

Randy P. Prescilla and Keira P. Mason

Infants and young children who are scheduled for nuclear medicine imaging studies often require sedation, and those with complicated medical conditions will require general anesthesia. There are several indications for sedation in nuclear medicine: Sedation can reduce patient motion during prolonged image acquisitions, facilitate a procedure which requires patient response to command and cooperation (e.g., voiding during a radionuclide cystogram) and minimize discomfort, anxiety, or pain [1]. Appropriate sedation is even more essential in neonates and infants, since they require special care, patience, adaptation, experience, and skillful hands. Infants undergo rapid growth and development, and sedative and radiopharmaceutical distribution and kinetics may vary from that of older children and young adults. Newborns and infants have a lower glomerular filtration rate, faster circulation, and faster pulmonary wash-in and washout of radioactive gases than older children [2].

Sedation is the most common technique of ensuring immobility in infants, children, and the developmentally compromised who are unable to remain motionless on their own. In rare circumstances, anesthesia services are required to ensure the safety of the patient and the surrounding people. In general, the relative contraindications to sedation include an allergy to the sedatives utilized, a prior adverse reaction to sedation, history of a difficult endotracheal intubation or difficulty providing positive pressure ventilation via mask, uncontrolled gastroesophageal reflux, and a patient who has significant cardiac or respiratory compromise [3] (Table 2.1). This chapter will review established sedation guidelines and recommendations, the logistics of setting up a sedation and anesthesia program, patient selection and sedation-related risk factors and adverse events, a review of the more commonly utilized sedatives, and the challenges of providing sedation and anesthesia in the nuclear medicine setting.

---

R.P. Prescilla, MD (✉) • K.P. Mason, MD  
Department of Anaesthesia,  
Harvard Medical School, Boston, MA, USA

Department of Anesthesiology,  
Perioperative and Pain Medicine,  
Boston Children's Hospital,  
Boston, MA, USA  
e-mail: [randy.prescilla@childrens.harvard.edu](mailto:randy.prescilla@childrens.harvard.edu);  
[keira.mason@childrens.harvard.edu](mailto:keira.mason@childrens.harvard.edu)

---

### The Depths of Sedation

The tenets of sedation rely on the ability to deliver sedation to a targeted depth and to be able to identify the achieved levels. The term “conscious sedation” is no longer acknowledged as appropriate terminology nor is it recognized as an indicator of depth of sedation. The Joint Commission, American Academy of Pediatrics (AAP), and American Society of Anesthesiologists (ASA)

define sedation as a sedation continuum that one can pass through escalating depths, described as minimal, moderate, and deep [4, 5] (Fig. 2.1). These depths of sedation rely on a subjective assessment of the patient’s response to verbal, tactile, and painful stimuli to predict the patient’s risk of respiratory and cardiovascular compromise. The associated risks with each level of the sedation continuum are assumed but have never been validated.

**Table 2.1** Relative contraindications to sedation

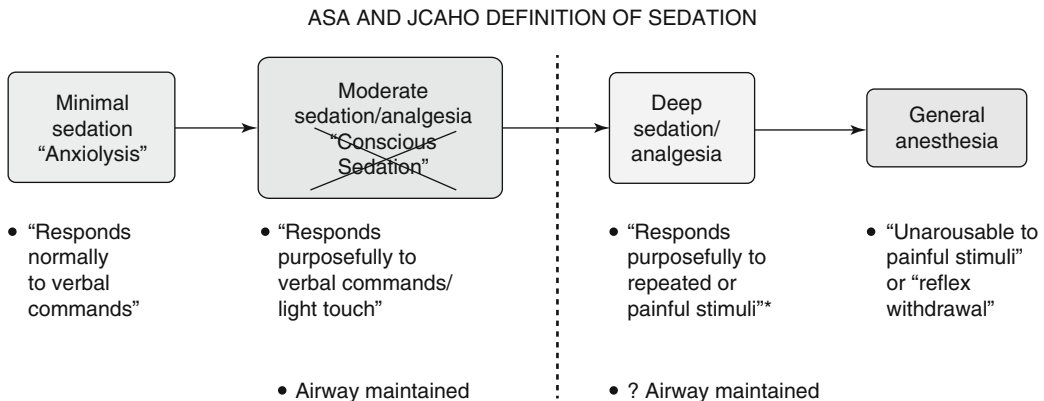
|   |
|---|
| Active uncontrolled gastroesophageal reflux   |
| Active uncontrolled vomiting  |
| Current (or within the past 3 months) history of apnea requiring an apnea monitor   |
| Active current respiratory issues that are different from the baseline status (pneumonia, exacerbation of asthma, bronchiolitis, 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   |

From Mason et al. [3] with permission

## Guidelines for Sedation Practice, Monitoring, and Qualifications

The practice of sedation has become a controversial topic over the past decade, as non-anesthesiologists have become sedation providers. Topics of debate include the sedatives appropriate for administration by non-anesthesiologists, the depth of sedation that is safe for non-anesthesiologists to achieve, the training and credentialing appropriate for non-anesthesiologists, and the reimbursement for non-anesthesiologists. In 2002, the American Society of Anesthesiologists (ASA) updated the 1995 document of *Practice Guidelines for Sedation and Analgesia by Non-anesthesiologists* [6, 7]. The purpose of this document was to “allow clinicians to provide their patients with the benefits of sedation/analgesia while minimizing the associated risks” [6]. These guidelines are consistent with the most recent updates of 2006 by the American Academy of Pediatrics (AAP) of *The Guidelines for Monitoring and Management of Pediatric Patients During and After Sedation for Diagnostic and Therapeutic Procedures* [4, 8–10]. Both the AAP and ASA guidelines were intended to standardize sedation practice in order to minimize the practice variance which has existed in the past [11].

The Joint Commission has also established standards for sedation and anesthesia care and, recently, in 2007, established recommendations



**Fig. 2.1** ASA and JCAHO definition of sedation (From Kaplan et al. [5] with permission). \* Reflex withdrawal from a painful stimulus is NOT considered a purposeful response

for the minimal training and qualifications expected of sedation providers: “Individuals administering moderate or deep sedation and anesthesia must be qualified and have the appropriate credentials to manage patients at whatever level of sedation or anesthesia is achieved, either intentionally or unintentionally” [12]. With respect to deep sedation, the Joint Commission specified that “individuals must be qualified to rescue patients from general anesthesia and are competent to manage an unstable cardiovascular system as well as a compromised airway and inadequate oxygenation and ventilation” [12]. The Joint Commission does not specify the methods required to validate a provider’s rescue skills but instead states that “each organization is free to...determine that the individuals are able to perform the required types of rescue” [12].

More recently, the Centers for Medicare & Medicaid Services (CMS) published in 2009 the *Revised Hospital Anesthesia Services Interpretive Guidelines – State Operations Manual (SOM) Appendix A.7, 8*, which mandated that deep sedation be identified as anesthesia services. Deep sedation was defined as “a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained” [12]. In 2010, the CMS limited the administration of deep sedation to an anesthesiologist, non-anesthesiologist physician, dentist, oral surgeon, podiatrist, certified registered nurse anesthetist (CRNA), or anesthesia assistant [13, 14]. One year later, these guidelines were revised in *Pub. 100–07 State Operations Provider Certification* which revised Appendix A of 42 CFR 482.52 and acknowledged that individual hospitals may establish their own policies with respect to the qualifications of sedation providers, provided that national guidelines of one or more specialties are followed [14].

## Setting Up a Sedation and Anesthesia Service

The Department of Radiology/Nuclear Medicine generally depends on the services of other specialties to provide sedation or anesthesia [15]. Frequently, these services are provided by departments of anesthesia, pediatrics, hospital medicine, emergency medicine, or intensive care medicine [16–20]. Each institution and health care facility must determine which specialists can be credentialed to administer sedation services.

In 2004, the ASA first issued guidelines for the delivery of anesthesia in locations outside of the operating room. This *statement on non-operating room anesthetizing locations* sets a minimum standard for these anesthetizing locations and, essentially, the expectation that they be similar to that of the operating room. Although these expectations may seem obvious, they are not always easy to meet in the Department of Radiology/Nuclear Medicine. For example, anesthetizing locations are expected to have a source of wall oxygen along with a means for removal of waste anesthesia gases. Older nuclear medicine suites, however, were not designed with anesthesia services in mind; many were designed prior to the ASA guidelines of 2004. Accommodation of anesthesia services has, for these sites, required that renovation and engineering services reconfigure these sites. As radiology units strived to become more efficient, they have found that the capability to recover patients postanesthesia within their department offsets the inefficiency of transporting patients to remote anesthesia recovery areas. However, even recovery sites remote to the operating room must provide identical postanesthesia care. This care requires additional resources, as there is the expectation that “appropriate post-anesthesia management should be provided. In addition to the anesthesiologist, adequate numbers of trained staff and appropriate equipment should be available to safely transport the patient to a postanesthesia care unit” [21]. To facilitate coordination between the Department of Radiology/Nuclear Medicine and the outside

services that provide anesthesia and sedation, it is preferable to appoint a director(s) of Radiology/ Nuclear Medicine Anesthesia and Sedation. This professional(s) should have a commitment to promoting safe and efficient care to all radiology patients through collaboration with the radiology/ nuclear medicine physicians, nurses, and technologists. As the technology and image techniques in the field of radiology advance, it is important that this director(s) remains current with these advances and proactively plans with the nuclear medicine physicians and technologists whenever specific imaging techniques require specialized anesthesia management.

### Patient Selection

The American Academy of Pediatrics advocates five safety goals for sedation: (1) guard the patient’s safety and welfare; (2) minimize physical discomfort and pain; (3) control anxiety, minimize psychological trauma, and maximize the potential for amnesia; (4) control behavior and/or movement to allow the safe completion of the procedure; and (5) return the patient to a state in which safe discharge is possible [4]. Multiple factors are required in order to achieve these goals such as careful patient selection for sedation, credentialing qualified individuals to administer the medications and to rescue from an adverse response, the use of appropriate physiologic monitoring, and the appropriate selection of sedatives and analgesics.

A thorough medical history and review of systems should be documented prior to scheduling a patient and should include pertinent prior surgical, sedative, and anesthetic histories. All current medications and drug allergies must be noted along with relevant clinical consultations and laboratory and clinical studies. To optimize the pre-evaluation and appropriate triage of patients, each patient and family should be directly contacted by a qualified health care professional prior to final scheduling. This direct contact enables the past and current history to be clarified and expounded upon and provides the family with the opportunity to ask questions. Fasting (i.e., NPO) instructions must also be finalized.

**Table 2.2** Red flags for sedation

|  |
|--|
| 1. Apnea   |
| 2. Full-term infant less than 1 month of age (unless an inpatient admitted to the hospital)  |
| 3. Respiratory-compromised patients  |
| 4. Uncontrolled/unpredictable gastroesophageal reflux or vomiting that poses an aspiration risk  |
| 5. Craniofacial abnormality that may make it difficult to establish effective mask airway  |
| 6. Cyanotic cardiac disease or unstable cardiac status   |
| 7. Painful procedure that may be challenging to provide adequate analgesia without a general anesthetic                                      |
| 8. High-risk procedure that may require presence of an anesthesiologist for resuscitation  |
| 9. Procedure that requires absolute immobility only achievable with a general anesthetic   |
| 10. Procedure being performed in remote location that is so removed that immediate emergency backup assistance would be virtually impossible |
| 11. Inadequate qualified personnel available to provide safe procedural sedation   |

In most radiology departments, this triage is performed by a core group of radiology nurses. These nurses also determine with the family and patient which medications, if any, should be continued even on the day of the intended procedure. All conversations and accompanying medical information should be documented in a manner consistent with individual institution policy.

There are no universally accepted criteria for the triage of patients to sedation or anesthesia. There are recommendations, however, which have been developed and followed, identifying “red flags” which warrant further assessment or consultation prior to receiving sedation (Table 2.2).

In general, those patients who are triaged to receive sedation, particularly by non-anesthesiologists, tend to be classified as American Society of Anesthesiologists (ASA) levels I and II and, occasionally, level III (Table 2.3). Children in ASA classes III and IV, those with special needs, anatomic airway abnormalities, or extreme tonsillar hypertrophy, often require additional and individual consideration and often require general anesthesia (as opposed to sedation). These and other patients with complicated medical histories may also warrant prior consultation with other specialties such as cardiology, otolaryngology, pulmonary, or neurology.

**Table 2.3** ASA physical status classification

|  |
|--|
| 1. A normal healthy patient  |
| 2. A patient with mild systemic disease  |
| 3. A patient with severe systemic disease  |
| 4. A patient with severe systemic disease that is a constant threat to life        |
| 5. A moribund patient who is not expected to survive without the operation         |
| 6. A declared brain-dead patient whose organs are being removed for donor purposes |

Excerpted from <http://www.asahq.org/Home/For-Members/Clinical-Information/ASA-Physical-Status-Classification-System> of the American Society of Anesthesiologists. A copy of the full text can be obtained from ASA, 520 N. Northwest Highway, Park Ridge, IL 60068-2573

**Risks of Sedation and Anesthesia**

The risks of sedation and anesthesia include hypoventilation, apnea, airway obstruction, cardiopulmonary arrest, and the morbidity and mortality associated with these events [1, 17, 22–25]. These adverse responses during and after sedation for a diagnostic or therapeutic procedure may be minimized, but not completely eliminated, by (1) a careful pre-procedure review of the patient’s underlying medical conditions and consideration of how the sedation process might affect or be affected by these conditions, (2) appropriate drug selection for the intended procedure, (3) presence of an individual with the skills needed to rescue a patient from an adverse response, and (4) appropriate physiologic monitoring and continuous observation by personnel not directly involved with the procedure which allow for accurate and rapid diagnosis of complications and initiation of appropriate rescue interventions [4].

**Most Common Medications Used in Pediatric Sedation**

Unfortunately, most drugs used for sedation in children do not carry pediatric information that have been reviewed and approved by the Food and Drug Administration. Only a small percentage of drugs approved by the FDA are labeled for pediatric use, with the rest being used where the

intent is the “practice of medicine.” The published medical literature includes off-label use in pediatrics.

The most common medications currently used to provide sedation in children have recently been reviewed [26]. These include chloral hydrate, pentobarbital, midazolam, dexmedetomidine, ketamine, propofol, ketorolac, morphine, and fentanyl. The mean features of these drugs are presented below.

**Chloral Hydrate and Pentobarbital**

Historically, chloral hydrate and pentobarbital have been the hypnotics of choice for pediatric sedation [27–30]. Both medications have no analgesic properties. They are useful for non-painful procedures as a sole agent (magnetic resonance imaging, computerized tomography, nuclear medicine). They can also be used with adjuvant analgesics in order to promote a hypnotic, sedative state for interventional procedures. Rates of successful sedation with chloral hydrate and pentobarbital range from 85 to 98 % [31, 32]. Both pentobarbital and chloral hydrate are medications which have almost 100 years of clinical experience. Because of their extended half-life (which approaches 24 h), they have been associated with prolonged recovery times and sedation-related morbidity. Adverse events with these medications include oxygen desaturation, nausea, vomiting, hyperactivity, respiratory depression, and failure to adequately sedate [29, 33].

Chloral hydrate is only available as an oral sedative. Pentobarbital, on the other hand, can be given by various routes; it may be administered intravenously, intramuscularly, and orally. Children less than 1 year of age respond well to these two medications when given in the oral form. Pentobarbital, flavored with cherry syrup, is more palatable and equally effective as chloral hydrate [34]. Comparing the two medications, oral pentobarbital has been associated with fewer respiratory events as compared to chloral hydrate. The incidence of a drop in oxygen saturation during sedation was over seven times higher in patients sedated with oral chloral hydrate compared to those sedated with pentobarbital [3].

Oral pentobarbital has been shown to have similar efficacy and a lower rate of respiratory complications compared with intravenous pentobarbital in infants [35].

Consideration should be given to the use of oral pentobarbital in infants less than 12 months of age, regardless of the presence of an intravenous line. Patients over 1 year of age receive intravenous sedation because it is more predictable and reliable. Pentobarbital is titrated up to 6 mg/kg intravenously to provide sedation and hypnosis. Patients who are on barbiturate therapy (for seizures) can develop tolerance to barbiturates and may receive a higher dose, up to 8 mg/kg body weight.

## Midazolam

Midazolam is a short-acting benzodiazepine with sedative, anxiolytic, muscle relaxant, and amnestic effects with rapid onset and short duration of action. It is administered orally, intravenously, intramuscularly, as well as intranasally. Midazolam is usually administered to provide anxiolysis, with accompanying mild sedation. This state usually suffices for short diagnostic procedures, especially in children who are tired, sleepy, or close to their regular nap time. Adverse effects with midazolam include respiratory depression and hypotension, with rare effects including headache, nausea, emesis, cough, and/or hiccups. Contraindications include acute narrow-angle glaucoma, uncontrolled pain, existing central nervous system depression, and shock [36].

## Dexmedetomidine

Dexmedetomidine (Precedex; Hospira, Lake Forest, IL) is a highly selective alpha-2 adrenoceptor agonist approved for use in intubated and non-intubated adults. Dexmedetomidine is not approved for pediatric use by the FDA. It is, however, used for pediatric sedation in several settings such as diagnostic radiologic imaging studies and intensive care units.

Dexmedetomidine offers the advantage of providing sedation and analgesia with little respiratory depression and in most a tolerable decrease in blood pressure and heart rate [37]. When administered to adults within clinical dosing guidelines, there are no accompanying changes in resting ventilation [38–40].

It can produce dose-dependent decreases in blood pressure and heart rate as a result of its alpha-2 agonist effect on the sympathetic ganglia with resulting sympatholytic effects [39, 40].

The half-life of dexmedetomidine is shorter than that of pentobarbital and chloral hydrate. A short half-life makes dexmedetomidine easier to titrate, quicker to recover from, and potentially associated with fewer prolonged sedation-related adverse events.

There is literature to support that dexmedetomidine has some analgesic properties [41–43]. It may be useful for select interventional radiology procedures that require sedation and minimal analgesia. It can be particularly effective when supplemented with a local anesthetic during the procedure. In addition, some feel that dexmedetomidine actually mimics some aspects of natural sleep [25].

Although there are no absolute contraindications to dexmedetomidine, the concurrent use of digoxin is often considered a relative contraindication, as it has been associated with extreme bradycardia in children and cardiac arrest in adults [44, 45]. Rarely, dexmedetomidine can cause potentially life-threatening cardiovascular complications in some adults and children [44, 46–49]. The use of dexmedetomidine in nuclear medicine has been recently reported [50].

## Ketamine

Ketamine is a rapid-acting dissociative agent that is administered via intravenous, intramuscular, oral, rectal, nasal, epidural, or intrathecal routes. Ketamine can produce a rapid onset of deep sedation and analgesia with minimal respiratory depression and cardiovascular side effects [51, 52]. Ketamine is unique because it provides deep sedation and profound analgesia while still



maintaining airway muscle activity and upper airway patency [53]. Large doses of ketamine can produce a state of general anesthesia.

When given in small bolus doses, ketamine provides analgesia for an average of 30 min. As an infusion, ketamine can produce a continuous state of analgesia which may be titrated up and down in response to (or in anticipation of) the painful stimulus. It is especially useful for patients who will undergo an exceptionally painful procedure, those on long-term treatment with opioids, or those who have a high tolerance to opiates. Ketamine provides an effective alternative to narcotics in these patients.

The use of ketamine for pediatric sedation and analgesia has been described in various nonoperating room settings. Most of the experience with ketamine in children is drawn from emergency medicine and, lately, from interventional radiology.

Hallucinations, delusions, nightmares, and emergence delirium are phenomenon most commonly described as a potential side effect of ketamine; these are more commonly noted in adults [53, 54]. The presence of these adverse events in the pediatric population is controversial [55, 56]. In adults, the concomitant administration of benzodiazepines (midazolam or diazepam) with ketamine has been shown to decrease the incidence of these events. Again, the utility of benzodiazepines in reducing these events in children is controversial [57–59]. Some reports indicate that the addition of benzodiazepines leads to an increased incidence of oxygen desaturation events [60]. Under age 5, there is no definitive evidence that benzodiazepine administration will reduce the hallucinations, delusions, and excitatory behavior that can occur with ketamine. Children over age 5 may benefit from concomitant benzodiazepine administration.

## Propofol

Propofol is an intravenous anesthetic approved for use in the induction and maintenance of general anesthesia in children and adults. It has a rapid onset of action, distributed extensively and

rapidly cleared from the body. Emergence from anesthesia occurs quickly.

Common adverse events include apnea (children and adults). Other common adverse events in adults include bradycardia, arrhythmias, blood pressure problems, decreased cardiac output, burning/stinging at the site of injection, hyperlipidemia, respiratory acidosis, rash, and pruritus.

Propofol is also used in monitored anesthesia care for deep sedation in intensive care units and areas outside the operating room, including radiology and nuclear medicine suites. There has been an increasing interest by non-anesthesiologists in using propofol as a sedation agent [16–18]. Propofol is commonly administered first via a slowly titrated load to achieve the targeted depth of sedation which is then maintained with a continuous infusion at doses of 100 mcg/kg/min upwards [61]. Propofol administration requires that the sedation provider be proficient and expert in the identification and management of airway compromise: even at low-dosing ranges, the cross-sectional area of the airway at the level of the tongue and epiglottis narrows, and patients can manifest signs of obstruction [62, 63]. There is literature to support that propofol can be as safely administered by gastroenterologists, pediatricians, nurse practitioners, and emergency room physicians as it can be by anesthesiologists [16–18, 64, 65].

## Ketorolac and Other Non-opioid Analgesics

Analgesics may be required for procedures in addition to the use of hypnotics, sedatives, or infiltration with local anesthesia. There are a variety of analgesics available. Ketorolac is a nonsteroidal anti-inflammatory drug administered intravenously every 6 h with a maximum of 72 h of administration. A one-time administration of ketorolac may be sufficient to provide analgesia for simple, short nuclear medicine procedures such as cerebral spinal fluid (CSF) flow studies and lymphangiograms.

Intravenous ibuprofen and intravenous acetaminophen were approved for use in the USA in

2009 and late 2010, respectively. However, the current costs of these medications have limited their routine clinical use.

Ketorolac and ibuprofen may inhibit platelet aggregation and prolong bleeding time, which may be an undesirable effect for some conditions. Alternative analgesics include narcotics or ketamine.

## **Narcotics**

The choice of narcotic should depend on the duration of the procedure and the extent of analgesia required. Morphine and fentanyl are the more popular narcotics. Morphine requires approximately 10 min to take effect and has a duration of action of approximately 2 h. Fentanyl works quicker, has 100 times the potency of morphine, and can produce analgesia in minutes. It generally needs to be re-dosed at least every 30–60 min depending on the procedure. Narcotics should be administered prior to (i.e., in anticipation of) the painful stimulus so that adequate analgesia is present at the time of the stimulus.

Respiratory depression is the most common adverse event resulting from narcotic use. In addition, rapid administration of fentanyl may result in rigid chest syndrome. Naloxone is the opioid antagonist indicated for the reversal of opioid-induced respiratory depression. Naloxone, as well as other drugs and equipment for resuscitation, should be readily available in the radiology/nuclear medicine suites.

## **Combination Therapy**

Additional medications increase the risk of adverse events, so the sedation physician or anesthesiologist should be aware of the possible adverse events that may result from the medications administered. Drugs with long durations of action must be allowed to manifest their pharmacologic actions and peak effects before additional doses are considered. The practitioner must know whether the previous dose of any

drug has taken full effect before administering additional medications [4]. If the mechanisms of action of concomitant medications are similar, synergistic effects may be potentiated, and the risk of adverse events is magnified. Respiratory depression is a common pathway of adverse events and may result unexpectedly and quickly.

Practitioners must also be cognizant that drug interactions may occur. Drugs such as protease inhibitors, macrolide antibiotics, some azole antifungals, and cimetidine inhibit the cytochrome P450 system, and concomitant use of these medications can result in prolonged sedation with midazolam and other hypnotics that involve the same enzyme systems.

---

## **Challenges in Nuclear Medicine**

As the availability and introduction of complex imaging studies continue to increase, anesthesiologists and sedation-care providers must maintain their understanding of associated principles, safety, and management concerns for the patients undergoing imaging studies [66]. The unique environment in nuclear medicine presents inherent challenges for providing sedation and the administration of general anesthesia.

## **Radiation Safety**

Unlike other modalities in pediatric imaging, there is a need for enhanced safety around the use of radioactive materials in nuclear medicine. Sedation and anesthesia providers must observe basic radiation safety practices, in the same manner that the nuclear medicine nurses and technologists practice radiation safety. The sedation and anesthesia providers may be required to complete radiation safety training and may be even required to wear dosimeters while working in the area. Exposure to radioactive materials should be minimized. Biologic fluids must be considered as radioactive and must therefore be handled and disposed of appropriately. Spills should be handled in accordance with existing



protocols and reported to the nuclear medicine technologist who will then report the incident to designated radiation safety officers.

## Duration and Timing of Procedures

The anticipated duration of the scan will impact on the medical decision on what pharmacologic agent to use (e.g., short-acting versus longer-acting sedative) and the preferred intervention (e.g., intubation versus use of oral airway for general anesthesia). It is therefore essential for all health professionals involved to discuss the expected duration of the imaging study as well as the anticipated recovery plans after sedation or anesthesia.

Unlike other pediatric imaging modalities, nuclear medicine studies require an uptake period following injection of the radioisotope. This uptake period can last from half an hour for brain studies to over an hour for whole-body scans. It may be helpful to contact the sedation or anesthesia provider prior to radioisotope injection, in order to confirm the availability of such services soon after the uptake period.

The degradation process of the isotopes also plays a role in the duration of the scan; as a general rule, the farther the time point of the injection of the isotope to the start of the scan, the longer the subsequent duration of the scan. It is therefore best to perform the scan as soon as the uptake of the isotope is completed (about half an hour for brain studies and an hour for whole-body PET scans). Again, sedation providers or anesthesiologists who are assigned concurrently to other units may need to be reminded in advance in order to ensure proper timing of the initiation of sedation or general anesthesia.

## Combination Studies

Combination studies in nuclear medicine require even more careful planning. In centers with positron emission tomography–computerized tomography (PET–CT) scanners, combination studies can be performed without moving the patient.

In centers that do not have PET–CT scanners, the patients will need to be transferred to a CT scanner after the PET scan. This may present problems of transporting patients who are intubated or who received short-acting sedating agents. In addition, the intake of oral contrast may be required for abdominal CT scans; in such cases, the patient will need to wake up, drink the oral contrast agent, and wait for at least an hour prior to being re-sedated. Other modalities such as MRI may also be required following nuclear medicine scans. There is a need to coordinate the availability of the subsequent scanners and the staff in order to minimize the duration of sedation and general anesthesia.

There may be requests for additional studies or procedures after a nuclear medicine imaging study. These include non-painful procedures such as blood draws through existing intravenous lines, dressing changes, or echocardiograms. Often, these do not create problems unless the schedule is so tight that no additional time in the scan room is permitted. In such cases, these procedures are best performed in the recovery area or postanesthesia care unit (PACU). Painful procedures such as spinal taps and fluid aspirations may also be requested. In such cases, the decision on whether these procedures can be performed, and if so, the timing, should be made with appropriate discussion prior to the nuclear medicine study. A consensus must also be reached on whether sedation or general anesthesia will be continued after the primary diagnostic scan.

## Painful Procedures

Painful diagnostic procedures in nuclear medicine such as cerebral spinal fluid (CSF) flow studies and lymphangiograms may require the administration of analgesic agents to decrease pain and optimize the procedures and scans. Again, the choice of analgesics should depend on the duration of the procedure and the extent of analgesia required. In addition, some diagnostic procedures by themselves do not inflict pain, but due to the underlying condition (e.g., fractures in children who require bone scans), children may

experience severe discomfort or pain during these procedures. In such cases, discussion with the inpatient service may be necessary to ensure the comfort of these patients prior to arrival at the nuclear medicine suite.

Some children will require repeat visits for tests that may cause discomfort or pain, such as radionuclide cystograms. Sedatives that tend to provide amnestic effects, such as midazolam, will be especially helpful for these children.

## Bladder Catheterization

Although extended fasting periods and certain medications (e.g., dexmedetomidine) can cause hypotension, the benefits of rehydration prior to and during sedation or anesthesia should be carefully weighed against the potential ramifications of the patient developing a full bladder. The presence of a full bladder may necessitate the need for bladder catheterization for several reasons [67]. First, a full bladder may obscure or cause reconstruction artifacts. The former may constitute a significant problem in oncologic cases where the pelvic area needs to be fully evaluated. Secondly, the urge to void may result in patient discomfort and potential spontaneous voiding with associated spillage of radioactive material. Although bladder catheterization will alleviate these risks, the procedure itself may require the administration of additional sedatives or analgesics. It is therefore essential to have a collaborative discussion prior to the scan, among the sedation provider, the nuclear medicine physician, and the technologist who will be performing the study, in order to create a contingency plan.

## Summary

Sedation and general anesthesia are required for certain patients who are scheduled for nuclear medicine imaging. The creation of a credentialed anesthesia and sedation service will enhance the efficiency of the radiology/nuclear medicine department while promoting safe care of pediatric patients. The nuclear medicine setting is

unique and poses inherent challenges. There is a need for ongoing discussions among the providers of sedation and anesthesia, the nuclear medicine nurses, technologists, and physicians.

**Acknowledgments** We wish to thank Joanne Louis, CNMT, for her technical review and Ms. Amanda Buckley for the editorial assistance and preparation of this chapter.

## References

1. Mandell GA, Cooper JA, Majd M, Shalaby-Rana EI, Gordon I. Procedure guideline for pediatric sedation in nuclear medicine. Society of Nuclear Medicine. *J Nucl Med.* 1997;38(10):1640–3.
2. Treves ST, Baker A, Fahey FH, et al. Nuclear medicine in the first year of life. *J Nucl Med.* 2011;52(6):905–25.
3. Mason KP, Sanborn P, Zurakowski D, et al. Superiority of pentobarbital versus chloral hydrate for sedation in infants during imaging. *Radiology.* 2004;230(2):537–42.
4. Cote CJ, Wilson S. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures: an update. *Pediatrics.* 2006;118(6):2587–602.
5. Kaplan RF, Cravero JP, Yaster M, Cote C. Chap. 48. Sedation for diagnostic and therapeutic procedures outside the operating room. In: Cote CJ, Lerman J, Todres ID, editors. *A practice of anesthesia for infants and children.* Philadelphia: Saunders/Elsevier; 2009. p. 1023–48.
6. American Society of Anesthesiologists Task Force on Sedation and Analgesia. Practice guidelines for sedation and analgesia by non-anesthesiologists. *Anesthesiology.* 2002;96(4):1004–17.
7. Practice guidelines for sedation and analgesia by non-anesthesiologists. A report by the American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. *Anesthesiology.* 1996;84(2):459–71.
8. Guidelines for the elective use of conscious sedation, deep sedation, and general anesthesia in pediatric patients. Committee on Drugs. Section on anesthesiology. *Pediatrics.* 1985;76(2):317–21.
9. American Academy of Pediatrics Committee on Drugs. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures. *Pediatrics.* 1992;89(6 Pt 1):1110–5.
10. Committee on Drugs. American Academy of Pediatrics. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures: addendum. *Pediatrics.* 2002;110(4):836–8.
11. Keeter S, Benator RM, Weinberg SM, Hartenberg MA. Sedation in pediatric CT: national survey of current practice. *Radiology.* 1990;175(3):745–52.

12. Joint Commission for Accreditation of Hospitals (JCAHO). Operative or other high-risk procedures and/or the administration of moderate or deep sedation or anesthesia. The Comprehensive accreditation manual for Hospitals: official handbook. Oakbrook Terrace: JCAHO; 2007. p. PC-41.
13. Department of Health & Human Services. Centers for Medicare & Medicaid Services. Revised hospital anesthesia services interpretive guidelines – state operations manual (SOM) Appendix A Ref: S&C-10-09-Hospital. Revised 2 May 2010. [https://www.cms.gov/SurveyCertificationGenInfo/downloads/SCLetter10\\_09.pdf](https://www.cms.gov/SurveyCertificationGenInfo/downloads/SCLetter10_09.pdf). Accessed 14 Feb 2011.
14. Department of Health & Human Services. Centers for Medicare & Medicaid Services. CMS Manual System. Pub. 100–07 State Operations Provider Certification. Transmittal 59. Clarification of the interpretive guidelines for the anesthesia services condition of participation. 21 May 2010. <https://www.cms.gov/transmittals/downloads/R59SOMA.pdf>. Accessed 20 Jan 2011.
15. McQuattie S. Pediatric PET/CT imaging: tips and techniques. *J Nucl Med Technol*. 2008;36(4):171–80.
16. Mallory MD, Baxter AL, Yanosky DJ, Cravero JP. Emergency physician-administered propofol sedation: a report on 25,433 sedations from the pediatric sedation research consortium. *Ann Emerg Med*. 2011;57(5):462–81.
17. Cravero JP, Beach ML, Blike GT, Gallagher SM, Hertzog JH. The incidence and nature of adverse events during pediatric sedation/anesthesia with propofol for procedures outside the operating room: a report from the Pediatric Sedation Research Consortium. *Anesth Analg*. 2009;108(3):795–804.
18. Srinivasan M, Turmelle M, Depalma LM, Mao J, Carlson DW. Procedural sedation for diagnostic imaging in children by pediatric hospitalists using propofol: analysis of the nature, frequency, and predictors of adverse events and interventions. *J Pediatr*. 2012;160(5):801–6.e1.
19. Mason KP, Fontaine PJ, Robinson F, Zgleszewski S. Pediatric sedation in a community hospital-based outpatient MRI center. *AJR Am J Roentgenol*. 2012;198(2):448–52.
20. Vespasiano M, Finkelstein M, Kurachek S. Propofol sedation: intensivists' experience with 7304 cases in a children's hospital. *Pediatrics*. 2007;120(6):e1411–7.
21. American Society of Anesthesiologists. Statement on Nonoperating Room Anesthetizing Locations. <http://www.asahq.org/For-Members/~media/For%20Members/documents/Standards%20Guidelines%20Stmts/Nonoperating%20Room%20Anesthetizing%20Locations.ashx>. Accessed 12 March 2013
22. Sanborn PA, Michna E, Zurakowski D, et al. Adverse cardiovascular and respiratory events during sedation of pediatric patients for imaging examinations. *Radiology*. 2005;237(1):288–94.
23. Maxwell LG, Tobias JD, Cravero JP, Malviya S. Adverse effects of sedatives in children. *Expert Opin Drug Saf*. 2003;2(2):167–94.
24. Metzner J, Posner KL, Domino KB. The risk and safety of anesthesia at remote locations: the US closed claims analysis. *Curr Opin Anaesthesiol*. 2009;22(4):502–8.
25. Bhananker SM, Posner KL, Cheney FW, Caplan RA, Lee LA, Domino KB. Injury and liability associated with monitored anesthesia care: a closed claims analysis. *Anesthesiology*. 2006;104(2):228–34.
26. Prescilla R. Pharmacology and clinical applications of sedatives, analgesics, and adjuncts. In: Mason K, Koka B, editors. *Pediatric sedation outside the operating room: a multispecialty collaboration*. New York: Springer; 2011. p. 93–122.
27. American Academy of Pediatrics Committee on Drugs and Committee on Environmental Health: use of chloral hydrate for sedation in children. *Pediatrics*. 1993;92(3):471–3.
28. Ferrer-Brechner T, Winter J. Anesthetic considerations for cerebral computer tomography. *Anesth Analg*. 1977;56(3):344–7.
29. Greenberg SB, Faerber EN, Aspinall CL, Adams RC. High-dose chloral hydrate sedation for children undergoing MR imaging: safety and efficacy in relation to age. *AJR Am J Roentgenol*. 1993;161(3):639–41.
30. Greenberg SB, Faerber EN, Aspinall CL. High dose chloral hydrate sedation for children undergoing CT. *J Comput Assist Tomogr*. 1991;15(3):467–9.
31. Napoli KL, Ingall CG, Martin GR. Safety and efficacy of chloral hydrate sedation in children undergoing echocardiography. *J Pediatr*. 1996;129(2):287–91.
32. Thompson JR, Schneider S, Ashwal S, Holden BS, Hinshaw Jr DB, Hasso AN. The choice of sedation for computed tomography in children: a prospective evaluation. *Radiology*. 1982;143(2):475–9.
33. Ronchera-Oms CL, Casillas C, Marti-Bonmati L, et al. Oral chloral hydrate provides effective and safe sedation in paediatric magnetic resonance imaging. *J Clin Pharm Ther*. 1994;19(4):239–43.
34. Chung T, Hoffer FA, Connor L, Zurakowski D, Burrows PE. The use of oral pentobarbital sodium (Nembutal) versus oral chloral hydrate in infants undergoing CT and MR imaging—a pilot study. *Pediatr Radiol*. 2000;30(5):332–5.
35. Mason KP, Zurakowski D, Connor L, et al. Infant sedation for MR imaging and CT: oral versus intravenous pentobarbital. *Radiology*. 2004;233(3):723–8.
36. Macias CG, Chumpitazi CE. Sedation and anesthesia for CT: emerging issues for providing high-quality care. *Pediatr Radiol*. 2011;41 Suppl 2:517–22.
37. Evers AS, Crowder CM, Balser JR. General anesthetics. In: Brunton LL, Laso JS, Parker KL, editors. *Goodman and Gilman's the pharmacological basis of therapeutics*. 11th ed. New York: McGraw-Hill; 2006.
38. Hall JE, Uhrich TD, Barney JA, Arain SR, Ebert TJ. Sedative, amnestic, and analgesic properties of small-dose dexmedetomidine infusions. *Anesth Analg*. 2000;90(3):699–705.
39. Talke P, Lobo E, Brown R. Systemically administered alpha2-agonist-induced peripheral vasoconstriction in humans. *Anesthesiology*. 2003;99(1):65–70.
40. Talke P, Richardson CA, Scheinin M, Fisher DM. Postoperative pharmacokinetics and sympatholytic

- effects of dexmedetomidine. *Anesth Analg.* 1997;85(5):1136–42.
41. Bamgbade OA. Dexmedetomidine for peri-operative sedation and analgesia in alcohol addiction. *Anaesthesia.* 2006;61(3):299–300.
  42. Jackson 3rd KC, Wohlt P, Fine PG. Dexmedetomidine: a novel analgesic with palliative medicine potential. *J Pain Palliat Care Pharmacother.* 2006;20(2):23–7.
  43. Rich JM. Dexmedetomidine as a sole sedating agent with local anesthesia in a high-risk patient for axillofemoral bypass graft: a case report. *AANA J.* 2005;73(5):357–60.
  44. Berkenbosch JW, Tobias JD. Development of bradycardia during sedation with dexmedetomidine in an infant concurrently receiving digoxin. *Pediatr Crit Care Med.* 2003;4(2):203–5.
  45. Precedex (dexmedetomidine hydrochloride) Hospira, Inc. Lake Forest, IL 60045 USA. [http://www.precedex.com/wp-content/uploads/Precedex\\_PI.pdf](http://www.precedex.com/wp-content/uploads/Precedex_PI.pdf). Accessed 12 March 2013.
  46. Belleville JP, Ward DS, Bloor BC, Maze M. Effects of intravenous dexmedetomidine in humans. I. Sedation, ventilation, and metabolic rate. *Anesthesiology.* 1992;77(6):1125–33.
  47. Ingersoll-Weng E, Manecke Jr GR, Thistlethwaite PA. Dexmedetomidine and cardiac arrest. *Anesthesiology.* 2004;100(3):738–9.
  48. Scheinin H, Aantaa R, Anttila M, Hakola P, Helminen A, Karhuvaara S. Reversal of the sedative and sympatholytic effects of dexmedetomidine with a specific  $\alpha_2$ -adrenoceptor antagonist atipamezole: a pharmacodynamic and kinetic study in healthy volunteers. *Anesthesiology.* 1998;89(3):574–84.
  49. Venn RM, Bradshaw CJ, Spencer R, et al. Preliminary UK experience of dexmedetomidine, a novel agent for postoperative sedation in the intensive care unit. *Anaesthesia.* 1999;54(12):1136–42.
  50. Mason KP, Robinson F, Fontaine PJ, Prescilla R. Dexmedetomidine offers an option for safe and effective sedation for nuclear medicine imaging in children. *Radiology.* 2013;267(3):911–7.
  51. Way WL, Trevor AJ. Pharmacology of intravenous nonnarcotic anesthetics. In: *Anesthesia.* 2nd ed. New York: Churchill Livingstone; 1986. p. 813–7.
  52. Drummond GB. Comparison of sedation with midazolam and ketamine: effects on airway muscle activity. *Br J Anaesth.* 1996;76(5):663–7.
  53. Fine J, Finestone SC. Sensory disturbances following ketamine anesthesia: recurrent hallucinations. *Anesth Analg.* 1973;52(3):428–30.
  54. Meyers EF, Charles P. Prolonged adverse reactions to ketamine in children. *Anesthesiology.* 1978;49(1):39–40.
  55. Roelofse JA, Joubert JJ, Roelofse PG. A double-blind randomized comparison of midazolam alone and midazolam combined with ketamine for sedation of pediatric dental patients. *J Oral Maxillofac Surg.* 1996;54(7):838–44; discussion 845–6.
  56. Sherwin TS, Green SM, Khan A, Chapman DS, Dannenberg B. Does adjunctive midazolam reduce recovery agitation after ketamine sedation for pediatric procedures? A randomized, double-blind, placebo-controlled trial. *Ann Emerg Med.* 2000;35(3):229–38.
  57. Green SM, Johnson NE. Ketamine sedation for pediatric procedures: part 2, review and implications. *Ann Emerg Med.* 1990;19(9):1033–46.
  58. Hollister GR, Burn JM. Side effects of ketamine in pediatric anesthesia. *Anesth Analg.* 1974;53(2):264–7.
  59. Wathen JE, Roback MG, Mackenzie T, Bothner JP. Does midazolam alter the clinical effects of intravenous ketamine sedation in children? A double-blind, randomized, controlled, emergency department trial. *Ann Emerg Med.* 2000;36(6):579–88.
  60. Sussman DR. A comparative evaluation of ketamine anesthesia in children and adults. *Anesthesiology.* 1974;40(5):459–64.
  61. Frankville DD, Spear RM, Dyck JB. The dose of propofol required to prevent children from moving during magnetic resonance imaging. *Anesthesiology.* 1993;79(5):953–8.
  62. Evans RG, Crawford MW, Noseworthy MD, Yoo SJ. Effect of increasing depth of propofol anesthesia on upper airway configuration in children. *Anesthesiology.* 2003;99(3):596–602.
  63. Reber A, Wetzel SG, Schnabel K, Bongartz G, Frei FJ. Effect of combined mouth closure and chin lift on upper airway dimensions during routine magnetic resonance imaging in pediatric patients sedated with propofol. *Anesthesiology.* 1999;90(6):1617–23.
  64. Pambianco DJ, Vargo JJ, Pruitt RE, Hardi R, Martin JF. Computer-assisted personalized sedation for upper endoscopy and colonoscopy: a comparative, multicenter randomized study. *Gastrointest Endosc.* 2011;73(4):765–72.
  65. Rex DK, Deenadayalu VP, Eid E, et al. Endoscopist-directed administration of propofol: a worldwide safety experience. *Gastroenterology.* 2009;137(4):1229–37; quiz 1518–29.
  66. Veenith T, Coles JP. Anaesthesia for magnetic resonance imaging and positron emission tomography. *Curr Opin Anaesthesiol.* 2011;24(4):451–8.
  67. Roberts EG, Shulkin BL. Technical issues in performing PET studies in pediatric patients. *J Nucl Med Technol.* 2004;32(1):5–9; quiz 10–11.

<http://www.springer.com/978-1-4614-9550-5>

Pediatric Nuclear Medicine and Molecular Imaging

Treves, S.T. (Ed.)

2014, XXIV, 712 p. 424 illus., 149 illus. in color.,

Hardcover

ISBN: 978-1-4614-9550-5