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Chloral Hydrate Sedation for Pediatric Echocardiography: Physiologic Responses, Adverse Events, and Risk Factors

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ABSTRACT

OBJECTIVE. The physiologic responses to chloral hydrate sedation in the setting of a pediatric echocardiography laboratory have not been well documented; neither has the population at risk been identified adequately. The purpose of this study was to describe the physiologic responses to chloral hydrate sedation, to report the occurrence of adverse events, and to identify any risk factors that predicted these adverse events in children who underwent sedation for echocardiography at our institution.

METHODS. We analyzed retrospectively 1095 patients who were sedated for echocardiography. Vital signs and oxygen saturations were recorded every 5 minutes, and adverse events were noted. Potential risk factors for sedation-related adverse events were analyzed.

RESULTS. Thirty-eight percent of patients were classified as American Society of Anesthesiologists class 3 or 4, reflecting the significant comorbidity in the study population. Hemodynamic responses to chloral hydrate sedation included ≥20% decreases in heart rate (24% of the patients) and blood pressure (59% of the patients). There were no deaths or permanent morbidity. Adverse events occurred in 10.8% of patients and included apnea ($n = 3$ [0.3%]), airway obstruction ($n = 15$ [1.4%]), hypoxia ($n = 65$ [5.9%]), hypercarbia ($n = 40$ of 603 [6.6%]), hypotension with poor perfusion ($n = 4$ [0.4%]), vomiting ($n = 4$ [0.4%]), and prolonged sedation ($n = 36$ [3.3%]). No intervention was required in 92.5%, minor interventions were necessary in 7%, and major interventions were required in 0.5% of all patients. Multivariate analysis identified only age younger than 6 months as a predictor for adverse events, whereas cyanosis, hospitalization, American Society of Anesthesiologists class, fasting time, oxygen requirement, and use of additional sedation were not predictors.

CONCLUSIONS. Moderate decreases in heart rate and blood pressure, in the absence of clinical deterioration, are expected responses to chloral hydrate sedation in this

pediatric population. The majority of adverse events were minor, and major events were uncommon. Infants who were younger than 6 months were found to be at higher risk for serious adverse events.

ECHOCARDIOGRAPHY IS THE primary modality for the evaluation of children with suspected congenital and acquired cardiac disease.[1–5] Often these children are at a young age, when the cooperation that is necessary to obtain a complete and accurate study is difficult to achieve without sedation. Thus, many pediatric centers rely on sedation when performing echocardiography in children who are younger than 3 years.[6,7]

The American Academy of Pediatrics (AAP) recommends that the sedated patient be observed continuously and monitored for all hemodynamic parameters, including oxygen saturation, heart rate, respiratory rate, and blood pressure (BP), and that vital signs be documented at least every 5 minutes until appropriate discharge criteria are met.[8] This suggests recognition of abnormal hemodynamic parameters for a patient at any given age, with a goal of early identification and intervention for potential adverse events. However, the administration of sedation medications may modify the patient's baseline physiologic state by causing alterations in parameters such as heart rate and BP, which in turn can influence hemodynamic measurements by echocardiography. Unfortunately, few data exist regarding the normal physiologic responses to sedation in the pediatric population. We hypothesized that alterations in these parameters outside the published normal ranges for nonsedated patients is common and often well tolerated without clinical deterioration. The purpose of this study was to describe the physiologic responses to chloral hydrate sedation, to report the occurrence of adverse events, and to identify any risk factors that predicted these adverse events in children who underwent sedation for echocardiography at our institution.

METHODS

With approval from the institutional review board, we conducted a retrospective cohort study of all children who underwent chloral hydrate sedation for echocardiography at Children's Medical Center from December 2001 through December 2003. In general, patients from 1 month to 3 years of age were sedated. Exceptions included patients who were considered to be too ill for sedation on the basis of the physician's clinical judgment, physician preference, or parental refusal. Only patients who were sedated in the echocardiography laboratory were included in this study. A designated sedation room was staffed by a registered nurse and a respiratory therapist and was overseen by a pediatric cardiologist at all times. All involved staff were pediatric advanced life support–certified and had successfully completed the hospital-administered sedation-training module.

The sedation protocol that was used during the study period included a patient history, physical examination, and assignment of the American Society of Anesthesiologists (ASA) Classification of Physical Status[9] performed by the ordering physician before obtaining written consent and administration of sedation. However, to reduce the variability of the ASA class assignment as a result of its subjective nature and its assignment by physicians with various levels of training (residents, fellows, and cardiologists), 2 of the authors (L.C.H. and M.S.L.) reviewed all of the ASA class assignments and adjusted these as needed. The nil per os guidelines from the hospital sedation policy allow infants who are younger than 6 months to receive formula and solids for up to 6 hours, breast milk for up to 4 hours, and clear liquids for up to 2 hours before sedation. Children who are 6 months or older may receive solids and liquids for up to 6 hours and clear liquids for up to 2 hours before sedation. However, modification of this protocol is recognized as acceptable on the basis of the clinical judgment of the physician. Oral chloral hydrate (80 mg/kg, maximum 1 g) was used in essentially all cases, with the addition of oral diphenhydramine (1 mg/kg, maximum 50 mg) or oral midazolam (0.5–1.0 mg/kg, maximum 20 mg) if needed to achieve adequate sedation. A registered respiratory therapist or a registered nurse monitored the patient continuously from the time when the sedative was administered until discharge. A physician and complete set of resuscitation equipment, including oxygen, wall suction, bag ventilation/intubation supplies, and resuscitative medications, were available immediately. Vital signs including respiratory rate, heart rate, BP, oxygen saturation, inspired oxygen concentration, cardiac rhythm, level of consciousness, and pain scale were recorded every 5 minutes. The decision to monitor end-tidal carbon dioxide using capnography (Nellcor Inc, Pleasanton, CA) was determined by the staffing physician or nurse. Children were monitored for heart rate, rhythm, and BP with Tram transport monitors (Marquette Electronics, Milwaukee, WI) and for oxygen saturation with pulse oximetry (Nellcor Inc). When the patient was still asleep after completion of the echocardiogram, the nurse or the parent stimulated the child. On awakening, the child was offered clear liquids as tolerated. Patients were discharged when they met standard age-appropriate procedural sedation discharge criteria. Patients had to be alert, be able to tolerate clear liquids, have stable vital signs, and have an Aldrete score of at least 9 or matching the presedation score.[10] Patients were monitored in the sedation room until discharged by a physician. Parents received postsedation guidelines regarding sleep, diet, and activity for their child per policy. Contact telephone numbers and instructions for seeking emergency care were also provided.

The initial assessment, procedural vital signs, adverse events, interventions, and discharge assessment were reported in the sedation record. These records were reviewed to evaluate the patients' physiologic parameters during sedation, including level of consciousness, respiratory rate, oxygen saturation, capnography, heart rate and rhythm, and BP. Normal ranges for these vital signs were adapted from the *Pediatric Advanced Life Support Provider Manual*,[11] the Report of the Second Task Force on Blood Pressure Control in Children,[12] and Martin's *The Pediatric Patient in Clinical Anesthesia Practice*.[13] An acceptable range for oxygen saturation was predetermined for each individual patient on the basis of the cardiac anatomy and baseline oxygen saturations. An abnormal heart rate was defined as <80 beats per minute for patients who were younger than 6 months, <75 beats per minute for patients who were from 6 months up to 24 months of age, and <60 beats per minutes for patients who were 24 months and older. Abnormal systolic BPs were defined as <60 mm Hg for patients who were younger than 6 months and <85 mm Hg for patients who were 6 months and older. Maximum decreases in oxygen saturation, heart rate, and BP and maximum increase in carbon dioxide were evaluated as percentages of the presedation values.

Sedation records were also reviewed for documented adverse events and related interventions. Hypoxia was defined as a >10% decrease from baseline oxygen saturation, prompting the administration of supplemental oxygen or increase in oxygen concentration for patients who were already receiving oxygen. Similarly, hypercarbia was defined as a >20% increase from baseline end-tidal carbon dioxide measurement. Bradycardia or hypotension associated with clinically apparent hemodynamic compromise was considered an adverse event. The duration of chloral hydrate sedation varies by dose and from patient to patient and potentially can last for up to 4 hours. The goal of sedation for echocardiography is to provide a short but adequate period of sedation that lasts for the duration of the procedure only. In our experience, using chloral hydrate, the time from administration to onset of sedation averages ~20 to 30 minutes. It takes ~30 to 50 minutes to perform a complete sedated echocardiogram. The patient then is actively stimulated to awaken after the procedure, thus shortening potential duration of sedation. Therefore, sedation that lasts for an additional hour after completion of the echocardiogram despite stimulation, suggesting a total sedation time of >2 to 2.5 hours, was classified as an adverse event. Oxygen administration by nasal cannula or blow-by, oral or nasal suctioning of secretions, upper airway repositioning, tactile stimulation, and aerosol administration were considered minor interventions. Escalation of respiratory and circulatory support beyond this was considered a major intervention.

The initial assessments were reviewed to identify patient characteristics that may be potential risk factors for sedation, including patient age, presence of cyanosis, hospitalization at the time of the study, comorbid conditions (eg, acute infection, chromosomal defect or syndrome, other systemic diseases) as accounted for during assignment of ASA class, fasting time, baseline oxygen requirement, and use of additional sedation.

Statistical Analysis

Statistical analysis included descriptive data presented as means, SDs, medians, ranges, and proportions where applicable. χ^2 and Fisher's exact tests were used to compare (parametric data as appropriate) baseline characteristics and adverse events. Potential predictors of adverse events were evaluated further for their association with baseline characteristics using univariate and multivariate logistic regression models. Significance was determined at $P < .05$. All calculations were performed by using JMP 5.0 statistical software (SAS, Chicago, IL).

RESULTS

A total of 1140 consecutive patients underwent sedation in the echocardiography laboratory from December 2001 through December 2003. Forty-five patients were excluded from the study as a result of incomplete sedation records. Two of the excluded patients experienced adverse events that required minor interventions. The remaining 1095 patients composed the study population.

Table 1 identifies the baseline characteristics of the study population. Ninety-four percent of patients who

TABLE 1 Patient Characteristics

Age, mo	
Median (range)	9 (0.13–64)
≤1, n (%)	58 (5.3)
>1–6, n (%)	398 (36.3)
>6–36, n (%)	630 (57.5)
>36–64, n (%)	9 (0.8)
Heart disease, n (%)	
None	134 (12.2)
Simple	570 (52.1)
Complex	391 (35.7)
Cyanotic, n (%)	202 (18.4)
Comorbid condition, n (%)	318 (29)
Baseline oxygen requirement, n (%)	56 (5.1)
Hospitalized, n (%)	372 (40)
Fasting time, median (range), h	4.5 (0.6–72)
Fasting time <2 h, n (%)	71 (6.5)
ASA class, n (%)	
1	80 (7.3)
2	596 (54.4)
3	410 (37.4)
4	9 (0.8)
Sedation medication, n (%)	
Chloral hydrate	1092 (99.7)
+ Diphenhydramine	234 (21.4)
+ Midazolam	7 (0.6)
Midazolam	3 (0.3)

were sedated were between the ages of 1 month and 3 years. Eighty-eight percent of patients had detectable heart disease, which was categorized into simple lesions, such as isolated acyanotic lesions (eg, septal defects, valvar stenosis), or complex lesions, such as acyanotic patients with multiple lesions (eg, ventricular septal defect, aortic stenosis, coarctation), cyanotic heart disease, or single ventricle physiology. Twenty-nine percent of patients had at least 1 comorbid condition. Five percent were receiving supplemental oxygen by nasal cannula or tracheostomy before sedation. Forty percent of patients were hospitalized at the time of sedation for the echocardiogram. Thirty-eight percent of patients were assigned to ASA class 3 or 4. Seventy-eight percent of patients received a single agent, and 22% received >1 medication.

Table 2 identifies the hemodynamic responses to sedation of all patients. The mean maximum percentage decrease in heart rate was 14% ± 10%, and the maximum percentage decrease in BP was 23% ± 13%. Of the 266 (24.2%) patients who had a >20% decrease in heart rate during sedation, the heart rate dropped below the normal range published for age in only 15 (1.4%) patients. Of the 646 (59%) patients who had a >20% decrease in BP during sedation, the systolic BP dropped below the normal range for age in 396 (36.2%) patients.

A total of 167 adverse events occurred in 118 patients, or 10.8% of the population (Table 3). Forty-three patients experienced 2 adverse events, and 3 patients experienced 3 adverse events. There were no aspiration events, significant arrhythmias, permanent morbidity, or death. Of patients who experienced an adverse event, 82 (7.5% of the total population) experienced an event that required at least 1 minor or major intervention (Table 4). Minor interventions were required in 92.6% and major interventions were required in 7.4% of patients who experienced an adverse event that required intervention. The remaining 36 patients had an adverse event that resolved without intervention.

Five (<0.5% of the total population) patients experienced adverse events that required major interventions (Table 5). None of the patients had a baseline oxygen requirement. One patient developed apnea, hypoxia, and bradycardia that responded to several seconds of bag-mask ventilation. Two other patients developed hypotension with decreased perfusion that resolved with stimulation and administration of normal saline. Another child experienced hypoxia, hypotension, and pro-

TABLE 2 Hemodynamic Responses

	Maximum Percentage Decrease	≥20% Decrease, n (%)	≥20% Decrease and Abnormal Value, n (%)
Heart rate	14 ± 10	266 (24)	15 (1.4)
BP	23 ± 13	646 (59)	396 (36.2)

TABLE 3 Adverse Events (n = 167)

	n (%)
Apnea	3 (0.3)
Airway obstruction	15 (1.4)
Desaturation	65 (5.9)
Hypercarbia	40/603 (6.6)
Hypotension with poor perfusion	4 (0.4)
Vomiting	4 (0.4)
Prolonged sedation	36 (3.3)

longed sedation, which responded to supplemental oxygen and stimulation. This child was hospitalized overnight for observation. A patient with significantly depressed cardiac function experienced respiratory depression, hypoxia, and hypotension. The patient was intubated, received an intravenous fluid bolus, and was hospitalized overnight in the intensive care unit. He was discharged from the hospital the next day.

Potential risk factors were assessed for their association with adverse events as listed in Table 6. Univariate analysis identified age younger than 6 months, cyanotic heart disease, and hospitalization at the time of the study as significant risk factors. Multivariate analysis identified only age younger than 6 months as a significant independent risk factor for the occurrence of an adverse event.

DISCUSSION

This is the first study to establish expected physiologic responses for potentially high-risk patients who undergo sedation for echocardiography. In addition, we were able to demonstrate that only minor interventions were required for the vast majority of the time in response to an adverse event. Last, with the exception of age, we illustrated the difficulty of predicting which patients were at risk for adverse events.

Physiologic Responses

Recognizing alterations in physiologic parameters that may or may not be indicators of impending or ongoing complications during sedation is an essential role of the practitioner. Thus, it is important to be able to distinguish appropriate physiologic responses to sedation from clinically relevant events when determining whether an intervention is warranted for a patient who is receiving sedation.

The existence of nocturnal decreases in heart rate and BP has been studied in children.[14–19] Using ambulatory BP monitoring, Soergel et al[16] demonstrated that in healthy children, mean nocturnal systolic and diastolic BPs were 13% ± 6% and 23% ± 9% lower than diurnal means, respectively. The widespread occurrence of nocturnal decreases in BP leads to the development of separate pediatric reference values for daytime and nighttime BPs.[16] This BP variability has been attributed in part

to factors such as physical activity, emotions, sympathetic and parasympathetic activity, and internal circadian rhythms.[17–19] However, normative BP data for pediatrics are based on resting daytime measurements.[12] We speculate that although hypotension is a side effect of certain sedative medications and that fasting states in young children can cause alterations in these physiologic parameters, parameters that are measured during sedation are similar to those during sleep.

We demonstrated that alterations in heart rate and BP that are outside the published normal ranges for nonsedated patients occur commonly in sedated children. However, we found that the incidence of clinical deterioration that is associated with these alterations was very low. Twenty-four percent of patients exhibited a >20% decrease from baseline heart rate, although only 1.7% developed a heart rate below the normal range for age. No patient required intervention for isolated bradycardia. Decreases in systolic BP were common, with 59% of patients developing and tolerating a >20% decrease from baseline BP and 36% developing a systolic BP below the normal range. It is important to realize that low BP was transient and self-resolving in the majority of patients. Only 4 of these patients showed signs of compromised perfusion, all of whom responded to tactile stimulation and/or fluid administration. It is possible that these alterations may be more pronounced in a population with cardiac disease. Previous studies in other settings either do not mention or have reported much lower incidences of sustained bradycardia (0–0.2%) and hypotension (0–12.9%).[20–30] However, variations in definitions of bradycardia and hypotension, in monitoring techniques, and in frequency of recorded vital signs may influence reporting. For example, a similar study[23] that described the safety and the efficacy of chloral hydrate sedation in 405 children who underwent echocardiography reported that no child had a "clinically significant" change in heart rate or BP during the study. Differences in heart rate were attributed to relatively high heart rates in fasted, anxious, awake children and more normal heart rates in sleeping, calm children. However, because BPs were measured only before and

TABLE 5 Patients With Adverse Events That Required Major Interventions.

Patient Characteristics	Daily Medications	Sedation Medication	Adverse Events	Interventions	Possible Risk Factors	Disposition
1. 3-wk-old boy; outpatient diagnosis ASD/PDA; npo: 6.25 h; ASA class 2	None	Chloral hydrate: 60 mg/kg	Apnea, bradycardia	Stimulation, bag-mask ventilation	Age <6 mo	Discharged home
2. 32-mo-old girl; inpatient diagnosis: TOF/AVSD repair, trisomy 21, GERD, asthma; npo: 5 h; ASA class 2	Digoxin, furosemide, captopril, ranitidine, fluticasone, salmeterol	Chloral hydrate: 80 mg/kg	Hypotension	Stimulation, fluid bolus	Hospitalized	Study aborted; returned to inpatient floor
3. 14-mo-old boy; inpatient diagnosis: PA/VSD repair, GERD, recent fever; npo: 1.5 h; ASA class 3	Digoxin, furosemide, Aldactone, methadone, diazepam, ranitidine	Chloral hydrate: 80 mg/kg	Hypotension	Fluid bolus	Hospitalized, ASA class, fasting time	Returned to inpatient floor
4. 2-wk-old boy; inpatient diagnosis: DORV/MS, CoA repair/PA band; npo: 6.25 h; ASA class 3	Furosemide, amoxicillin	Chloral hydrate: 60 mg/kg ×2 = 120 mg/kg	Desaturation, hypotension	Stimulation, blow-by O_2	Age <6 mo, cyanosis, hospitalized, ASA class, additional sedation	Returned to inpatient floor; required 1 additional hospital day
5. 2-mo-old boy; inpatient diagnosis: CoA/ventricular dysfunction; bacteremia; npo: 6.5 h; ASA class 4	Digoxin, furosemide, Aldactone, captopril, methadone, diazepam	Chloral hydrate: 80 mg/kg	Desaturation, hypotension, prolonged sedation	Stimulation, intubation, fluid bolus	Age <6 mo, hospitalized, ASA class	Transferred to the ICU for <24 h; required 1 additional hospital day

ASD indicates atrial septal defect; PDA, patent ductus arteriosus; npo, nil per os; TOF, tetralogy of Fallot; AVSD, atrioventricular septal defect; GERD, gastroesophageal reflux disease; PA/VSD, pulmonary atresia/ventricular septal defect; DORV, double outlet right ventricle; MS, mitral stenosis; CoA, coarctation of the aorta; PA, pulmonary artery.

TABLE 6	Risk Factors	
	Univariate P	Multivariate P
Age <6 mo	<.01	<.01
Cyanosis	<.01	.07
Hospitalization	<.02	.15
ASA class	.11	
Fasting time	.36	
Baseline oxygen requirement	.11	
Use of additional sedation	.44	

after the sedation, it is not known whether these patients experienced changes in BP or heart rate during sedation.

It is very important to be cognizant of the physiologic responses that occur in response to sedation, because these responses have an impact on the hemodynamic assessments that are obtained during echocardiography. These assessments are highly dependent on the child's physiologic state as a result of changes in heart rate, BP, stroke volume, and cardiac output and can vary significantly among a sedated infant, an alert child, and an anxious teenager. Previous literature has reported the importance of sedation when measuring pressure gradients by Doppler echocardiography.[31] We suspect that sedated patients in the echocardiography laboratory may be in a condition more similar to the sedated or anesthetized patient in the cardiac catheterization laboratory. Thus, for achieving accurate data, it is important to report systemic BP during sedation at the time when Doppler estimated pressure gradients are being measured.

Adverse Events and Risk Factors

Concern regarding the safety of pediatric procedural sedation and analgesia that are administered by nonanesthesiologists has led to the development of guidelines by the AAP, the ASA, and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO).[8,32,33] Previous studies have reported experiences with these guidelines, which vary by sample size, clinical setting, patient population, specific sedatives and analgesics used, monitoring techniques, experience of the administering medical personnel, and reporting techniques. Thus, adverse event rates for procedural sedation range from 0% to 20.1%.[20–23,25–27,29–30,34–40] One study demonstrated the safety and the efficacy of sedation in 405 children who underwent echocardiography.[31] Adverse events included oxygen desaturation (6%), vomiting (6%), and paradoxic agitation (1.9%). Our study in a similar but larger population reaffirms the safety of sedation in this clinical setting.

Despite the intrinsically high-risk nature of a young cardiac population, 89% of patients did not experience an adverse event during chloral hydrate sedation. In addition, the vast majority of adverse events were of only minor significance. Only 7.5% of patients who experienced an adverse event required a minor inter-

vention. However, patients could have progressed to more serious complications if correct and timely interventions had not been performed, stressing the importance of well-trained health care personnel, appropriate available equipment, and immediate availability of physician support.

Five patients experienced adverse events that required major interventions, which were performed in response to severe respiratory depression and/or hypotension with compromised perfusion. These cases were reviewed for continuing quality improvement. Two of the 5 cases that required major interventions were identified as potentially preventable. One patient had received a total dose of chloral hydrate that exceeded 100 mg/kg. Another patient had received enalapril and methadone just before sedation, which presumably contributed to the development of hypoxia, hypotension with poor perfusion, and prolonged sedation. In retrospect, this patient was not an appropriate candidate for sedation. Although human error is unavoidable, continual review of such cases has prompted modifications in our protocol in an effort to prevent similar events.

Statistical analysis of the entire study population identified age younger than 6 months, cyanotic heart disease, and hospitalization at the time of the study as significant risk factors for adverse events. However, multivariate analysis identified only children who were younger than 6 months to be at higher risk for such complications. It is interesting that ASA class, fasting times, baseline supplemental oxygen as a surrogate marker for significant underlying respiratory disease or cyanosis, and use of additional sedation were not statistically important risk factors.

The ASA classification is a non–peer-reviewed standard that is intended for adult patients who undergo general anesthesia. Recently, this classification system has been endorsed by the JCAHO for adoption into many pediatric hospital sedation policies. Previous authors, including the ASA, have questioned its applicability to the clinical setting secondary to its vague description that relies heavily on individual interpretation. In fact, the ASA does not endorse the use of this system for sedation policies, as it is not intended as a tool for risk stratification.[41] Our study suggests that this classification system may not be useful for identifying high-risk patients for chloral hydrate sedation for echocardiography.

The optimal fasting time before sedation continues to be a controversial subject. Although the evaluation of fasting times was not a primary focus of this study, it is interesting that the duration of fasting times failed to predict adverse events. This is consistent with previous work, including a study from our laboratory, demonstrating that the duration of fasting does not correlate with improved outcomes and that longer fasting times can even preclude the ability to sedate the patient adequately.[22,42–44] However, on the basis of experience from

procedures that were performed in an emergency department setting, limited evidence suggests that aspiration is more common in emergency procedures and nonfasted patients.[22,43] Thus, one must be careful when analyzing the risks and benefits of optimal fasting times until more comprehensive studies can be performed.

A baseline oxygen requirement also failed to predict adverse events. There is a paucity of literature for the use of an oxygen requirement as a surrogate marker for disease severity. Our data suggest that patients with a stable oxygen requirement do not pose additional risk. Most of these patients were hospitalized, were receiving oxygen for cyanosis and/or pulmonary disease, and had been observed closely for significant periods of time before sedation.

Use of oral midazolam or oral diphenhydramine in addition to chloral hydrate did not predict adverse events in our study. This is contrary to most of the existing literature. However, other study populations typically involved older children who were treated in an emergency department setting for painful procedures that required analgesia as well. A sedative or anxiolytic administered with an opioid is the combination that has been found to be more likely to result in adverse events.[45] In addition, most of the complications in these studies occurred in patients who received ≥3 medications.[43]

Previous literature has documented the importance of proper monitoring during pediatric sedation.[8,32] Children with chronic illnesses such as heart disease are reported to be at higher risk for sedation-related adverse events. Our study demonstrates that this group of patients can be sedated safely with chloral hydrate by cardiologists and personnel who are experienced in the care of this population, using a sedation protocol derived from the current guidelines developed by the AAP, the ASA, and the JCAHO.[8,32,33]

Limitations

Although this study is limited by its retrospective nature, the study design accurately reflects the daily activity of our echocardiography laboratory. Data relied on appropriate documentation, and incomplete records were excluded. No records were kept of patients who were potential candidates but did not receive sedation on the basis of the clinical judgment of the cardiologist or for those whose parents refused sedation. This policy likely may have prevented significant adverse events in patients who were judged to be high risk, thus introducing potential bias regarding the adverse event and intervention rates reported in this study. It is important to recognize that this study was performed at a large tertiary children's hospital within the confines of the echocardiography laboratory in a subspecialty population that was younger than 3 years. In addition, patients were monitored extensively during the sedation process, and by nature of the test, we had continuous visualization of the heart and electrocardiogram. Essentially all patients were sedated using chloral hydrate. Our conclusions concerning safety cannot be extrapolated to other locations or to the use of other drugs in this patient population. Physiologic responses, adverse events, and interventions were not always independent of each other, although for the purposes of the study were reported individually. Finally, postdischarge complications were not followed or documented formally. However, no patient was evaluated in the emergency department or readmitted to the hospital after sedation, and there were no reported late complications in the hospitalized patients. Postsedation follow-up at 72 hours has been implemented via telephone contact as part of our sedation protocol since the time of this study.

CONCLUSIONS

Although physiologic variations during a sleeping state have been documented, variations that occur in response to sedation have not been defined similarly. In this study, we have shown that decreases in heart rate and BP below published normal ranges for age often occur in the absence of clinical deterioration in our population and rarely require intervention. Such variations should not be considered sedation-related complications. However, these variations should alert the sedation staff as being possible early indicators of potential serious adverse events. Thus, frequent and close observation of a patient's vital signs and clinical status is important for identifying potential complications. Serious adverse events are uncommon, and our sedation protocol using appropriately trained personnel and proper equipment has allowed us to perform echocardiograms safely. Regular case review of adverse events is important for preventing similar events in the future. In addition, patients who are younger than 6 months should receive special consideration during risk assessment for chloral hydrate sedation in the echocardiography laboratory.

REFERENCES

1. Zellers TM, Zehr R, Weinstein E, Leonard S, Ring WS, Nikaidoh H. Two dimensional and Doppler echocardiography alone can adequately define preoperative anatomy and hemodynamic status before repair of complete atrioventricular septal defect in infants < 1 year old. *J Am Coll Cardiol.* 1995;24:574–575
2. Minich L, Snider AR, Bove EL, Lupinetti FM, Vermilion RP. Echocardiographic evaluation of atrioventricular orifice anatomy in children with atrioventricular septal defect. *J Am Coll Cardiol.* 1992;19:149–153
3. Levine JC, Geva T. Echocardiographic assessment of common atrioventricular canal. *Prog Pediatr Cardiol.* 1999;10:137–151
4. Need LR, Powell AJ, del Nido P, Geva T. Coronary echocardiography in tetralogy of Fallot: diagnostic accuracy resource utilization and surgical implications over 13 years. *J Am Coll Cardiol.* 2000;36:1371–1377
5. Pasquini L, Sanders SP, Parness IA, et al. Coronary echocardiography in 406 patients with d-loop transposition of the great arteries. *J Am Coll Cardiol.* 1994;24:763–768
6. Silverman NH. *Pediatric Echocardiography.* Baltimore, MD: Williams & Wilkins; 1993:1

7. Snider AR, Serwer GA, Ritter SB. *Echocardiography in Pediatric Heart Disease*. 2nd ed. St Louis, MO: Mosby-Year Book, Inc; 1997:23

8. 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;89:1110–1115

9. Saklad M. Grading of patients for surgical procedures. *Anesthesiology*. 1941;2:281–284

10. Aldrete JA. The post-anesthesia recovery score revisited. *J Clin Anesth*. 1995;7:89–91

11. Zaritsky AL, Nadkarni VM, Hickey RW, et al, eds. *PALS Provider Manual*. Dallas, TX: American Heart Association and American Academy of Pediatrics; 2002:33–35

12. National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents. Update on the 1987 Task Force Report on High Blood Pressure in Children and Adolescents: a working group report from the National High Blood Pressure Education Program. *Pediatrics*. 1996;98:649–658

13. Martin TW, Stoner JM. *The Pediatric Patient in Clinical Anesthesia Practice*. 2nd ed. Philadelphia, PA: WB Saunders Co; 2002:1089–1125

14. Portman RJ. While you were sleeping. *J Pediatr*. 2003;142:93–95

15. Gellermann J, Kraft S, Ehrich JHH. Twenty-four-hour ambulatory blood pressure monitoring in young children. *Pediatr Nephrol*. 1997;11:707–710

16. Soergel M, Kirschstein M, Busch C, et al. Oscillometric twenty-four-hour ambulatory blood pressure values in healthy children and adolescents: a multicenter trial including 1141 subjects. *J Pediatr*. 1997;130:178–184

17. Profant J, Dimsdale JE. Race and diurnal blood pressure patterns. A review and meta-analysis. *Hypertension*. 1999;33:1109–1104

18. Khoury AF, Sunderajan P, Kaplan NM. The early morning rise in blood pressure is related mainly to ambulation. *Am J Hypertens*. 1992;5(pt 1):339–344

19. Pickering TG. *Ambulatory Monitoring and Blood Pressure Variability*. London, United Kingdom: Science Press Ltd; 1991:5.1–5.15

20. Lowrie L, Weiss AH, Lacombe C. The pediatric sedation unit: a mechanism for pediatric sedation. *Pediatrics*. 1998;102(3). Available at: www.pediatrics.org/cgi/content/full/102/3/e30

21. Pitetti RD, Singh S, Pierce MC. Safe and efficacious use of procedural sedation and analgesia by nonanesthesiologists in a pediatric emergency department. *Arch Pediatr Adolesc Med*. 2003;157:1090–1096

22. Agrawal D, Manzi SF, Gupta R, Krauss B. Preprocedural fasting state and adverse events in children undergoing procedural sedation and analgesia in a pediatric emergency department. *Ann Emerg Med*. 2003;42:636–646

23. Malviya S, Voepel-Lewis T, Tait AR. Adverse events and risk factors associated with the sedation of children by nonanesthesiologists. *Anesth Analg*. 1997;85:1207–1213

24. Myers GR, Maestrello CL, Mourino AP, Best AM. Effect of submucosal midazolam on behavior and physiologic response when combined with oral chloral hydrate and nitrous oxide sedation. *Pediatr Dent*. 2004;26:37–43

25. Pena BMG, Krauss B. Adverse events of procedural sedation and analgesia in a pediatric emergency department. *Ann Emerg Med*. 1999;34:483–491

26. Barbi E, Gerarduzzi T, Marchetti F, et al. Deep sedation with propofol by nonanesthesiologists. *Arch Pediatr Adolesc Med*. 2003;157:1097–1103

27. Wheeler DS, Jensen RA, Poss WB. A randomized, blinded comparison of chloral hydrate and midazolam sedation in children undergoing echocardiography. *Clin Pediatr (Phila)*. 2001;40:381–387

28. D'Agostino J, Terndrup TE. Chloral hydrate versus midazolam for sedation of children for neuroimaging: a randomized clinical trial. *Pediatr Emerg Care*. 2000;16:1–4

29. Mehta UC, Patel I, Castello FV. EEG sedation for children with autism. *J Dev Behav Pediatr*. 2004;25:102–104

30. Napoli KL, Ingall CG, Martin GR. Safety and efficacy of chloral hydrate sedation in children undergoing echocardiography. *J Pediatr*. 1996;129:287–291

31. Stevenson JG, Kawabori I, French JW. Doppler pressure gradient estimation in children. Accuracy, effect of activity and exercise, and the need for sedation during examination. *Acta Paediatr Scand Suppl*. 1986;329:78–86

32. An updated report by the American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-anesthesiologists. Practice guidelines for sedation and analgesia by nonanesthesiologists. *Anesthesiology*. 2002;96:1004–1017

33. Joint Commission on Accreditation of Healthcare Organizations. *Comprehensive Accreditation Manual for Hospitals: The Official Handbook. Sedation and Anesthesia Care Standards*. Oakbrook Terrace, IL: Joint Commission on Accreditation of Healthcare Organizations; 1997

34. Malviya S, Voepel-Lewis T, Prochaska G, Tait AR. Prolonged recovery and delayed side effects of sedation for diagnostic imaging studies in children. *Pediatrics*. 2000;105(3). Available at: www.pediatrics.org/cgi/content/full/105/3/e42

35. Olson DM, Sheehan MG, Thompson W, Hall PT, Hahn J. Sedation of children for electroencephalograms. *Pediatrics*. 2001;108:163–165

36. Egelhoff JC, Ball WS, Koch BL, Parks TD. Safety and efficacy of sedation in children using a structured sedation program. *AJR Am J Roentgenol*. 1997;168:1259–1262

37. Mason KP, Sanborn P, Zurakowski D, et al. Superiority of pentobarbital for sedation in infants during imaging. *Radiology*. 2004;230:537–542

38. Meyer S, Aliani S, Graf N, Reinhard H, Gottschling S. Sedation with midazolam and ketamine for invasive procedures in children with malignancies and hematological disorders: a prospective study with reference to the sympathomimetic properties of ketamine. *Pediatr Hematol Oncol*. 2003;20:291–301

39. Guenther E, Pribble CG, Junkins EP Jr, Kadish HA, Bassett KE, Nelson DS. Propofol sedation by emergency physicians for elective pediatric outpatient procedures. *Ann Emerg Med*. 2003;42:783–791

40. Okutan V, Lenk MK, Sarici SU, Dundaroz R, Akin R, Gokcay E. Efficacy and safety of rectal thiopental sedation in outpatient echocardiographic examination of children. *Acta Paediatr*. 2000;89:1340–1343

41. Lema MJ. Using the ASA Physical Status Classification may be risky business. *ASA Newslett*. 2002;66(9):1–2

42. Ghaffar S, Haverland C, Ramaciotti C, Scott WA, Lemler MS. Sedation for pediatric echocardiography: evaluation of preprocedure fasting guidelines. *J Am Soc Echocardiogr*. 2002;15:980–983

43. Roback MG, Bajaj L, Wathen JE, Bothner J. Preprocedural fasting and adverse events in procedural sedation and analgesia in a pediatric emergency department: are they related? *Ann Emerg Med*. 2004;44:454–459

44. Hoffman GM, Nowakowski R, Troshynski TJ, Berens RJ, Weisman SJ. Risk reduction in pediatric procedural sedation by application of an American Academy of Pediatrics/American Society of Anesthesiologists process model. *Pediatrics*. 2002;109:236–243

45. Cote CJ, Karl HW, Notterman DA, Weinberg JA, McCloskey C. Adverse sedation events in pediatrics: analysis of medications used for sedation. *Pediatrics*. 2000;106:633–634

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Responses, Adverse Events, and Risk Factors

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