AJNR

Sedation in pediatric neuroimaging: the science and the art.

R S Boyer

AJNR Am J Neuroradiol 1992, 13 (2) 777-783
http://www.ajnr.org/content/13/2/777

Sedation in Pediatric Neuroimaging: The Science and the Art

Richard S. Boyer[1]

From the Department of Pediatric Medical Imaging, Primary Children's Medical Center, Salt Lake City, UT

Recent advances in imaging technology have revolutionized the evaluation of infants and children with neurologic diseases (1). Each of the currently used modalities, with the exception of real-time ultrasound (US), requires a motionless patient. The advent of computed tomography (CT) in the 1970s required radiologists to become increasingly involved in pediatric sedation to allow the long acquisition times required by the early-generation CT scanners (2). As technology improved and faster scanners became routinely available, the need for sedation for CT was avoided in most children.

However, in the past 6 years, the increasing use of magnetic resonance (MR) imaging in pediatric neurodiagnosis has necessitated a reluctant return to the frequent use of sedation for pediatric brain and spine examinations. In pediatric centers, this return has been reasonably well tolerated because of the greater comfort level of pediatric radiologists with the challenges of sedation and of monitoring children, and the greater availability of pediatric-trained technologists and nurses. In contrast, personnel at many primarily adult MR facilities now find themselves faced with the need to perform occasional pediatric studies, and feel discomfort or anxiety in sedating children safely.

This paper is written for those using sedation to perform the occasional neuroimaging study on an infant or child. The major emphasis is directed toward sedation for MR, but the basic principles also apply in CT, angiography, and myelography. The focus is on safety and efficacy using a limited number of familiar drugs in a methodical approach. Whether using sedation several times a day or once a month, the challenge is the same—to control patient motion safely and effectively in infants and children in order to allow the acquisition of optimal diagnostic images.

Predictability vs Safety

Sleep produced by a natural (nonpharmacologic) approach is inherently safer, though less predictable, than medication-induced sedation. Therefore, whenever possible, a natural form of sleep is preferable to pharmacologic sedation. In the infant, a well-timed feeding, a warm blanket and a quiet, dark room may stimulate a postprandial nap that is sufficient for a noninvasive imaging study. However, scanners are busy and schedules cannot usually accommodate the lack of predictability required by the natural approach. In addition, long exam times and external stimuli may awaken the infant and terminate the exam prematurely. Therefore, the pharmacologic approach to sedation is usually preferred for its predictability.

Predictability must not be at the expense of safety for the child. Safety is the most important consideration in pediatric sedation. Elements of an approach to pediatric sedation that favor safety include:

1. establishment of a written protocol in each imaging department that follows the guidelines for pediatric sedation developed by the American Academy of Pediatrics Section on Anesthesiology (3) specifically addressing such issues as candidates for sedation, facilities, equipment, informed consent, drugs and dosages, documentation, personnel, monitoring procedures, recov-

[1] Address reprint requests to Dr Boyer, Department of Pediatric Medical Imaging, Primary Children's Medical Center, 100 North Medical Drive, Salt Lake City, UT 84113.

Index terms: Patients, sedation; Chloral hydrate; Pediatric neuroradiology

AJNR 13:777-783, Mar/Apr 1992 0195-6108/92/1302-0777

ery care, discharge criteria, and emergency contingencies;
2. direct physician involvement in the sedation process;
3. limiting the number of drugs used for sedation to a few with which all involved personnel can become very familiar;
4. regular quality assurance evaluation of complications, sedation failures, adverse reactions, and other negative outcomes with appropriate modification of protocols and procedures;
5. routine use of state-of-the-art monitoring equipment, especially in MR, where direct visualization of the sedated child is more difficult; and
6. employment of properly-trained personnel, preferably nurses or specially-trained technologists, to care for sedated patients.

Techniques

Pediatric sedation must be tailored to the patient, the examination, and the clinical setting. A detailed consideration of the pharmacology of the agents commonly used for pediatric sedation is beyond the scope of this article. Interested readers are referred to standard reference texts and pertinent review articles (4).

Table 1 lists some common pediatric sedative drugs used in our department with dosage guidelines and comments. Table 2 summarizes the order of our preferences for sedation in the different neuroimaging modalities stratified by patient weight.

MR

In our imaging department at a children's hospital, the most frequent use of sedation is for MR studies of the head, neck and spine. Children under age 7 or 8 years of age are routinely sedated, though we have had exceptionally cooperative children as young as age 3 undergo an MR study without sedation.

Sleep deprivation is an important adjunct to sedation with any drug regardless of the imaging

TABLE 1: Commonly used drugs for pediatric sedation[a]

Drug	Route	Dose	Comments
Chloral hydrate	P.O. or gastric tube	75 mg/kg (initial) 25 mg/kg (supplement if not asleep in 30 min) Maximum total dose 2000 mg	Good results at this dose Safe Many years experience Flavored syrup
Sodium pentobarbital (Nembutal)	IV or IM	5–6 mg/kg (initial) 2–3 mg/kg (supplement after 30 min prn) Maximum total dose 200 mg	IV more predictable and shorter recovery
Nalbuphine (Nubain) + Midazolam (Versed)	IV	0.1 mg/kg mixed with 0.05–0.1 mg/kg May repeat × 2 prn Maximum total Versed dose 5 mg	Less predictable in younger children Maximum effect lasts approximately 30 min Partially reversed by Naloxone Nubain is a partial agonist of other narcotics
"Cardiac cocktail" Meperidine (Demerol) Promethazine (Phenergan) Chlorpromazine (Thorazine)	IM	25 mg (0.5 mL) 6.25 mg (0.25 mL) 6.25 mg (0.25 mL) Dose per Table 3	Good analgesia Longer action (often >2 hr) More risk respiratory depression Partially reversed by Naloxone
Sodium thiopental (Pentothal)	Rectal	25 mg/kg Repeat ½ dose in 15 min prn	Does not require IV access Onset 7–15 min

[a] Note.—Abbreviations: IV, intravenous; IM, intramuscular; prn, *pro re na'ta* ("as circumstances may require"); P.O., *per os* ("by mouth").

TABLE 2: Sedation preferences for pediatric neuroimaging

Modality	Patient Group	Order of Preference	Comments
US	Infants	1. None 2. Chloral hydrate	Sedation rarely necessary
MR	Infants–small children (0–25 kg)	1. Chloral hydrate 2. Nembutal 3. Cardiac cocktail	Reduce dose in neonates
	Larger children–adolescents (25+ kg)	1. Nembutal, Pentothal 2. Cardiac cocktail or Nubain + Versed 3. General anesthesia	Most children under 8 require sedation Sedation usually not required, but if sedation is required, this is the most difficult group
CT	Infants–young children	1. Immobilization 2. Chloral hydrate 3. Nembutal	Sedation rarely required for routine exams Sedation may be necessary for 3-D or thin section studies
	Older children–adolescents	1. Television 2. Versed + Nubain 3. Nembutal	Sedation rarely needed unless patient is neurologically impaired
Angiography	Infants–children (0–40 kg)	1. Cardiac cocktail	See Table 3
	Older children–adolescents (40 kg +)	1. Nubain + Versed 2. Demerol (1 mg/kg) + Phenergan (.5 mg/kg)	
Myelography	Infants–young children 0–7 yr	1. Cardiac cocktail 2. Nubain + Versed	
	Older children–adolescents	1. None 2. Nubain + Versed	Sedation rarely needed unless neurologically impaired

modality (5). Our protocol for sleep deprivation is to keep the child up approximately 2 hours after the usual bedtime at night and awaken them 1 to 2 hours earlier than usual in the morning. The child is not allowed to nap either in the car on the way to the exam or while in the waiting room. For afternoon studies, the usual morning nap is denied. We even sleep-deprive older children scheduled for MR examinations even though no sedation is planned. The monotonous sounds of the MR scanner will often put to sleep a tired but nonsedated patient, allowing for a better study.

Oral chloral hydrate is the most frequently used drug for pediatric sedation in North American pediatric centers (6). In our pediatric MR experience since September 1986, representing more than 3000 sedated studies, chloral hydrate with sleep deprivation has been successful in over 90% of sedation attempts. Our results agree with those of a recent report (7) in which sedation with an average dose of 58 mg/kg (range 25–81 mg/kg) of chloral hydrate was successful on the first attempt in 86% of 50 children. We use a routine dose of 75 mg/kg to a maximum of 2000 mg. An additional 25 mg/kg may be given if the

patient does not go to sleep in 30 minutes after the first dose. The use of higher doses of chloral hydrate has been reported (8) but is associated with increased frequency of side effects, especially vomiting and hyperactivity. Our initial dose of chloral hydrate is reduced to 50–60 mg/kg for neonates, patients recently started on sedative doses of anticonvulsant medications, and for children who are lethargic before the medication is given. Flavored preparations of chloral hydrate are reasonably palatable. We have also found that a popsicle given after the liquid chloral hydrate "helps the medicine go down." Occasionally, the medication is administered through an oral or nasogastric tube. Infants and young children are allowed clear liquids after their sedative dose, because an empty stomach makes it harder for them to sleep. To our knowledge, we have had no episodes of aspiration related to this practice.

Patients who fail chloral hydrate sedation or who are too large to receive an adequate dose/kg within the 2000-mg guideline, are more of a challenge to sedate. Our second-line drug in MR is pentobarbital (9) administered either intramuscularly or (preferably) intravenously in doses up to 6 mg/kg (10). Rectal thiopental 25 mg/kg, though not as commonly used nationwide, is also a useful second-line drug in this setting and does not require intravenous access (11). Older children and adolescents who require sedation for MR usually respond to a combination of midazolam (12) and nalbuphine (13). General anesthesia is reserved for the most refractory cases and requires specialized equipment and monitoring.

Ultrasound and CT

Sedation is rarely required for US examinations of the head or spine and for routine CT examinations of the head. Sedation in CT is reserved for thin-section studies as of the temporal bone or for 3-D reconstruction, when coronal positioning is required, or when the patient has significant neurologic impairment. We have found that a television monitor suspended from the ceiling of the CT scanning room connected to a video cassette recorder in the control room provides adequate distraction for most neurologically normal children 3 years and older, almost completely eliminating the need for sedation in this group. A patient technologist carefully watching a fussy child and pushing the scan button at just the right moment, combined with effective immobilization of the infant or young child (see below), allow routine CT examinations to be performed on infants and small children, with a surprisingly small number of repeat scans being necessary and with little or no motion artifact. Safety and throughput are both enhanced by this nonsedated approach to CT. When sedation is required for CT, the approach is similar to that previously described for MR.

The art of immobilizing a nonsedated infant is accomplished by: 1) wrapping the child in a receiving blanket folded into a triangle with the shoulders across the widest portion of the triangle and the points folded over the arms and under the body; 2) securing the child on the scan table with restraints over the chest and knees and a sandbag under the knees to keep the child from sliding down; and 3) immobilizing the head in its holder with a combination of rectangular and triangular sponges and adhesive tape pulled tightly across the head holder and forehead.

Angiography and Myelography

Angiography and myelography, though becoming less commonly used because of advances in MR imaging and MR angiography, are special situations requiring analgesia in addition to sedation. In infants and young children, we prefer a combination of meperidine, chlorpromazine, and promethazine ("cardiac cocktail") for these studies. Table 3 provides a dose schedule for this combination in patients weighing up to 40 kg. The prolonged sedative effect of this cardiac cocktail may be helpful in these longer procedures and continues into the recovery period.

TABLE 3: Cardiac cocktail dosage schedule

Mix/per mL:	Meperidine	(Demerol)	25 mg (0.5 mL)
	Chlorpromazine	(Thorazine)	6.25 mg (0.25 mL)
	Prometazine	(Phenergan)	6.25 mg (0.25 mL)
Dosage scale (administer deep IM)[a]			
	2.5 kg (5 lbs)		0.17 mL
	4.5 kg (10 lbs)		0.33 mL
	6.8 kg (15 lbs)		0.5 mL
	9.0 kg (20 lbs)		0.67 mL
	11.4 kg (25 lbs)		0.83 mL
	13.6 kg (30 lbs)		1.0 mL
	18.3 kg (40 lbs)		1.22 mL
	22.7 kg (50 lbs)		1.47 mL
	27.3 kg (60 lbs)		1.70 mL
	31.8 kg (70 lbs)		1.80 mL
	36.4 kg (80 lbs)		1.90 mL
	40.1 kg (90 lbs)		2.0 mL

[a] Note.—IM, intramuscular.

However, the duration of sedation may be long enough to be a problem in some patients (4). General anesthesia for angiography is an expensive luxury to be used only in patients refractory to routine sedative drugs or for interventional procedures.

Routine angiography can be performed in older children and teenagers with combinations of meperidine and promethazine or nalbuphine and midazolam. We have been particularly pleased with our results with the latter combination in this group. Teenagers are particularly prone to vagal-mediated hypotension during angiography when only lightly sedated. We have found that wrapping the legs with elastic bandages prior to the procedure is helpful in preventing this problem. Older children rarely require sedation for myelography when an affirmative, supportive approach is used.

Before Sedation

Regardless of the examination to be performed and the sedation approach planned, preparation of the patient and family is essential. Referring physicians offices and hospital units must properly instruct patients and parents regarding sleep deprivation, withholding of food and water (3) (see Table 4), proper clothing to wear, and what to expect from the exam. In our experience, a phone call to the parent by a nurse or technologist on the day prior to the examination is valuable in confirming that this information has been accurately communicated and in answering questions and concerns. Printed literature and specially-prepared video presentations are also helpful in educating parents and children.

Evaluation of the patient by a nurse, technologist and/or physician is helpful in determining whether sedation is required, and if so, what regimen is optimal. Review of previous sedation records (kept in the folder with previous imaging studies) is essential. MR studies can be performed on many children in the 5- to 8-year range without sedation using an affirmative approach. Allowing them to observe another child in the MR scanner and the comforting presence of a parent or other care-giver are helpful. A reassuring hand on their leg during the exam may obviate the need for sedation. Some MR scanners have a pause button, which can be judiciously used to successfully scan a "wiggly" child.

When the decision is made to sedate the child, careful explanation of expected effects, possible complications, and alternative choices to the parent or guardian is essential. Institutions vary as to whether to obtain written informed consent for routine sedation in noninvasive exams (6). Regardless, information must be shared and consent to proceed be obtained. A brief medical history with attention to current medications, history of airway problems, chronic cardiac or respiratory disorders, and any concurrent illness is obtained by the nurse or technologist. If necessary, consultation with the radiologist and/or referring physician precedes administration of sedation.

TABLE 4: NPO guidelines for pediatric sedation (3)

1. No milk or solids after midnight
2. Clear liquids prior to exam as follows:

Age		
	0–2 yr	Up to 4 hr before
	3–6 yr	Up to 6 hr before
	7+ yr	Up to 8 hr before

Monitoring

Once sedated, and until adequately recovered, the child requires careful attention to monitoring and safety. The airway is protected by extension of the neck. Occasionally an oral airway is necessary to prevent the tongue from obstructing breathing. Oxygen is a very useful adjunct to sedation. In an editorial commentary from an anesthesiologist's perspective, Fisher (14) recommended administration of oxygen to all sedated patients (with the possible exceptions of premature neonates at risk for retinopathy and patients with abnormal ventilatory responses to oxygen). Oxygen administered by such simple devices as nasal prongs or a mask "markedly increases pulmonary oxygen reserves and permits prolonged apnea or airway obstruction without hypoxia." Furthermore, "its benefits are great, it is inexpensive, and it is not toxic (when administered briefly to healthy patients)".

Monitoring sedated patients in MR continues to be a challenge. But monitoring is *essential.* Initial experience with monitoring in MR was limited to plastic stethoscopes with long tubing to listen to heart sounds, taping a cup on the chest of a sedated child to watch respirations, and direct observation by a nurse, technologist or parent lying in the scanner with the child. More recently, apnea monitors measuring expired carbon dioxide content and pulse oximeters have added greatly to our ability to monitor patients in MR. Shellock (15) has reviewed availability, use,

and limitations of these devices. Simple techniques for radio frequency shielding of the detector and wires of a pulse oximeter may be helpful in preventing artifacts (16, 17). Rare instances of skin burns have occurred from monitoring wires coiled under or around a part of the sedated child while he is lying in the changing magnetic flux of the MR scanner (18).

Continuous monitoring, frequent observation, airway care and protection against aspiration continue after completion of the examination until the child is satisfactorily recovered. Carefully-prepared guidelines are available to assist in determining a child's suitability for discharge after sedation (3). Discharge instructions are reviewed with a family member or care-giver and are confirmed in writing, translated into the appropriate language if necessary. Hydration is occasionally a problem in infants and younger children kept "N.P.O. (nothing by mouth)" for a prolonged time. Fluids may be administered via a gastric tube or an intravenous catheter. Dehydration prolongs recovery from sedatives and should be corrected before it becomes a problem.

Special Considerations

Brief consideration of some miscellaneous points related to pediatric sedation may be helpful to those with less experience in this arena.

Sedation Failure

In spite of one's best efforts, sedation failures occur. They are more frequent when instructions regarding sleep deprivation are not followed, in mentally impaired older children, and with suboptimal doses of medication. We inform parents prior to administration of a sedative drug that, if it does not work, we have alternative choices for sedation, one of which will be successful. We prefer to begin with the least toxic drug(s) that we think will be sufficient in each case. Only rarely do we mix sedative regimens, preferring to reschedule the patient for another day rather than risk a polypharmacy approach to sedation. General anesthesia is rarely needed, but may be the only resort is some patients.

High Risk Patients

Certain patients require extra care when sedated. Premature infants are at risk in the hostile environment of the MR scanner. We prefer to limit their imaging studies to US and CT (when necessary), rarely performing MR on a premature neonate. In our department, an MR exam on any child in the first month of life requires specific radiologist approval. Hypothermia may be prevented by covering the neonate's head, wrapping the child in plastic or bubble wrap, and monitoring temperature (19).

Infants and children with underlying diseases, especially cardiac and/or respiratory, are at greater risk for complications from sedation. We frequently consult with referring physicians on a case-by-case basis to be certain they have weighed the risks of sedation against the value of the information to be gained.

Occasionally, a child with an undiagnosed brain tumor or other cause of increased intracranial pressure will be sedated for an imaging study. When this potentially dangerous situation is recognized, the child must be very carefully monitored until the examination is completed and appropriate measures immediately instituted to prevent hypoventilation and to decrease intracranial pressure.

Choice of Sedative

The judicious physician will limit his or her choices for sedation to a small number of agents in order to become thoroughly familiar with their dosages, side effects, idiosyncrasies, and contraindications. The broad spectrum of drugs and combinations of drugs used for sedation in this country attest to the fact that there are many ways to satisfactorily accomplish the task (6).

Chloral Hydrate Controversy

Concern was recently raised regarding animal mutagenicity of chloral hydrate in a letter to the editor of *Science* (20). Citing data that have been available in the literature for several years, a concerned father who is a "consultant in toxicology" pointed out that "chloral hydrate is a toxic metabolite of the rodent carcinogen trichloroethylene (TCE) and is a mutagen and chromosome damaging agent."

We have not changed our use of chloral hydrate or felt the need to discuss this issue with parents prior to using it for pediatric sedation. In my unofficial survey of 40 North American pediatric radiologists (personal communications) 61% of those responding were aware of this controversy. Of those who were aware of the

letter, 78% have not changed their approach to the use of chloral hydrate. Of those who have changed, they indicated that they now use intravenous pentobarbital and rectal thiopental far more frequently than before. Only 8% discussed the controversy with parents.

My conversations with regional officials of the Food and Drug Administration (FDA) indicate that there is no new policy or recommendation regarding chloral hydrate (personal communication with the Public Affairs Office of U.S. Food and Drug Administration, Denver, CO). I feel that chloral hydrate is the safest, most effective agent for pediatric sedation in most infants and young children and, therefore, will continue to use it unless instructed otherwise by the FDA, another government agency, or by the pharmaceutical manufacturer.

Parents

The participation of parents in the care of their children during sedation and imaging studies is a double-edged sword. Parents are often very helpful in supplying important medical information, assisting in calming or holding a child before and after scanning, and have a right to be involved in their child's care. Therefore, we allow one parent or guardian to accompany the child through the entire process of sedation, scanning, and recovery for MR and CT. However, parents may occasionally be somewhat difficult or even obstructive to the efforts of nurses, technologists, and physicians. In this setting, we endeavor to tactfully explain our perception of the situation to the parents and invite them to retire to the waiting room until the exam is completed. Most understand and are willing to cooperate.

Summary

Sedation of infants and children for neuroimaging is a "necessary evil" that will be with us for the foreseeable future. Sedation must be accompanied safely in all patients with a high frequency of success on the first attempt. A carefully-considered written sedation plan that addresses the issues raised in this review will assure maximum safety and success in sedating infants and children at each facility involved in pediatric neuroimaging. An affirmative approach and careful attention to both the science and the art of pediatric sedation by all concerned professionals will produce excellent results and facilitate application of current imaging technology in the diagnosis of pediatric neurologic disease.

Acknowledgments

I extend appreciation to Valerie Kemp for secretarial assistance and to Cheryl Fitzgerald, RT, for technical assistance.

References

1. Barkovich AJ. *Pediatric neuroimaging.* New York: Raven Press, 1990: 1
2. Thompson JR, Schneider S, Ashwal S, Holden BS, Hinshaw DB Jr, Hasso AN. Choice of sedation for computed tomography in children: a prospective evaluation. *Radiology* 1982;143:475–479
3. American Academy of Pediatrics-Committee on Drugs, Section on Anesthesiology. Guidelines for the elective use of conscious sedation, deep sedation, and general anesthesia in pediatric patients. *Pediatrics* 1985;76:317–321
4. Nahata MC. Sedation in pediatric patients undergoing diagnostic procedures. *Drug Intell Clin Pharm* 1988;22:711–715
5. Barkovich AJ. Techniques and methods in pediatric magnetic resonance imaging. *Semin Ultrasound CT MR* 1988;9:186–191
6. Keeter S, Benator RM, Weinberg SM, Hartenberg MA. Sedation in pediatric CT: national survey of current practice. *Radiology* 1990; 175:745–752
7. Rumm PD, Takao RT, Fox DJ, et al. Efficacy of sedation of children with chloral hydrate. *South Med J* 1990;83:1040–1042
8. Patel M, Leonidas JC, Newman GG, Dickinson D, Golden B. *High dose chloralhydrate: a safe and effective sedative for pediatric MRI and CT.* Paper presented at the 29th Annual Meeting of the American Society of Neuroradiology. Washington, DC, June 9–14, 1991
9. Merrick PA, Case BJ, Jagjivan B, Stackman TJ. Care of pediatric patients sedated with pentobarbital sodium in MRI. *Pediatr Nurs* 1991; 17:34–38
10. Strain JD, Campbell JB, Harvey LA, Campbell JB. IV Nembutal: safe sedation for children undergoing CT. *AJR* 1988;151:975–979
11. Burckart GJ, White TJ III, Seigle RL, Jabbour JT, Ramey DR. Rectal thiopental versus an intramuscular cocktail for sedating children before computerized tomography. *Am J Hosp Pharm* 1980;37: 222–224
12. Diament MJ, Stanley P. The use of midazolam for sedation of infants and children. *AJR* 1988;150:377–378
13. Glanville JN. Nalpuhine hydrochloride (Nubain, DuPont) as premedication for radiological procedures. *Clin Radiol* 1990;42:212–213
14. Fisher DM. Sedation of pediatric patients: An anesthesiologist's perspective [comment]. *Radiology* 1990;175:613–615
15. Shellock FG. Monitoring sedated pediatric patients during MR imaging [letter]. *Radiology* 1990;177:586–587
16. Wagle WA. Technique for RF isolation of a pulse oximeter in a 1.5 T MR unit [letter]. *AJNR* 1989;10:208
17. Fisher DM, Litt L, Cote CJ. Use of pulse oximetry during MR imaging of pediatric patients [letter]. *Radiology* 1991;178:891–892
18. Kanal E, Shellock FG, Talagala L. Safety considerations in MR imaging. *Radiology* 1990;176:593–606
19. McArdle CB, Richardson CF, Nicholes DA, et al. Developmental features of the neonatal brain: MR imaging. I. Gray-white matter differentiation and myelination. *Radiology* 1987;162:223–229
20. Smith MT. Chloral hydrate warning [letter]. *Science* 1990;19:359