Reports of Investigation

Trained nurses can provide safe and effective sedation for MRI in pediatric patients

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Purpose: To determine the success rate, safety and complications using a standard protocol and trained nurses to provide sedation for MRI under the supervision of a radiologist.

Materials and Methods: Nurses were trained to provide sedation via a standard protocol for pediatric patients undergoing diagnostic MRI. Oral chloral hydrate (80-100 $mg \cdot kg^{-1}$) was used for children less than 18 mo of age. Older children received either 1-6 $mg \cdot kg^{-1}$ pentobarbital *iv*, with or without 1-2 $\mu g \cdot kg \cdot hr^{-1}$ fentanyl, or 25 $mg \cdot kg^{-1}$ thiopental *pr*. Sedation was defined as successful if it allowed completion of the MRI without image distorting patient movement. The records of 572 MRIs performed on 488 pediatric patients (mean age 5 ± 4 yr; age 2 mo-14 yr) from 1991 to July 1995 were reviewed to determine the success rate and complications using the sedation program.

Results: Most, 91.8% (525/572), of the MRIs were successfully completed in 445 patients. The reasons for failure were inadequate sedation (45, 95.7%) and coughing (2, 4.2%). The failure rate was much higher before 1994 (38/272, 14%) than after (9/300, 3%; $P < 0.0001$). Failure was more common if rectal thiopental was used (23/172, 14%) than intravenous pentobarbital (19/256, 7.4%; $P < 0.05$). The failure rate was also high in patients with a history of a behavioural disorder (10/59,17%). There were no deaths or unexpected admissions as a result of the sedation program.

Conclusion: A high success rate can be achieved as experience is gained using a standard protocol and trained nurses to sedate children for MRI.

Objectif : Évaluer le taux de succès, la sécurité et les complications liés à l'usage, par du personnel infirmier formé, d'un protocole standard d'administration d'une sédation en vue d'un examen d'IRM sous la supervision d'un radiologiste.

Méthode : Des infirmières ont été formées pour administrer la sédation selon un protocole standard à des patients pédiatriques devant subir un examen diagnostique d'IRM. L'hydrate de chloral oral (80-100 $mg \cdot kg^{-1}$) a servi pour les enfants de moins de 18 mois. Les plus âgés ont reçu soit 1-6 $mg \cdot kg^{-1}$ de pentobarbital *iv*, avec ou sans 1-2 $\mu g \cdot kg \cdot hr^{-1}$ de fentanyl, soit 25 $mg \cdot kg^{-1}$ de thiopental *pr*. On considérait la sédation réussie quand l'IRM était achevé sans distorsion d'image par un mouvement du patient. Les enregistrements de 572 IRM réalisés chez 488 enfants (âge moyen de 5 ± 4 ans; limite d'âge de 2 mois-14 jrs) de 1991 à juillet 1995 ont été revus pour l'évaluation du taux de succès et des complications liés au programme de sédation.

Résultats : La plupart des examens d'IRM, 91,8 % (525/572), ont été réalisés avec succès chez 445 patients. Les échecs ont eu pour cause une sédation insuffisante (45, 95,7 %) et la toux (2, 4,2 %). Le taux d'échec a été beaucoup plus élevé avant 1994 (38/272, 14 %) qu'après (9/300, 3 %; $P < 0,0001$). L'échec était plus fréquent avec l'usage de thiopental rectal (23/172, 14 %) qu'avec le pentobarbital intraveineux (19/256, 7,4 %; $P < 0,05$). Le taux d'échec a été élevé également chez les patients qui présentaient des antécédents de troubles de comportement (10/59, 17 %). Aucun cas de décès ou d'admission imprévue n'a résulté de ce programme de sédation.

Conclusion : Un fort taux de réussite peut être atteint à mesure que se développe l'expérience des infirmières formées à utiliser un protocole standard d'administration d'une sédation à des enfants pour un examen d'IRM.

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MOST young children cannot lie still for magnetic resonance imaging (MRI) without deep sedation. With deep sedation, children may loose their protective airway reflexes, ability to maintain a patent airway, and the ability to respond purposefully to stimulation. Deep sedation requires that personnel trained in airway management continuously monitor the child.[1] To ensure adequate pre-sedation assessment and proper monitoring during and following MRI scanning, a standard sedation protocol was developed at the University of Minnesota. As part of this protocol special nurses were trained by the departments of Radiology and Anesthesiology to administer sedation and monitor the patients as they received MRI. This report describes the success and complication rates of sedation for MRI during the three-year period following establishment of this protocol at the University of Minnesota.

Methods

The protocol was established in August 1991, and was developed in accordance with the American Academy of Pediatrics guidelines.[1] The referring physician performed the pre-sedation physical examination and did the initial assessment. The assessments were reviewed by the radiologist performing the study as well as the nurse administering the sedation. A radiologist was responsible and in attendance for each child sedated and functioned as the medical supervisor. Children with unusual airways or major medical problems were discussed with an anesthesiologist prior to administering sedation. The nurse also made prescreening calls to all parents of outpatients requiring sedation to ensure compliance and to instruct the parents on the guidelines for withholding food or fluids. The nurse also tried to identify any pertinent past health history as well as discuss post-sedation observation. This initial triage was designed to detect children with complicated medical histories that required further evaluation before administering sedation.

All nurses selected to provide pediatric sedation had previously worked in the post-anesthesia care unit of the University of Minnesota. The education process of the nurses consisted of instruction in airway management skills, pediatric advanced life support, and proper monitoring and assessment techniques. The physiological and pharmacological effects of the sedatives used were reviewed. The nurses also received practice and training in placing intravenous catheters in infants and small children under the supervision of an anesthesiologist in the operating room.

According to the protocol, children less than 18 mo of age received 80-100 $mg \cdot kg^{-1}$ chloral hydrate *po*. Older children received either 1-6 $mg \cdot kg^{-1}$ pentobarbital *iv* or, if an intravenous contrast agent was not required, 25 $mg \cdot kg^{-1}$ thiopental *pr*. The pentobarbital was administered initially as 1-2 $mg \cdot kg^{-1}$ boluses *iv* every minute until sedation was achieved or the maximum dose of 6 $mg \cdot kg^{-1}$ was reached. Fentanyl could be added to the pentobarbital if sedation with this agent alone proved to be inadequate (1-2 $\mu g \cdot kg \cdot hr^{-1}$ administered as 0.25 $\mu g \cdot kg^{-1}$ boluses). Additional pentobarbital could be administered during the procedure as well if the maximum dose of 6 $mg \cdot kg^{-1}$ had not been reached. Midazolam (0.02 – 0.1 $mg \cdot kg^{-1}$) *iv* could be administered to older children who did not require heavy sedation or to children with a contraindication to barbiturates.

Monitoring of the heart rate, electrocardiogram, pulse oximetry, respiratory rate, and blood pressure was performed by the nurses using MRI compatible equipment. Five-minute vital signs and pulse oximetry data were recorded on a standard form. The nurses also recorded any difficulties encountered during the scan or reasons for terminating the scan on these standard forms.

Most (75%) children received 2-5 $L \cdot min^{-1}$ of supplemental oxygen blown by the face with oxygen tubing. The remainder received oxygen by facemask or nasal tubing.

After the scan, outpatients were transported to the day surgery hospital observation area for recovery. Inpatients recovered in an area adjacent to the MRI suite, then returned to their patient care units. Patients were discharged from the recovery room when the American Academy of Pediatrics (AAP) discharge criteria were met, ie. 1) cardiovascular function and airway patency were satisfactory and stable, 2) the patient was easily rousable and protective reflexes were intact, 3) the patient could talk (if age appropriate), 4) the patient could sit up unaided (if age appropriate), 5) the level of responsiveness had returned to normal for that child, and 6) the level of hydration was adequate.[1] Outpatients were given a written post-sedation instruction sheet that included the sedation given and activity instructions as well as resource phone numbers.

If the sedation failed (inability of the child to hold still in spite of receiving the drugs in the protocol), the MRI was rescheduled another day to be attempted again with either sedation or, more often, general anesthesia. General anesthesia was administered by or was under the direct supervision of an anesthesiologist, and consisted of propofol and a neuromuscular blocking drug. If general anesthesia was used, recovery occurred in the postanesthesia recovery room and discharge was determined by the responsible anesthesiologist.

The patient charts and sedation records for the three-year period beginning in late 1991 when the protocol was established, until July 1995, were retrospectively reviewed. The ages and weights of the children requiring sedation were determined, as were their preexisting medical conditions. Successful sedation was defined as when the MRI could be completed without excessive movement. If the MRI had to be repeated, either because the patient could not tolerate the length of the procedure or moved so often that the image was distorted, the sedation was called a failure. The success rate and reasons for failure were recorded from the sedation notes, as were other complications the nurses had documented. Finally, the time to recovery and discharge to home or the ward was noted. The data were presented as absolute numbers, percentage or mean ± SD as appropriate. Significance ($P < 0.05$) was determined by Fischer's exact tests.

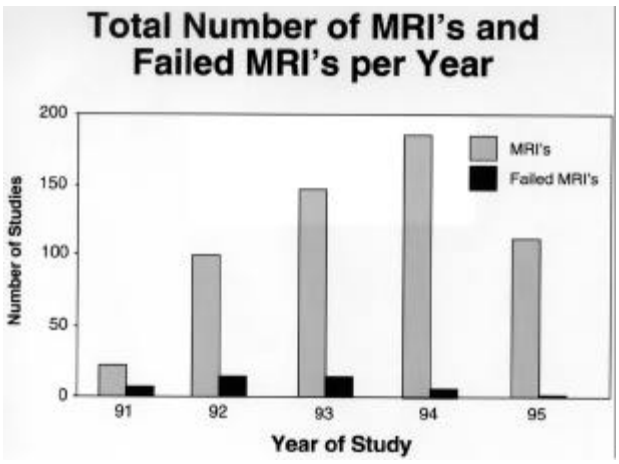

FIGURE 1 Numbers of MRI studies and of failures for each year of the review. Only the first six months of 1995 were included in this study.

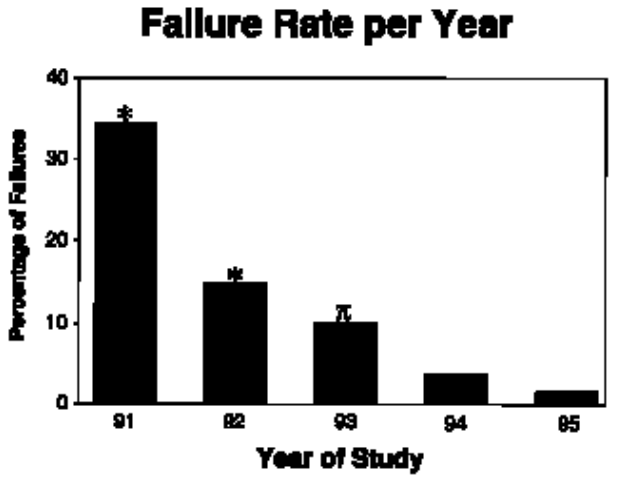

FIGURE 2 Failure rate for each year of the review. * $P \leq 0.0005$ compared with 1995. † $P < 0.01$ compared with 1995.

Results

There were 572 MRI scans attempted on 488 pediatric patients (mean age 5 ± 4 yr; age range 2 mo – 14 yr) during the study period. The reasons for the scans included: developmental delay (19%), brain tumour or other malignant disease (47%), seizure disorder (16%), and behaviour problems (12%). Twenty four percent of the patients had more than one neurological problem requiring evaluation with MRI. Thirty one percent of patients (172/572) received thiopental *pr*, 48% (256/572) pentobarbital *iv*, either alone or supplemented with fentanyl (119/256), 22.7% (130/572) oral chloral hydrate, and 2.4% (14/572) midazolam *iv* or other drugs such as diazepam not on the protocol. All patients who received oral chloral hydrate were less than 18 mo of age.

There were 525 of the 572 MRI scans (91.8%) successfully completed in 445 patients. Four patients failed more than one study. Of the 47 scans that were not completed the reasons for failure were inadequate sedation (45, 95.7%) and coughing (2, 4.2%). The failure rate declined markedly over time during the study as the number of scans increased (Figures 1,2). Only nine of the 300 scans performed in 1994 and 1995 failed (3%) compared with 38 of the 272 scans performed prior to 1994 (14%, $P < 0.0001$).

The failure rate for sedation was higher in children that were studied, in part, because of a behavioural disorder (10/59, 17%) than in children scanned for other reasons (33/396, 8.3%; $P < 0.05$). There were no other medical conditions or reasons for performing the MRI scans associated with a higher failure rate.

Rectal thiopental had the highest failure rate (23/172, 14%) of all the drugs utilized. All of the failures were due to inadequate sedation. In six of the 23 patients in whom rectal thiopental failed the patient expelled the drug by defecation before sedation could occur. Perhaps as a result, rectal thiopental was used less frequently for sedation in 1994 and 1995 (67/300, 22.3%) than earlier (105/272, 38.6%; $P < 0.0001$). However, the failure rate of rectal thiopental was actually lower in 1994 and 1995 [4/67 (6%) *vs* 19/105 (18.1%); $P < 0.05$].

Four of the patients who failed rectal thiopental had scans attempted using intravenous pentobarbital

the following week, three of which were completed successfully. Two patients had scans attempted at another date using rectal thiopental, but both failed. The remainder of the patients who failed sedation with rectal thiopental were given general anesthesia.

Intravenous sedation with pentobarbital with or without fentanyl had an overall failure rate of 7.4% (19/256). This failure rate was approximately half that of rectal thiopental (14%; $P < 0.05$). Two patients failed because of coughing and 17 because of inadequate sedation. The failure rate of patients receiving intravenous pentobarbital was higher prior to 1994 (15/92, 16.3%) than after (4/164, 2.4%; $P < 0.0001$). Intravenous pentobarbital with or without fentanyl was also used much more frequently in 1994 and 1995 (164/300, 55%) than in the earlier years of the study (92/272, 33.8%; $P < 0.0001$).

One patient who failed sedation with intravenous pentobarbital alone was successfully sedated at a later date with pentobarbital and fentanyl. One patient who failed intravenous pentobarbital earlier was given pentobarbital for another study one year later, which also failed. The remainder of the patients who failed intravenous sedation had their studies performed under general anesthesia on a different date.

The failure rate for oral chloral hydrate was low throughout the study (3/130, 2.3%). All of the failures were due to inadequate sedation. One child who failed was successfully sedated at a later date with rectal thiopental. Another child had a successful study using a higher initial dose of chloral hydrate, and the third required general anesthesia.

Other complications from sedation that did not prevent completion of the MRI studies are listed on the Table.

The average sedation time (from when the drugs were administered until the scan was completed) was 69 ± 32 min. The average recovery times until the patient was discharged to home or the ward was 61 ± 53 min. There were no deaths or unexpected admissions in any of the 488 patients studied.

TABLE Complications that did not halt MRI.

Complications	*Number*
Defecation after thiopental	9
Emesis following pentobarbital and fentanyl	2
Emesis following chloral hydrate	1
Transient oxygen saturation < 90%	2
Apnea following pentobarbital	1
Choreiform movement during scan	1
Seizure during scan	1

Discussion

Recently, there has been a considerable increase in the number of diagnostic MRI scans performed in pediatric patients. Most of the younger children require heavy sedation or general anesthesia to obtain good images. Many institutions have had difficulty finding the resources and personnel necessary to sedate or anesthetize large numbers of children undergoing these procedures safely. Often, it is not possible or economical to have an anesthesiologist present for every case involving sedation. A recent survey of 31 children's hospitals in the United States showed that sedation for children is ordered by the radiologist (87%) or referring pediatrician (9.7%) in most institutions. In only one institution was the medication ordered and administered by an anesthesiologist. Also, monitoring was provided by a registered nurse alone in most (92%) hospitals.[2] However, complications and mortality have occurred in children when untrained personnel have administered sedation or inadequate monitoring was provided.[3] For this reason the American Society of Anesthesiologists have published practice guidelines for sedation and analgesia for non-anesthesiologists.[4] Failure rates may be high as well if individuals not trained in anesthesiology administer sedation in the absence of a written protocol.[5]

Our study demonstrated that infants and small children could safely and successfully undergo MRI using a standard sedation protocol administered by nurses specially trained by the Department of Anesthesiology. The training of these nurses meets both the American Academy of Pediatrics Sedation Guidelines and the Practice Guidelines published by the American Society of Anesthesiologists.[1–4] Their previous experience in the recovery room made them familiar with working with anesthetized patients and patients recovering from anesthesia. Complications such as vomiting or apnea were easily and properly handled so that major morbidity or mortality did not occur. We believe the fact that the nurses were trained by and had extensive experience working with the anesthesiologists at our institution facilitated proper consultation and referral of patients with difficult medical problems.

The failure rate declined markedly throughout the study. Currently, it is very rare (< 2% of cases) that general anesthesia must be administered because of failed sedation. Since the same nurses were administering the sedation throughout the study, the improved success rate was primarily due to increased skill with the use of intravenous sedation. Determination of how much pentobarbital to administer to children initially for adequate sedation requires experience. Also, as their experience with intravenous sedation improved, rectal

sedation was used less often. The more selective use of rectal thiopental to cases short enough where rectal sedation is likely to be adequate may have improved the overall success rate.

This study suggests that rectal thiopental should be used less frequently for sedation for MRI. Many of the failures from rectal thiopental were related to inadequate absorption due to defecation. Other studies have demonstrated that rectal thiopental results in irritation of the rectal mucosa in as many as 34% of children.[6] It is likely that some sedation failures will occur from irritation of the rectal mucosa and subsequent defecation regardless of the experience or training level of the person administering the agent.

Some authors suggest that rectal methohexital is preferable to thiopental for sedation for MRI.[7] Methohexital has a clearance rate twice as fast as thiopental and a shorter elimination half-life (4 *vs* 12 hr). Children sedated with rectal methohexital may have a more rapid recovery of psychomotor function.[8] However similar problems with defecation, rectal irritation and a high failure rate can occur and have been reported with rectal methohexital as with thiopental.[9] In addition, seizures have been reported with rectal methohexital.[10]

In contrast, the success rate of oral chloral hydrate was high throughout the study with few complications. Other studies have shown higher failure rates. However, most of the failures occurred in older children.[11,12] The high success rate in our study using oral chloral hydrate was probably due to restricting its use to patients less than 18 mo of age.

This study also showed that the failure rate for sedation was high in children that had failed sedation previously. This suggests that patients who have failed sedation should receive general anesthesia rather than risk a second failure. The failure rate was also higher in patients with behavioural disorders. Many of these patients would benefit from receiving general anesthesia.

Recently intravenous propofol has become popular both for providing sedation as well as general anesthesia for MRI. Propofol is usually administered by continuous infusion for sedation for MRI because of its rapid elimination. Most studies show a more rapid recovery and discharge to home or the hospital ward when propofol is used compared with other sedative agents, and it is the agent that most anesthesiologists use for general anesthesia for MRI.[1 3] However, apnea requiring ventilatory support occurs more often when intravenous propofol is used for sedation for MRI than with pentobarbital.[1 4] Also, although new automatic infusion pumps that are compatible with MRI are being developed, continuous administration of propofol currently requires regulating the rate of drug administration with a drip chamber or mechanical flow regulator.[1 3] This may cause inaccurate drug administration, increase the workload of the nurse, and distract from patient observation. In contrast, longer acting agents such as pentobarbital can be administered by bolus.

Each facility has unique concerns that may affect how sedation is administered to children undergoing MRI. Failure rates are likely to be high when a sedation program is first initiated before nurses become comfortable using a sedative protocol. Some authors suggest that if an institution is in an environment where 100% success is required for each MRI, sedation or general anesthesia should be administered by an anesthesiologist.[1 5] However, this study demonstrated that excellent success rates can be achieved with little morbidity and mortality by trained and experienced nurses under the direct supervision of a radiologist.

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