, Goldberg noted approximately 5% of radiological exams with radiocontrast media (RCM) are complicated by adverse reactions, with 1/3 of these being severe and requiring immediate treatment(70)Reactions occur most commonly in patients between 20 and 50 years of age and are relatively rare in children. The male: female ratio is about 2.5:1, not dissimilar to the gender distribution of other allergies such as latex, aspirin and neuromuscular blocking agents. With a history of atopy or allergy the risk of a reaction is increased from 1.5-10 fold. Reactions vary from mild, subjective sensations of restlessness, nausea and vomiting to a rapidly evolving, angioedema-like picture accompanied by bronchospasm, arrhythmias and cardiac arrest. Because of the high osmolar concentration of these agents (often > 1,000 mOsm, and sometimes > 2,000 mOsm), caution should be exercised with patients who have a limited cardiovascular reserve such as patients in congestive heart failure or those with cardiomyopathy. In addition, volume depleted young children who have been kept NPO for prolonged intervals or who have had bowel preps should be pre-hydrated prior to RCM administration. Those patients dependent on a full intravascular volume status (patients with sickle cell disease, restricted pulmonary circuit volume with cyanotic congenital heart disease, patients with arteriovenous shunts, etc.) should be monitored carefully for an initial rise in filling pressures and intravascular volume and subsequent diuresis following an osmolar load. Patients with impaired excretory mechanisms, such as those in renal failure, must be monitored closely following high osmolar loads. Low osmolar RCM are relatively safe with regard to life-threatening reactions, but moderate non life-threatening reactions requiring some treatment occur 0.2-0.4% of the time and a severe life-threatening reaction can occur in 0.04% of patients.(71)

Gadolinium acid (DTPA) is a low osmolar ionic contrast medium used for MRI, with a slower clearance in neonates and young infants than adults, yielding longer windows for imaging. Free(72) gadolinium has a biological half life of several weeks with uptake and excretion taking place in the kidneys and liver. Unfortunately, free gadolinium is quite toxic and is therefore chelated to another structure that restricts the ion and decreases its toxicity. The clinical safety profiles for the three available MRI contrast agents are quite comparable, with the most common reactions being nausea, vomiting, hives and headache. Local injection site symptoms include irritation, focal burning or a cool sensation. Transient elevations in serum bilirubin (3-4% of patients) have been reported and a transient elevation in iron for Magnevist® and Omniscan®

(15-30% of patients) occurs, which tends to reverse spontaneously within 24-48 hours.(73) Anaphylactoid reactions occur on the order of 1:100,000 to 1:500,000 and are more rare (< 1:100,000 doses) in children.

Allergic reactions rarely occur with oral agents. The incidence of severe anaphylactoid reactions to gastrointestinally administered agents is approximately 1:2,500,000 and the causes remain unknown. There are no pretreatment protocols established for these types of reactions and no well-defined risk factors. Gastrointestinal complications include nausea, vomiting and diarrhea. One of the factors that may protect against having an allergic reaction is the poor absorption of oral iodinated contrast agents. Indeed, disruption of the GI mucosa is recognized as causing an increase in absorption of oral contrast and the urinary excretion of contrast in a gastrointestinal study is a well-recognized sign. Yet rarely they will be associated with bronchospasm, flushing, periorbital edema, pruritus, rash, rhinitis, and urticaria.

Difficult Airway Management in the Outfield
If a child with a known difficult airway requires intubation in order to complete the scheduled procedure, then it is wise to perform the anesthetic induction in the OR, an area where access to emergency airway equipment is readily available. . Regardless of an anesthesiologist's comfort level and familiarity with extramural environments, the same depth of back-up coverage is simply not available.

The unrecognized difficult airway is problematic in a remote location. Therefore, it is important to have LMAs stocked in all extramural anesthesia carts. If a child cannot be intubated or mask ventilated, LMAs can provide a successful alternative. Case reports describe the successful use of LMAs in children with difficult craniofacial anomalies, such as Goldenhar's syndrome (74,75)and even Pierre Robin association.(76) Similarly, a lightwand may facilitate endotracheal intubation in the child with a difficult airway.(77)

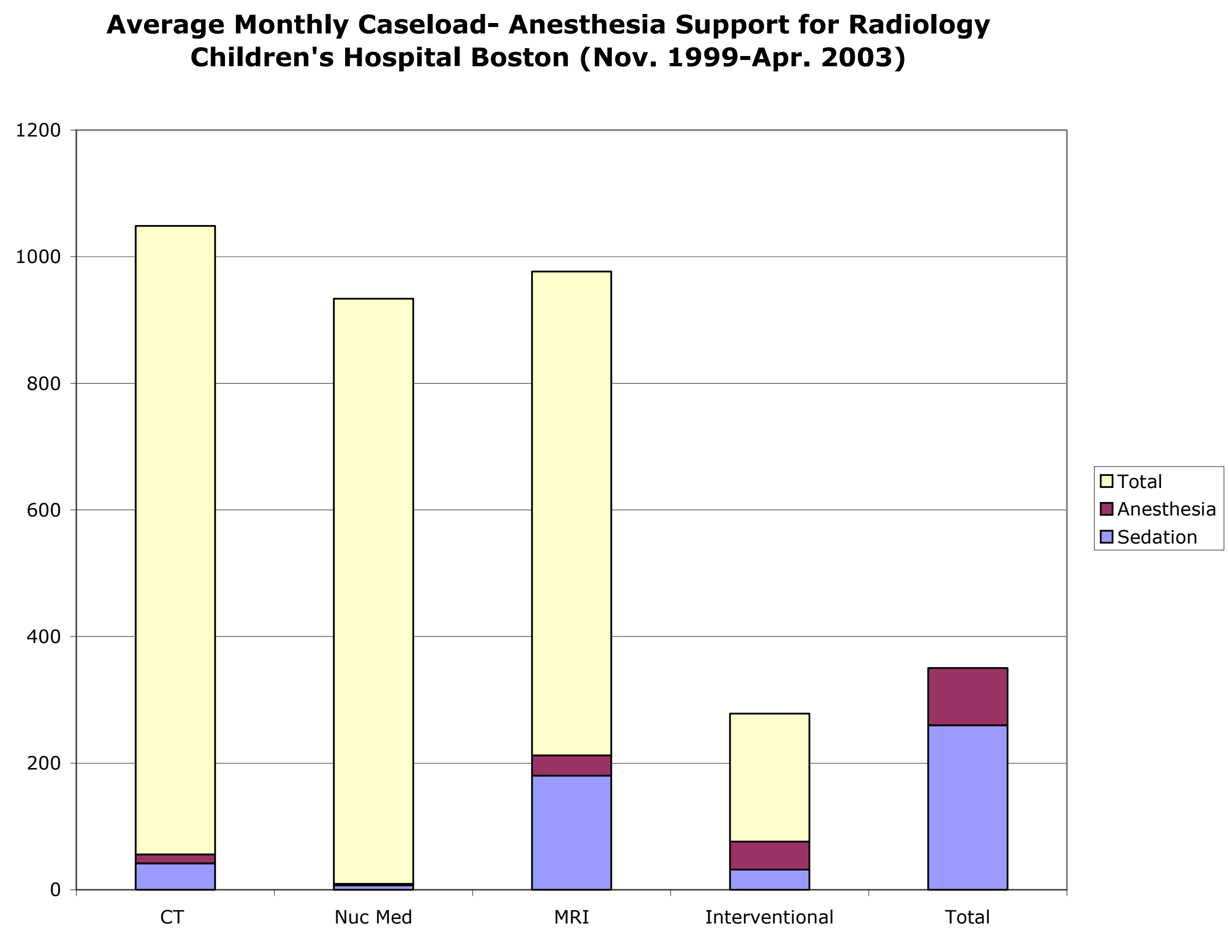
It is important to recognize that the airway that had not been difficult on induction may become difficult on emergence following sclerotherapy with alcohol and subsequent tissue edema, particularly at the base of the tongue, the neck or the mediastinum.(78-80) These patients will often require several days of airway support and ongoing evaluation in the intensive care unit until airway swelling is no longer a concern.

Blood Loss Management Outside of the Operating Room
Transfusion requirements are rare in extramural locations, yet pre-procedural anemia, accidental perforation of vascular structures or medical transfusion requirements such as sickle cell disease or prematurity may require transfusion therapy. Equipment familiar to the anesthesiologist and identical to that available in the operating room is a welcome sight in a life-threatening emergency. Calling for additional help, establishing additional vascular access and coordinating with the blood bank is crucial. Having a runner available may be critical when there is no designated “circulating nurse.” It may become necessary to involve a surgeon urgently and transport the patient to the operating room, in which case another anesthesia team setting up the OR while the patient is being prepared for transport would be optimal.

Summary

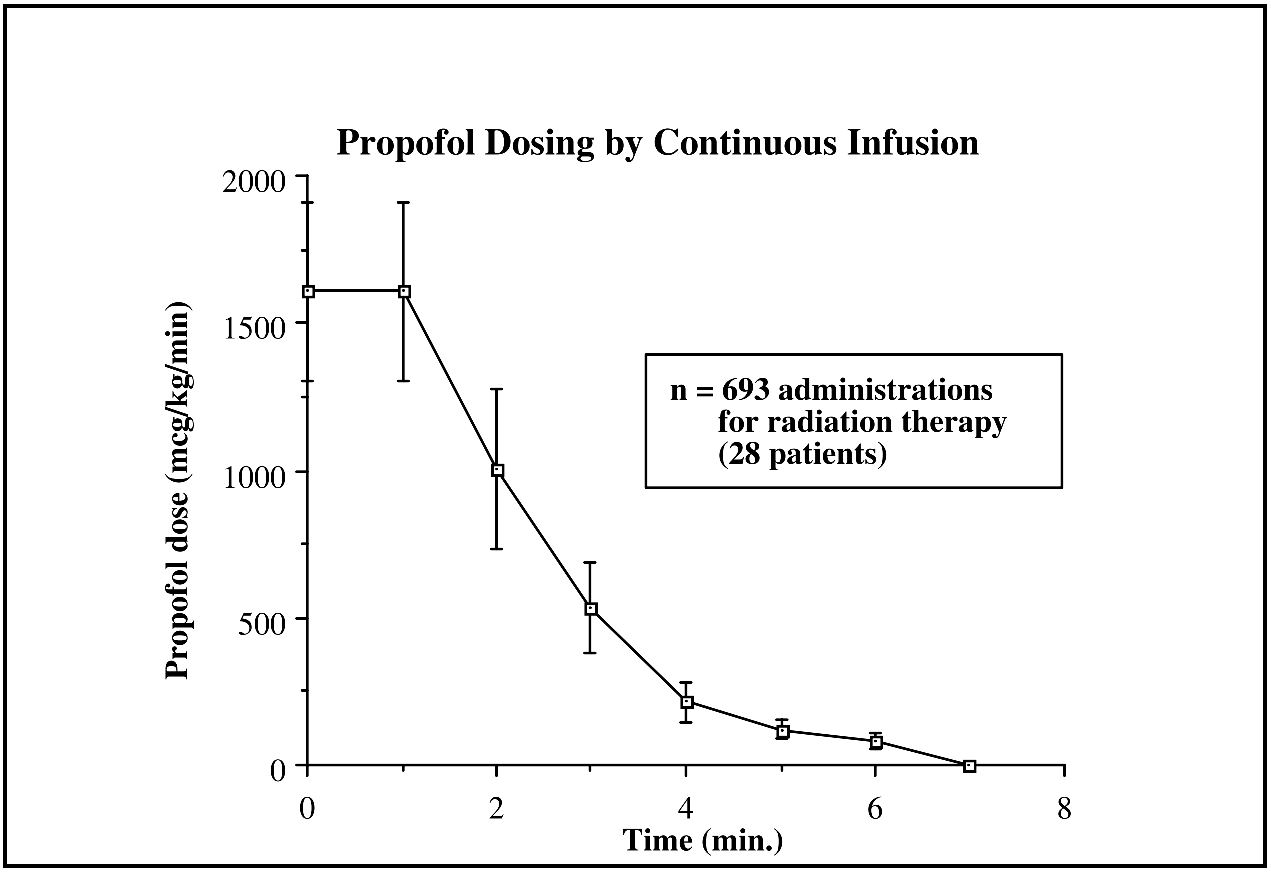
This chapter has reviewed some general issues as well as some specific situations for anesthetizing children outside the operating room. There is no "correct technique" for delivering anesthesia to patients in these areas. Versatility must be maintained to adapt to many different clinical situations and remote locations. Due to the evolution of specialized equipment and procedures for radiology in particular, it is likely that anesthesiologists' involvement in caring for children outside of the operating room will increase in years to come.

Figure 1



Legend: while the overwhelming majority of radiology studies are accomplished without anesthesia or sedation, a significant minority (> 3,000 per year) involve anesthesiologists directly or by consultation.

Figure 2



Propofol Dosing by Continuous Infusion
Propofol dose (mcg/kg/min)
2000
1500
1000
500
0
0
2
4
6
8
Time (min.)
n = 693 administrations
for radiation therapy
(28 patients)

Table I

MEDICAL CONDITIONS THAT CONTRAINDICATE NURSE-ADMINISTERED SEDATION

Active uncontrolled gastroesophageal reflux

Active uncontrolled vomiting

Current (or within past 3 months) history of apnea requiring an apnea monitor

Anterior mediastinal mass

Active current respiratory issues that are different from the baseline status (pneumonia, exacerbation of asthma, bronchiolitis, respiratory syncytial virus)

Unstable cardiac status (life-threatening arrhythmia, abnormal cardiac anatomy, significant cardiac dysfunction)

Craniofacial anomaly, which could make it difficult to effectively establish a mask airway for positive pressure ventilation, if needed

History of adverse or paradoxical events occurring following administration of barbiturate or chloral hydrate

Allergy to barbiturates or chloral hydrate

History of failed sedation in this institution's Radiology Department

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