Sedation and anesthesia for magnetic resonance imaging in pediatric patients: is dexmedetomidine the answer?

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Pediatric anesthesia; Sedation; Magnetic resonance imaging; Dexmedetomidine

We reviewed the current state of knowledge regarding pediatric sedation mainly for nonpainful procedures, such as MRI studies. The increasing number of requests for pediatric sedation has triggered intense research for finding various solutions that would enable the safe administration of sedation by nonanesthesiologist physicians, supervised trained nursing personnel (CRNAs and/or RNs), or sedation teams combining different provider types. We also reviewed the current data on the use of dexmedetomidine in children, as a sedative agent in the MRI suite. Dexmedetomidine is an excellent sedative, has analgesic properties, and appears to be clinically safe from a respiratory point of view even at high doses, although instances of bradycardia and hypotension have been reported. Dexmedetomidine appears to be a promising option for sedation in the pediatric population in the MRI setting.

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The indications for magnetic resonance imaging (MRI) have increased steadily over the years. In 2004, the National Electrical Manufacturers Association (NEMA,http://www.NEMA.org) estimated that 9704 MRI units were available in the US. This large number of available MRI machines has made it easier to refer patients for diagnostic scans, and the requests are continuously increasing in number. At Children’s Medical Center at Dallas, Texas, the number of requests for anesthesia/sedation for MRI has increased over 200% in the last 2 years (from 1078 cases in 2005 to 2557 cases in 2006). In other centers with long-standing sedation services, the increase is not so impressive.1 Whereas both the number of MRI units and the number of MRI exams have increased in recent years, some of the technological constraints have remained the same.

For the MRI study to be successful, patients have to remain still inside a hollow, noisy, and cold tube within the machine. Patients who require sedation/anesthesia for an MRI scan consist of two groups: a small number of adults (due to claustrophobia, back pain, tremor, etc.)2 and the majority of pediatric patients. For MRI patients receiving sedation, the pediatric population represents the subgroup with the highest risk and the lowest error tolerance, especially when care is provided by inexperienced sedation providers.3,4

The goal of this article is to review the current knowl-
edge in the field of MRI pediatric sedation, inclusive of a promising new drug: dexmedetomidine.

Sedation/anesthesia providers for MRI scans

Historically, pediatric radiologists have administered their own sedation using relaxation techniques or medications such as chloral hydrate. Other sedation medications, such as phenobarbital, fentanyl, midazolam, and ketamine, have also been used by both sedation-trained nurses and physicians. However, when traditional sedation techniques have failed, pediatric anesthesiologists have been consulted and have become more involved in providing sedation/anesthesia for radiological studies, as well as in developing sedation and anesthesia protocols for infants.

During the past two decades, the involvement of anesthesiologists in the MRI suite has evolved into a distinct anesthesia subspecialty that has a unique skill set, a growing number of indications, and expanding practice locations.

However, in centers where anesthesiologists are not readily available, some sedation services are directed by trained nursing personnel. Others have developed the concept of a sedation room or a sedation team combining different provider types.

Conflicting sedation guidelines and medicolegal aspects

British guidelines disagree with the use of deep sedation by non-anesthesiologists, but these guidelines mainly refer to the adult sedation. Despite this, and without reference to pediatric opinion, the Royal College of Surgeons of Edinburgh in 1993 stated: “Intravenous sedation is hazardous in children as the therapeutic margin between sedation and anesthesia is very narrow. In view of this, sedation should be administered only under very special circumstances.”

The report of the National Confidential Enquiry into Perioperative Deaths (NCEPOD) in 2000 provided evidence for sedation problems in radiology in the UK. This report stated that the gold standard monitoring during interventional vascular procedures should include pulse oximetry, blood pressure measurements, and electrocardiography. In addition, someone other than the radiologist should be responsible for monitoring the patient during the procedure. A total of 303 deaths were identified during the period surveyed. Of the patients that died, 19 were not monitored at all, 60 did not have pulse oximetry monitoring, and 40 did not have their blood pressure measured. Sixteen patients died while being monitored by a radiography technician, and 97 died while being monitored by the interventional radiologist alone.

British pediatric anesthesiologists are opponents of deep sedation by non-anesthesiologists, but do not have objective evidence to unequivocally support their position.

Nevertheless, whereas it is impossible for anesthesiologists to provide sedation for all radiological studies and imaging procedures, it is possible for anesthesiologists to have a key advisory role in establishing the safeguards and protocols that would ensure individual and public safety.

In a recent controversy regarding sedation versus general anesthesia for MRI in children, Bray and Davis and coworkers argued that general anesthesia is safer and more reliable for management of children undergoing MRI scanning, even though deep sedation may possibly produce satisfactory conditions for the scanning. In this paper they state: “Just because something is possible does not mean that it is best practice, and that is what we should be providing for our children.”

From a complications standpoint, it is not known whether general anesthesia or deep sedation for MRI scans are equal in safety, or if one is superior to the other. Lawson and Sury and coworkers argue in favor of allowing deep sedation for MRI and other procedures (providing that the existing guidelines are implemented) until a national British inquiry will determine the relative risk of deep sedation versus general anesthesia.

In the US, pediatric guidelines were published by the American Academy of Pediatrics in 1985 and revised in 1992. These guidelines state that deep sedation in children is an acceptable end point and that it is not mandatory that deep sedation be supervised by an anesthesiologist. These conclusions were reinforced by the Joint Commission on Accreditation of Healthcare Organization’s recommendations that went into effect on January 1, 2001 and emphasized the need for adequate patient observation and monitoring. The Joint Commission also pointed out the crucial importance of acquisition of appropriate skills by the providers of sedation, including skills in rescuing the patient whenever it becomes necessary.

Contrary to these recommendations, Freeman and Vining contend that sedation alone for a nonpainful procedure such as an electroencephalogram (or MRI) is inherently safe, and that the use of chloral hydrate alone in such cases does not warrant any monitoring or attendance by qualified medical personnel. They justify their stand on the grounds that it is fiscally unsound to subsidize a nurse to monitor each child and that cost is always a consideration. While accentuating the need for enhanced safety of sedated children, Malvy and coworkers argue that it is morally irresponsible not to monitor each child and, if this cannot be done in a certain institution, it is ethical to advise the patients and their families to undergo the procedure elsewhere.

Sedation/anesthesia and safety

During the last 15 years, a series of studies showed a wide range of serious adverse events to sedation, including upper airway obstruction, hypoxemia, and even death. And al-
though this is troubling, it is difficult to assess the safety of sedation practice even with prospective studies. The majority of available studies are underpowered and performed on a relatively small number of patients (200-300).\textsuperscript{5,32-37} In addition, these studies were designed mainly to follow serious adverse events (severe hypoxemia, neurologic injury, etc.) and lacked the ability to estimate the frequency of critical incidents.\textsuperscript{37} Considering that the likely incidence of a sedation-induced crisis is around 1/10,000, it is not surprising that these studies rarely uncover a critical event.

At present, there is only one large multicenter study\textsuperscript{37} that has addressed the issues concerning adverse outcomes during sedation. Clearly, more large-scale investigations are needed in this regard. It may be that new methods of evaluation of the impact of hypoxemic events are required in order to understand their importance.

One of the most often quoted studies looking at the safety of sedation practice was published by Cote and coworkers in 2000.\textsuperscript{3,4} Using critical incident analysis of a database that consists of descriptions of adverse sedation events derived from FDA’s adverse drug reporting system, the authors examined the factors that contributed to adverse sedation events in children undergoing procedures outside of the operating room.

Spread over 27 years, this database included 95 incidents from which 51 resulted in death, 9 in permanent neurologic injury, and 21 in prolonged hospital stay. Of the 95 fatalities, 15 (15.8\%) patients were sedated in the radiology department, with 11 (73\%) patients sustaining permanent neurologic injury or death and 4 (27\%) being hospitalized for long periods of time. These findings emphasize that sedation events can lead to devastating injuries that are largely preventable with adequate monitoring, skilled providers, and proper patient selection.

Other studies\textsuperscript{5,32-37} of sedation in children examined prospectively the incidence of hypoxemia and the need for airway interventions (Table 1). Taking into account that the oxyhemoglobin desaturation definition was not uniformly defined (desaturation was defined as a SpO2 between 90\% and 95\%), the incidence of desaturation ranged from 1.1\% to 5.3\%.

Chloral hydrate is one of the sedation agents most frequently employed by non-anesthesiologists and has led to multiple studies regarding its safety related to hypoxemia. In the great majority of cases, there is no significant respiratory depression; however, with increasing depth of sedation, airway obstruction followed by hypoxemia can occur.\textsuperscript{38}

A study on 295 children who received chloral hydrate for 326 computer tomography (CT) scans reported a 1.2\% incidence of untoward respiratory events, including wheezing in 1 child, aspiration of secretions in another, and 2 incidents of airway obstruction that required endotracheal intubation.\textsuperscript{32}

The same authors evaluated the use of chloral hydrate for 300 MRI scans, and then reported a 4\% incidence of hypoxemia that required intervention.\textsuperscript{6}

Other authors, Pereira and coworkers,\textsuperscript{33} had sedated 110 children with chloral hydrate to facilitate CT scans and found a 3.6\% incidence of hypoxia. Repositioning of the head, supplemental oxygen administration, and/or suctioning of the airway were frequently required.

Malvyia and coworkers\textsuperscript{34} reported a 5.3\% incidence of significant oxyhemoglobin desaturation (≤90\% of baseline) in 854 children who received chloral hydrate alone (mean dose: 65 mg/kg) for non-painful procedures. Similarly, supplemental oxygen, repositioning of the airway, stimulation, and bag and mask ventilation were necessary.

Other investigators have reviewed adverse events encountered in their institutional practice. Pena and coworkers\textsuperscript{35} prospectively evaluated sedation safety in 1180 patients using a single venue (emergency department), and most recently, Sanborn and coworkers\textsuperscript{36} investigated 16,467 patients who underwent radiology procedures. Each of these studies came from a single institution and focused on a limited number of procedure types. Although none of the children in these studies experienced any permanent sequelae, it is likely that such sequelae were averted by vigilant monitoring that permitted early detection of hypoxemia and appropriate intervention.

To allow a more comprehensive approach to the study of the safety and the reliability of pediatric sedation, a group of

### Table 1: Incidence of hypoxia and airway interventions on pediatric sedation studies for noninvasive procedural sedation in pediatric patients

<table>
<thead>
<tr>
<th>Author and reference no.</th>
<th>Year</th>
<th>No. of patients</th>
<th>Anesthesia/sedation used</th>
<th>Hypoxia (%)</th>
<th>Airway interventions</th>
<th>Radiology suite (MRI, CT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malvyia S et al\textsuperscript{35}</td>
<td>1997</td>
<td>854</td>
<td>CH, PB, F, M, K</td>
<td>5.3</td>
<td>Yes</td>
<td>Emergency room</td>
</tr>
<tr>
<td>Pena BM et al\textsuperscript{36}</td>
<td>1999</td>
<td>1180</td>
<td>Yes, Yes, —, —, —</td>
<td>1.1</td>
<td>Yes</td>
<td>Emergency room</td>
</tr>
<tr>
<td>Sanborn PA et al\textsuperscript{37}</td>
<td>2005</td>
<td>16,467</td>
<td>Yes, Yes, Yes, Yes, —</td>
<td>0.3</td>
<td>Unknown</td>
<td>Emergency room</td>
</tr>
<tr>
<td>Craverio JP et al\textsuperscript{38}</td>
<td>2006</td>
<td>30,037</td>
<td>Yes, Yes, Yes, Yes, Yes</td>
<td>1.6</td>
<td>Yes (1/200 patients)</td>
<td>Emergency room</td>
</tr>
<tr>
<td>Greenberg SN et al\textsuperscript{35}</td>
<td>1991</td>
<td>32</td>
<td>Yes, —, —, —</td>
<td>Not available</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Greenberg SN et al\textsuperscript{35}</td>
<td>1993</td>
<td>300</td>
<td>—, —, —, —</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pereira JK et al\textsuperscript{34}</td>
<td>1993</td>
<td>110</td>
<td>Yes, —, —, —</td>
<td>3.6</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

CH, chloral hydrate; PB, pentobarbital; F, fentanyl; M, midazolam; K, ketamine.
35 institutions dedicated to improving sedation/anesthesia practice formed the Pediatric Sedation Research Consortium (PSRC). Data from 26 institutions on 30,037 sedation/anesthesia procedures were included within the study. Serious adverse events were rare in the institutions involved in this study; there were no deaths, and cardiopulmonary resuscitation was required once. Less serious events were more common with O2 desaturation below 90% for >30 seconds, occurring 157 times per 10,000 sedations. Stridor and laryngospasm both occurred in 4.3 per 10,000 sedations. Other associated airway complications including unexpected apnea, excessive secretions, and vomiting had frequencies of 24, 41.6, and 47.2 per 10,000 sedations, respectively. The authors concluded that pediatric sedation/anesthesia for procedures outside the operating room were unlikely to yield serious adverse outcomes in a collection of institutions with well-organized sedation services.

**Sedation failure rate**

Although the health-related complications are important, so is the sedation failure rate with conventional sedation methods. In spite of the large number of published studies, it is difficult to identify an accurate sedation failure rate. The reported rate of sedation failure ranges largely from 0.89% to 28%.6,34,35,37,39-46 (Table 2). The reasons for this large variability in the failure rates are multiple and include differences in the definition of sedation failure. In most studies, any sedation regimen that allows a procedure to be completed is counted as successful. According to this description, patients with complications (apnea, hypoxemia) or those moving during the scan will still be considered as “successfully” sedated if the scan was ultimately completed.

Although the global sedation failure rates are not known, it is documented that the skills of the sedation provider have a critical influence on the incidence of sedation failure. The lowest failure rate was reported (0.89%) by the PSRC study and occurred in a large group of patients from institutions with highly motivated and organized sedation services and with providers specialized in anesthesia care. These results have been echoed by other studies with demonstrated sedation failure rates that were decreased dramatically when sedation was provided by a dedicated team, by implementing clear protocols, or when anesthesiologists provide sedation. Support for these findings also came from Malviya and coworkers, who found that 12% of sedated patients required repeated scans due to motion artifacts as compared with 1% in the anesthetized patients. The highest incidence of sedation failure (28.6%) was reported by Malviya and coworkers in patients sedated by non-anesthesiologists. In those cases, procedures were often rescheduled, and the sedation for the subsequent scan was undertaken by an expert in anesthesia or sedation.

The incidence of sedation failures is also associated with the type of sedation agent and whether the agent is used alone or in combination with other medications. Malviya and coworkers found a higher failure rate (24%) with a multiple agent anxiolytic combination, as compared with a single agent such as chloral hydrate (4%) or a benzodiazepine (9%).

An ASA status III or IV was associated with more inadequate sedation as compared with children with ASA status I and II. In addition, more children with an ASA physical status III or IV experienced more respiratory events compared with children with an ASA physical status I or II (P < 0.0001).42

<table>
<thead>
<tr>
<th>Table 2 Sedation failure rate in pediatric sedation studies for painful and non-painful procedural sedation in pediatric patients</th>
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<tbody>
<tr>
<td><strong>Author and reference no.</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Karian VE et al39</td>
</tr>
<tr>
<td>Malviya S et al15</td>
</tr>
<tr>
<td>Greenberg SB et al40</td>
</tr>
<tr>
<td>Merola C et al40</td>
</tr>
<tr>
<td>Ruess L et al41</td>
</tr>
<tr>
<td>Malviya S et al42</td>
</tr>
<tr>
<td>Barst SM, et al43</td>
</tr>
<tr>
<td>Karian VE et al44</td>
</tr>
<tr>
<td>Cravero JP et al48</td>
</tr>
<tr>
<td>Crock C, et al55</td>
</tr>
<tr>
<td>Pena BM et al36</td>
</tr>
<tr>
<td>Law AK, et al46</td>
</tr>
</tbody>
</table>

CH, chloral hydrate; PB, pentobarbital; Op, opioid; Benz, benzodiazepine; K, ketamine; P, propofol.
Although any of the above reasons can lead to a sedation failure, the end result is the same; repeat scans lead to a significant increase in costs, due to lost time in the scanner, and to an increase in workload for the sedation providers.

Sedation regimens for children

Pediatric sedation regimens should ideally be customized for each patient and each specific scheduled procedure. First, the provider should consider whether the procedure is painful or not. Non-painful procedures, such as MRI, CT, or nuclear scans, are best accomplished with a rapid-acting, pure sedative agent such as propofol, which has a well-known safety profile, high efficacy, and smooth recovery characteristics. The advantages of propofol caused non-anesthesiologists to readily accept its use, despite airway management concerns regarding individuals who are not expertly trained to handle airway emergencies. Other agents (chloral hydrate, diazepam, midazolam, methohexital, pentobarbital, etomidate) have also been used within the setting of non-painful procedures. Alternatively, for painful procedures such as a bone marrow biopsy, procedures in emergency room (such as reduction of fractures) or burn scrubs, opiate analgesics such as fentanyl, morphine, remifentanil, or non-opiate analgesics such as ketamine are often added to the treatment regimen.

Second, patient factors influence the choice of sedative used for a given imaging study or procedure. For example, a patient with decreased ventricular function due to a cardiomyopathy may tolerate etomidate better than propofol for sedation. These patient factors may influence not only the type of sedation used, but also the person who is administering the sedation. Contraindications to sedation by non-anesthesiologists at our institution include the presence of a difficult airway, a mediastinal mass, or significant cardiac disease.

Finally, the skills and experience of the team members involved with monitoring and sedation delivery will affect the decision in favor of a certain sedation agent. Anesthesiologists accustomed with airway management can use any sedative agent such as propofol, which has a well-known safety profile, high efficacy, and smooth recovery characteristics. The advantages of propofol caused non-anesthesiologists to readily accept its use, despite airway management concerns regarding individuals who are not expertly trained to handle airway emergencies. Other agents (chloral hydrate, diazepam, midazolam, methohexital, pentobarbital, etomidate) have also been used within the setting of non-painful procedures. Alternatively, for painful procedures such as a bone marrow biopsy, procedures in emergency room (such as reduction of fractures) or burn scrubs, opiate analgesics such as fentanyl, morphine, remifentanil, or non-opiate analgesics such as ketamine are often added to the treatment regimen.

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Finally, the skills and experience of the team members involved with monitoring and sedation delivery will affect the decision in favor of a certain sedation agent. Anesthesiologists accustomed with airway management can use any sedatives, or analgesics alone, or a combination thereof. Recently, in the US, there is a clear trend of using more potent sedatives and hypnotics by non-anesthesiologists (physicians and nurses). Non-anesthesiologists, in the authors’ opinion, on the other hand, should probably use only drugs with a generally acceptable safety margin, and for which there is a known antagonist. For example, an excess administration of benzodiazepines can be countered with flumazenil, and an excess amount of narcotics can be treated with naloxone.

Another tool that can be employed by anesthesiologists is general anesthesia. In addition to sedation used by anesthesiologists, any procedure outside of the operating room can be performed under general anesthesia provided that essential anesthesia and resuscitation equipment is available. Crock and coworkers showed improved satisfaction and procedural conditions when general anesthesia was used instead of midazolam, for moderate sedation for painful oncology procedures (ie, bone marrow aspiration, lumbar puncture, etc.). General anesthesia, however, has the known disadvantages of increased cost and the concomitant need to allocate an anesthesiologist. However, recovery room and turnover times may be longer with general anesthesia compared with sedation, depending on how a service is structured.

Dexmedetomidine and the MRI suite

Anesthesiologists have successfully used both intravenous propofol for sedation and general anesthesia to aid in the completion of MRI studies. However, the quest for medications with a superior sedation and safety profile continues. Dexmedetomidine is an agent that has generated much interest in the literature and has great potential to become the sedative of choice for MRI scanning.

Dexmedetomidine is a centrally acting α2-agonist with a remarkable specificity for the receptor site: compared with clonidine, which exhibits α2/α1 ratio of 200:1, dexmedetomidine has an α2/α1 ratio of 1600:1. In addition, dexmedetomidine has a shorter half-life (2-3 hours) as compared with clonidine (12-24 hours). Along with its specificity and relatively short half-life, dexmedetomidine appears to have a larger safety index margin, which is due to its lack of propensity to cause central hypoventilation as routinely seen with other sedative medications.

Dexmedetomidine stands apart from other sedatives in that it appears to be clinically safe from a respiratory point of view, even when used in doses high enough to cause unresponsiveness. Dexmedetomidine maintains respiratory rate while slightly decreasing tidal volume. In the rare cases when respiratory problems do occur, they tend to be due to obstruction and not by central depressant effect, even at doses 10 times larger than recommended. This safe respiratory profile of dexmedetomidine makes it ideal for use in the spontaneously breathing patient, with or without a secured airway.

From the hemodynamic point of view, bolus administration of dexmedetomidine may lead to severe bradycardia and even asystole. Surprisingly, in 1 case series, 3 adult patients who received accidental overdoses of dexmedetomidine remained hemodynamically stable, with oversedation being the only untoward effect. In the pediatric literature, an accidental overdose of dexmedetomidine, in a 3-year-old child, resulted from a malfunctioning infusion pump that delivered dexmedetomidine at a dose 60 times higher than recommended, resulting in slight hypertension and extended somnolence. A biphasic hemodynamic response (low, than high) for blood pressure and vascular resistance has been reported with larger doses of dexme-
Dexmedetomidine, resulting in systemic and pulmonary hypertension, increased sedation and analgesia without changes in respiration. Although there is the concern for bradycardia, especially in the pediatric population, Deutch and Tobias did not find this to be true in their study. The authors found no clinically significant hypotension or bradycardia with intraoperative administration of dexmedetomidine (0.5 µg/kg) during anesthesia at 1 minimum alveolar concentration with either desflurane or sevoflurane in 80 children, ranging in age from 1 to 12 years old.

Dexmedetomidine has analgesic properties, which combined with its potent sedative actions led investigators to use it as a sole anesthetic agent. Ramsay and Luterman successfully used dexmedetomidine in high doses (up to 10 µg/kg/hour) in three adult patients as a sole anesthetic for challenging airway operations. In the pediatric literature, dexmedetomidine has also been used as a sole anesthetic for direct laryngoscopy and bronchoscopy in a series of four infants (age 2 weeks to 11 months). The anesthesia was successful, except that one patient required an additional dose of propofol. Not only do these articles show how dexmedetomidine can be used as a lone general anesthetic, they also underscore the ability of dexmedetomidine to maintain respirations at even supraclinical doses.

Nevertheless, given its limited analgesic effects, dexmedetomidine may not be the ideal agent for painful procedures. Additional midazolam/ketamine, propofol, or ketamine alone were necessary for completion of these painful sedation procedures. The studies showing successful anesthesia/analgesia used much higher doses of dexmedetomidine than standard doses as compared with the cases where additional sedative/analgesics were needed.

The sedative quality of dexmedetomidine is what truly sets it apart from other sedation medications that have been used in the past. The interest in dexmedetomidine in the area of sedation is not without merit; the sedation provided by dexmedetomidine is more consistent with normal sleep patterns than other medications.

Dexmedetomidine has been approved for sedation within adult intensive care units (ICU) for durations of less than 24 hours. The use of dexmedetomidine in the pediatric ICU has also been described. Although the recommended dexmedetomidine dose range for sedation in the adult ICU patient is 0.2 to 0.7 µg/kg/hour, there tends to be a wide range of different doses for different applications. For sedation, the loading doses of dexmedetomidine range from 0.5 µg/kg over 5 minutes to 2 µg/kg over 10 minutes,67,68 and the typical subsequent infusion rate of dexmedetomidine ranges from 0.3 µg/kg/hour to 1 µg/kg/hour.68-70

The same sedation qualities that are used within the ICU setting have also led to dexmedetomidine’s popularity in the operating room, and in “off site” locations, such as MRI and CT, for sedation. Dexmedetomidine has been successfully used in the past. The interest in dexmedetomidine in the area of sedation is not without merit; the sedation provided by dexmedetomidine is more consistent with normal sleep patterns than other medications.

### Table 3: Studies and case reports of use of dexmedetomidine for noninvasive (non-painful) procedural sedation in pediatric patients

<table>
<thead>
<tr>
<th>Author and reference no.</th>
<th>No patients</th>
<th>Study type</th>
<th>Dex dose</th>
<th>Dex compared with other medications?</th>
<th>Additional meds needed?</th>
</tr>
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<tbody>
<tr>
<td>Cravero JP71</td>
<td>393</td>
<td>Prospective, non-randomized trial</td>
<td>Unspecified</td>
<td>no</td>
<td>unspecified</td>
</tr>
<tr>
<td>Koroglu A et al72</td>
<td>80</td>
<td>Prospective, randomized trial</td>
<td>1 µg/kg load over 10 minutes then an infusion at 0.5 µg/kg/hr</td>
<td>yes</td>
<td>no</td>
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<tr>
<td>Mason KP et al67</td>
<td>62</td>
<td>Prospective, open label trial</td>
<td>2 mcg/kg loading dose over 10 minutes, repeated PRN, then an infusion of 1 µg/kg/hr</td>
<td>no</td>
<td>yes, in 2 patients</td>
</tr>
<tr>
<td>Koroglu A et al70</td>
<td>60</td>
<td>Prospective, randomized trial</td>
<td>1 µg/kg load over 10 minutes then an infusion at 0.5 µg/kg/hr</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Berkenbosch JW et al74</td>
<td>48</td>
<td>Prospective, open label trial</td>
<td>0.5 µg/kg load over 5 minutes, repeated PRN, then an infusion was started that equaled the total loading dose</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Luscri N, Tobias JD72</td>
<td>3</td>
<td>Case series</td>
<td>1 µg/kg load then an infusion of 1 µg/kg/hr</td>
<td>no</td>
<td>yes, in one patient, yes, in 3/12 studies</td>
</tr>
<tr>
<td>Shukry M, Ramadhanyi U73</td>
<td>1</td>
<td>Case report</td>
<td>1 mcg/kg load then an infusion of 0.7–0.8 µg/kg/hr</td>
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<td></td>
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<tr>
<td>Young ET74</td>
<td>1</td>
<td>Case report</td>
<td>1 mcg/kg load then an infusion of 0.5 µg/kg/hr</td>
<td>no</td>
<td>Yes</td>
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<tr>
<td>Fahy SJ and Okumura M69</td>
<td>1</td>
<td>Case report</td>
<td>0.3–0.7 µg/kg/hr, then 1 mcg/kg load then an infusion that maxed out at 1.4 µg/kg/hr</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Kunisawa T and Iwasaki H75</td>
<td>1</td>
<td>Case report</td>
<td>1 µg/kg load then 0.7 µg/kg/hr</td>
<td>no</td>
<td></td>
</tr>
</tbody>
</table>

Dex, dexmedetomidine; meds, medications.
employed in children for sedation for non-invasive imaging studies. In these prospective trials, dexmedetomidine was given as a loading dose (range 0.5 μg/kg to 2 μg/kg) and then continued as an infusion (0.5 μg/kg/hour to 1 μg/kg/hour). To date, Koroglu and coworkers, in two studies in children, compared dexmedetomidine sedation with midazolam and with propofol with some mixed conclusions as to favoring one medication over another. The quality of sedation during radiological imaging was better, and the need for rescue sedation was less with dexmedetomidine compared with midazolam. When dexmedetomidine sedation was compared with propofol, the onset of sedation, recovery, and discharge times was significantly shorter with propofol. Although the “time” comparison is in favor of propofol, hypotension and oxygen desaturation were noted with propofol but not with dexmedetomidine.

Mason and coworkers found dexmedetomidine effective for sedation for CT scan in all but 2 of 62 children studied, whereas Berkenbosch and coworkers found it effective either after other agents had failed or as a primary agent for pediatric patients undergoing radiological imaging. From these data, it appears that dexmedetomidine as a sole agent is sufficient to produce adequate sedation for MRI scanning. The available prospective studies and case reports on use of dexmedetomidine for noninvasive procedural sedation are presented in Table 3.

Conclusion

In conclusion, we reviewed the current knowledge in pediatric sedation mainly employed for non-painful procedures. The increasing number of requests for pediatric sedation has triggered intense research for finding various solutions that enable the administration of sedation by non-anesthesiologist physicians, supervised trained nursing personnel (CRNAs and/or RNs), or sedation teams combining different provider types.

We also reviewed the current data on use of dexmedetomidine in children as a sedative agent in the MRI suite. Dexmedetomidine appears to be a promising option for sedation in this setting. In spite of its existing excellent safety record, further studies of recovery time, safety, and cost are imperative to conclude that this agent is suitable for extensive use in pediatric sedation for non-painful procedures in the radiology suite.

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