Procedural sedation and analgesia in children

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Providing relief from pain and anxiety associated with diagnostic and therapeutic procedures has become an ethical imperative in children, as well as a measured quality of care from the family perspective. This, along with a tremendous increase in the number of procedures performed in children outside the operating room, has placed an increasing demand for procedural sedation and analgesia (PSA) to be provided by nonanesthesiologists. Safe sedation for children requires a systematic approach with careful pre-sedation assessment and patient selection, appropriate physiologic monitoring during and after the procedure, clear understanding of the pharmacodynamics and pharmacokinetics of sedation medications that are used, and necessary skills to rescue the patient from sedation related adverse outcomes. In this article, we review the indications for PSA in children, the principles of providing safe and effective sedation, including pre-sedation assessment and monitoring during sedation, adverse events related to sedation and pharmacology of commonly used drugs for sedation. In addition, we also present the alternative and adjunctive nonpharmacologic approaches that can be used in children requiring PSA.

Keywords: adverse events, analgesia, children, monitoring, pre-sedation assessment, sedation

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Procedural sedation and analgesia (PSA) is defined as the use of sedative, analgesic and dissociative medications to overcome anxiety and pain, which allows a patient to tolerate unpleasant and painful procedures while maintaining cardiorespiratory function [1]. It is estimated that over a quarter of a million children will receive PSA in the emergency department (ED) alone. With increasing numbers of procedures being performed outside the operating room, it is imperative that the clinician is familiar with the different options for providing safe sedation to children to complete these procedures successfully and with minimal adverse events.

The continuum of sedation

Traditionally, four levels of sedation have been defined by the American Society of Anesthesiologists (ASA). In addition to these, the unique dissociative state produced by ketamine has also been added (**Table 1**) [2–5,101]. The progression from one level of sedation to another is not divided into discrete stages, but rather constitutes a continuum. It is hard to predict the level of sedation achieved in a given patient, and it is critical to recognize that deep sedation can occur after administration of sedatives in any child, and that the child can progress quickly from one stage of sedation to another.

Indications for PSA in children

Sedation and analgesia are commonly required by children for four clinical scenarios:

- Anxiolysis: administration of a benzodiazepine to an adolescent prior to rape-kit examination following sexual assault;
- Procedural sedation for painless intervention: administration of chloral hydrate or barbiturate to facilitate MRI or a CT scan;
- Procedural sedation for painful intervention: administration of ketamine for fracture reduction or debridement of burns;
- Extended sedation: administration of a benzodiazepine infusion for ventilator management in an intubated patient.

Indeed, orthopedic reduction, diagnostic imaging and laceration repair have been identified as the top three reasons for PSA in children [6,7].

Pre-sedation assessment

A focused pre-sedation assessment has been shown to reduce adverse events related to procedural sedation [7,8]. This assessment consists of a directed medical history of the child, risk stratification and a focused physical examination. The medical history should include any major medical illness, particularly those pertaining to the respiratory, cardiovascular or neurological systems, current medications that the child is receiving, medication allergies, and a history of previous experiences with sedation or anesthesia not only in the patient, but also in family members. In addition, particular attention should be paid to the history of snoring, central or obstructive

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Table 1. Levels of sedation.

Level of sedation	Description
Minimal sedation (anxiolysis)	A drug-induced state during which patients respond normally to verbal commands. Although cognitive function might be impaired, ventilatory and cardiovascular functions are unaffected.
Moderate sedation/analgesia ('conscious sedation')	A drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patient's airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.
Dissociative sedation	A trance-like cataleptic state induced by the dissociative agent ketamine or *S*-ketamine, and characterized by profound analgesia and amnesia, with retention of protective airway reflexes, spontaneous respirations and cardiopulmonary stability.
Deep sedation	A drug-induced depression of consciousness during which patients cannot be easily aroused, but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function might be impaired. Patients might require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained.
General anesthesia	A drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired.

apnea, and gastroesophageal reflux diseases, which have all been shown to increase the potential of developing respiratory adverse events related to sedation. The mnemonic 'AMPLE' helps to cover all the important historical points that should be elicited prior to PSA.

- A: Allergies
- M: Medications
- P: Past medical history, including previous procedures
- L: Last meal
- E: Events prior to the procedure

Documentation of the pre-procedural fasting, or *nil per os* (NPO), status is a Joint Commission on Accreditation of Health Care Organization (JCAHO) requirement prior to administration of PSA. Although recent studies have shown no association between pre-procedural fasting state and adverse events related to sedation [9,10], there has been no change in the recommended ASA guidelines for fasting prior to elective procedures. These guidelines still recommend that patients should be NPO prior to sedation for at least 6 h after consumption of a light meal or infant formula, 4 h after intake of breast milk and 2 h after clear liquids. A clinical practice advisory committee has recently proposed specific recommendations for fasting before ED PSA, and has described limits for targeted sedation depth and length based on a four-step method of aspiration risk stratification, taking into account patient risk factors, timing and nature of recent oral intake, and the urgency of the procedure [11].

The ASA classification has been used to stratify the child's risk related to sedation based on his/her physical health (**Table 2**) [12]. Patients with diseases of two systems may be considered to be in class 3, even if each of the two diseases are well controlled, and some practioners suggest assigning a higher ASA class to children with certain congenital problems, such as Down's syndrome, and skeletal dysplasias owing to multiple anomalies associated with these conditions. An ASA physical status of 3 or higher has been shown to be associated with increased incidence of sedation-related adverse events [13], and hence the American Academy of Pediatrics (AAP) recommends consultation with appropriate subspecialists or anesthesiologists for children with ASA class 3 or higher, children with special healthcare needs or those with anatomic airway abnormalities [14].

A focused physical examination should begin with assessment of the airway for the features that may predispose to upper-airway obstruction, including size of the mandible and chin, adequacy of mouth opening, presence and size of dentition, size of the tongue relative to the oropharynx, presence and degree of tonsillar enlargement, anatomical abnormalities of the neck or airway, and neck mobility. A Mallampati score [15] – a clinical score that is used to predict the difficulty of tracheal intubation – should be

Table 2. American Society of Anesthesiologists classification of physical status.

Class	Description
1	A normally healthy patient
2	A patient with mild systemic disease
3	A patient with severe systemic disease
4	A patient with severe systemic disease that is a constant threat to life
5	A moribund patient who is not expected to survive without operation

assigned. A cardiopulmonary assessment should be performed, as drugs used for sedation can cause respiratory depression, hypotension and vasodilatation. Presence of active wheezing or current upper respiratory tract infection should be noted, as they have been shown to predispose to an increased incidence of laryngospasm with the use of inhalational anesthetics [16], although the relationship between these clinical findings and laryngospasm with PSA is not clear. Informed consent should be obtained from the patient's caregiver prior to sedation after explaining the risks versus benefits of sedation, as well as treatment alternatives.

Monitoring during sedation

In addition to understanding drug pharmacology, providers of sedation must have the ability to recognize various levels of sedation, possess advanced pediatric life support skills and have the ability to rescue the patient from sedation-related complications. Procedural sedation generally requires at least two experienced providers, one physician who administers the medication in addition to occasionally performing the procedure, and a nurse or a respiratory therapist who continuously monitors the patient and documents the vital signs according to the sedation protocol. Such continuous observation of the patient's face and chest wall motion by the healthcare professional is critical for early recognition of sedation-related respiratory adverse events. The AAP has published a checklist using the acronym of 'SOAPME' to be reviewed prior to each and every sedation (**Box 1**) [14].

JCAHO-recommended basic documentation includes, but is not limited to, the patient's level of consciousness, heart rate, blood pressure, respiratory rate and oxygen saturation. Continuous ECG monitoring is not recommended for children without cardiovascular disease. Current recommendations state that for moderate and deep sedation, oxygen saturation and heart rate should be monitored continuously, with respiratory rate and blood pressure recorded at least every 5 min [14,17,18].

Recently, end tidal carbon dioxide ($ETCO_2$) monitoring has been added to the existing modalities of noninvasive monitoring during PSA. Changes in $ETCO_2$ have been shown to be the earliest indicator of airway compromise [19] and more sensitive than a clinical examination by healthcare professionals in detecting respiratory compromise [20]. Since partial pressure of arterial oxygen does not correlate linearly with oxygen saturation, a large reduction in the partial pressure of oxygen is required before the oxygen saturation is reduced. However, unlike oxygen, there is a linear relationship between the partial pressure of CO_2 in the lung and the blood, and hence $ETCO_2$ measurements correlate accurately with the patient's ventilatory status. Two recent studies noted that respiratory depression or apnea was detected by capnography before treating physicians identified the respiratory depression and prior to the development of hypoxia, as detected by pulse oximetry [21,22]. There is, however, no evidence that suggests a correlation between early detection of hypoventilation and improved clinical outcomes, and the significance of elevated $ETCO_2$ capnogram without hypoxemia is unknown at this time. The AAP currently recommends capnography as an essential monitoring tool only during deep sedation in children [23].

The bispectral index (BIS) monitor is another novel monitoring modality that processes the electroencephalogram (EEG) obtained from a sensor placed on the patient's forehead into a neurophysiologic variable that correlates with the depth of sedation [23]. A score of less than 40 correlates with a deep hypnotic state, 40–60 with general anesthesia, 60–70 with deep sedation and 70–90 with light to moderate sedation. As the EEG undergoes significant changes with age-related changes in development, the usefulness of this monitoring is not certain in children. Furthermore, BIS scores are unreliable during the dissociative state produced during sedation with ketamine [24]. There is also a time lag of 15–30 s, which is required for processing of the data, and hence the scores do not necessarily reflect the level of sedation at the exact time of recording [23]. The role of BIS monitoring with PSA is uncertain at this time, and future studies are warranted in the pediatric population before its use can be advocated in settings outside the operating room.

Discharge

Specific discharge criteria should be established for children undergoing PSA. The child should have returned to his/her baseline respiratory status, have

Box 1. 'SOAPME' checklist.

- **S** (suction): size-appropriate catheters and functioning suction apparatus
- **O** (oxygen): adequate supply and functioning flow meters
- **A** (airway): size-appropriate airway equipment
- **P** (pharmacy): basic drugs for life support, including antagonists
- **M** (monitors): as appropriate for the standard sedation
- **E** (equipment): ancillary equipment, such as a defibrillator

protective airway reflexes and normal vital signs, and the motor activity and level of consciousness should be improving, although the latter two might not return completely to baseline with the use of certain longer-acting agents. Since adverse events can occur after the child is discharged [25], the caregiver should be provided with detailed instructions on an appropriate diet, level of activity and a telephone number to call incase of unexpected, post-discharge adverse events [26].

Adverse events related to PSA

Studies have quoted a wide range in the incidence and severity of adverse events related to PSA, with incidence rates of 2.3–17.8% being reported [6,7,9,27]. Since adverse events related to PSA are rare, the previous studies have lacked a sufficient number of patients to define the true incidence of adverse events and the risk factors associated with such adverse events. The establishment of a Pediatric Sedation Research Consortium, a collaborative group of 35 institutions, has provided the first large-scale prospective database of sedation/anesthesia encounters, which has defined the nature and frequency of adverse events related to PSA in children [28]. In their study of 30,037 sedation and anesthesia encounters, there were no deaths reported. Cardiopulmonary resuscitation was required only once. Only one aspiration was reported. Less serious events were reported to be more common, with oxygen desaturation below 90% for more than 30 s occurring 157 times per 10,000 sedations. Vomiting occurred approximately once in every 200 procedures. Approximately one in 400 procedures was associated with stridor, laryngospasm, wheezing or apnea. Indeed, one in 200 sedations required airway and ventilation interventions, ranging from bag-mask ventilation, to oral airway placement, to emergency intubation. The authors concluded that 'even though the incidence of serious adverse events is low, the reported incidence of events that have the potential to harm and that require timely rescue interventions is significant, occurring once per 89 sedation encounters.

Newman *et al.* prospectively studied the timing of sedation-related adverse events in 1367 pediatric sedation encounters [29]. Of the reported 13.7% adverse events, 92% occurred during the procedure. There were no primary serious adverse events beyond 25 min after final medication administration. All of the 'late' adverse events were repeated occurrences in children who had already experienced previous hypoxia during the expected peak drug effect. They concluded that patients may be discharged home safely from the ED 30 min after the final sedation medication administration, provided they have not experienced any adverse event.

A study by Cote *et al.* performed a critical incident analysis of the factors that contributed to adverse sedation outcomes in children, and concluded that adverse outcome associated with PSA was more related to failure to rescue the patient from developing an adverse event, rather than individual patient characteristics [30]. The study also noted that more serious outcomes, such as death and permanent neurological injury, occurred more frequently in non-hospital-based facilities where there was a lack of documented monitoring. Adherence to published guidelines on sedation in children has been shown to reduce the incidence of adverse events [8]. The studies on risk factors that are related to adverse sedation outcomes have yielded conflicting results. While some studies have found that younger age [25], higher ASA class [13], increasing depth of sedation [8] and combination of three or more drugs used for sedation [31] are associated with increased risk of adverse events, other studies have refuted these associations [6,9]. A large prospective study involving patient cohorts of thousands, such as the pediatric sedation consortium, would be required to fully define risk factors that lead to adverse sedation outcomes given the rare occurrence of sedation-related serious adverse outcomes.

There have been very few studies that have studied delayed (after the child is discharged home) side effects related to sedation, and most of these are related to sedation for diagnostic imaging [25,32]. These studies report a significant incidence of delayed side effects in the form of motor imbalance, gastrointestinal effects and restlessness. In the study by Malviya *et al.*, 5% of children did not return to baseline activity until the second day after the procedure [25]. In a study by Wathen *et al.*, half of the children who experienced vomiting post-ketamine sedation in the ED had no documented episodes of emesis in

the ED [33]. Future studies are needed to define the incidence and nature of the delayed side effects related to PSA in order to educate the caregivers of the children about these side effects.

Medications used in PSA

There is no single ideal agent that can be used for pain control, anxiety management and procedural sedation in children. The choice of medication that is used is usually determined by the type and duration of procedure, the child's age, level of anxiety prior to procedure, medical history and physical examination and the personal preference and experience of the clinician providing the care. The five classes of drugs that are commonly used are sedative hypnotics, analgesics, dissociative agents, inhalational agents and antagonists. Oral, transmucosal and intramuscular routes of administration are more convenient and may be preferred for children with difficult intravenous access, or for procedures such as diagnostic imaging, but they lack the ability to provide reliable drug levels and titrability to the desired effect.

Sedative hypnotics

Chloral hydrate

Chloral hydrate is one of the oldest drugs used in PSA, and is a pure sedative hypnotic drug without analgesic properties. It is commonly used for sedation during diagnostic imaging and EEG and its effects are said to more reliable in infants and children less than 3 years of age. At the commonly used dose of 50–100 mg/kg, the onset of action is between 15 and 60 min, and its effects can last up to 4 h. The significant side effects are airway obstruction and respiratory depression, and these effects can be particularly pronounced in very young infants or those born prematurely. Paradoxical excitability is known to occur in children with developmental delay. It can also cause prolonged sedation. Despite the risk of potential carcinogenicity, the AAP has concluded that there is insufficient evidence at this time to withhold single doses of chloral hydrate for this reason alone [34].

Barbiturates

The barbiturates, which include pentobarbital, thiopental and methohexital, act by suppression of the reticular activating system via the γ-hydroxybutyric acid $(GABA)_A$ receptors. They produce profound sedation, hypnosis and amnesia in a dose-dependent fashion, but have no inherent analgesic properties. They are commonly used for sedation for diagnostic imaging, and are regarded superior to midazolam or chloral hydrate for this indication [35,36]. Pentobarbital when used in the dose of 1–2 mg/kg, has a rapid onset of action within 3–5 min, with a duration of action between 20 and 40 min. Methohexital is commonly used as a rectal preparation in the dose of 20–30 mg/kg for sedation for diagnostic imaging, and has a shorter onset and recovery time when compared with chloral hydrate. Barbiturates can cause respiratory depression and induce hypotension through both myocardial and peripheral vascular effects.

Benzodiazepines

Benzodiazepines also act via the GABA receptor, but they bind to proteins that are not used by the barbiturates or GABA. They have anxiolytic, sedative and amnestic properties, and also cause muscle relaxation. For painful procedures, they are usually combined with an opioid analgesic. They possess the advantage of being effective via multiple routes of administration, including oral, transmucosal and parenteral routes, although the transmucosal route requires a higher dose. Midazolam has a shorter onset and duration of action compared with lorazepam and diazepam, and hence, is the preferred drug in its class for PSA. Benzodiazepines can cause paradoxical agitation in children. When combined with opioids, the risk of respiratory depression and apnea increases. The effects of benzodiazepines can be reversed by use of flumazenil, which can be administered in the initial dose of 0.02 mg/kg and can be repeated every 1 min to a maximum dose of 1 mg. It should be remembered that the duration of action of flumazenil is shorter than that of medium- and long-acting benzodiazepines, and hence re-sedation can occur.

Etomidate

Etomidate is an imidazole hypnotic agent that has a rapid onset and short duration of action, and has fewer hemodynamic and respiratory effects than other sedative hypnotic agents. Recent studies have reported a high level of efficacy when used for procedural sedation and analgesia, especially for fracture reductions [37–39]. The dose used varies between 0.1 and 0.3 mg/kg. The lower dose produces a shorter duration of sedation, which is especially useful in some rapidly performed procedures such as reduction of anterior shoulder dislocations. The commonly reported adverse events with etomidate include myoclonus, vomiting, transient oxygen desaturations, respiratory depression

and pain with injection. The incidence of myoclonus varies from 8 to 18%, and although they resemble seizure-like activity, they are benign, usually last less than 1 min [40] and do not result in post-procedure myalgia. Transient adrenal suppression has been demonstrated for up to 24 h, even with a single dose of etomidate. This effect is caused by a dose-dependent effect via inhibition of the mitochondrial hydroxylase activity in the adrenal glands, and does not seem to have much clinical significance with one-time use in a nonseptic ED patient.

Propofol

Propofol is a modified phenol that is thought to prolong the duration of action of GABA with its receptor site by its interaction with the GABA receptor system. Its extremely rapid onset of action, extremely short recovery time (5–15 min), marked potency, and anti-emetic and euphoric properties make it a desirable drug for use in PSA [41]. There is growing evidence that when used in pediatric PSA, it has good efficacy and safety [42,43]. When used in PSA, propofol is typically started with a bolus dose of 1 mg/kg followed by repeat doses of 0.5 mg/kg as needed. It is contraindicated for use in patients who are allergic to eggs or soy. The most significant adverse event seen with propofol is potent respiratory depression and apnea, with a reported incidence between 2 and 31%, which may require head positioning, supplemental oxygen and occasional bag-mask ventilation [40]. Propofol can also cause hypotension by negative inotropy, as well as vasodilation. It can also cause severe pain at the injection site, which can be reduced by pretreatment with lidocaine, rapid infusion rates of normal saline and a slower rate of infusion of propofol. The propofol-infusion syndrome, which is a combination of acidosis and renal and cardiac failure, occurs mainly in patients who receive greater than 5 mg/kg/h for 48 h or longer. As propofol is known to produce deep sedation, it involves more personnel requirements for monitoring, with a physician solely delegated to monitoring during the sedation. The current proposed role for propofol in PSA is for brief, intensely painful procedures, such as cardioversion, orthopedic manipulation or bone marrow aspiration, and brief interventions that require marked anxiolysis and immobilization to be accomplished, such as ocular burn examination and intrathecal medication administration [41].

Analgesics

Topical agents

Lidocaine is used as 1% solution at a dose of 3–5 mg/kg and provides excellent local anesthesia for wound repair, drainage of abscesses and foreign-body removal. The pain with injection of local anesthetics can be reduced by use of a small, long needle for infiltration, warming and buffering with sodium bicarbonate, and slowing the rate of injection. Several systems to enhance drug delivery, such as iontophoresis and needle-free jet injection of local anesthetics, are now becoming available. Another alternative to overcome the pain with local anesthetic injections is the use of topical anesthetic gels, such as lidocaine, epinephrine and tetracaine (LET), a eutectic mixture of lidocaine and prilocaine (EMLA) and lidocaine 4% (LMX-4). These have to be applied 20–40 min prior to the procedure. Protocols for placement of local anesthetics at triage can significantly reduce the negative impact on the ED flow.

Opioids

Opioids modulate cerebral cortical pain by specifically binding to the opioid receptor, usually of the μ-class. Morphine is the traditional opioid analgesic, which is a pure agonist with excellent analgesic properties, with the advantage that it can be administered orally, intramuscularly, subcutaneously, intravenously, epidurally and intrathecally. It is used to provide extended pain relief during the waiting period prior to the procedure. Fentanyl, which has a faster onset and a shorter duration of action than morphine, is preferred for PSA. Since it does not have anxiolytic, amnestic or sedative effects at lower doses, it is usually combined with midazolam. This combination is a popular PSA regimen with proven efficacy [6,7]. All opioids produce dose-dependent respiratory depression. In addition, fentanyl can cause chest-wall rigidity with rapid infusion and with use of a higher dose (>5 μg/kg). Fentanyl does not cause histamine release like morphine and meperidine, and nausea and vomiting is less common with fentanyl than the latter, although fentanyl lozenges have become unpopular owing to the high incidence of vomiting. Sufentanil, alfentanil and remifentanil are short-acting opioids, and experience with these newer drugs is limited in children. The respiratory depression produced by opioids can be reversed by administration of the antagonists naloxone and nalmefene, and the latter's long half-life outlasts the duration of action of fentanyl.

Dexmedetomidine

Dexmedetomidine is a central α-2 agonist of the imidazoline class similar to clonidine that has been shown to produce sedation, anxiolysis and analgesia [44]. There have been few studies involving pediatric patients demonstrating its efficacy in painless as well as painful procedures [45–47]. Its adverse effects include bradycardia, hypo/hypertension, decreased cardiac output and obstructive apnea. Currently, there are no US FDA-approved indications for its use in children.

Inhalational agents

Nitrous oxide

Nitrous oxide is an odorless gas that produces sedation, anxiolysis, amnesia with mild analgesic effects and recovery within 5 min. It is dispensed at concentrations between 30 and 70%, with oxygen composing the remainder of the mixture. It has a unique advantage in that it does not require an intravenous access. Children are also able to follow commands while breathing nitrous, which is useful for children who do not wish to be 'put to sleep' for procedures. It does not produce cardiorespiratory adverse effects and, in fact, the most common reported adverse effect with nitrous oxide is vomiting, especially in patients who are prone to motion sickness. Nitrous oxide is contraindicated in patients with pneumothorax, bowel obstruction or head injury and those who are pregnant. The current methods of delivery using a demand-valve mask are hard for children younger than 8 years of age to activate, which limits its use. In frightened, uncooperative and younger children, continuous-flow nitrous oxide has been used with a face mask strapped over the nose, but this requires a dedicated physician for gas titration. A scavenging system should also be in place to comply with occupational safety guidelines. The common indications for its use are laceration repair [48,49], venipuncture and burn dressing.

Dissociative agent

Ketamine

Ketamine has become one of the most popular agents for PSA in children in the ED. It is unique amongst the agents used for PSA in that it exerts its effect by 'disconnecting' the thalamoneocortical and limbic systems, effectively dissociating the CNS from outside stimuli [50]. It does not exhibit a dose–response continuum, but rather the dissociative state produced by ketamine is either present or absent. The only need for titration is to maintain the dissociative state over a period of time. Ketamine maintains protective upper-airway reflexes and preserves spontaneous respirations and cardiopulmonary stability. The dissociative sedation produced by ketamine also does not need adherence to fasting guidelines. It is effective by both intravenous and intramuscular routes [51]. The recommended dose by intravenous route is 1.5 mg/kg, and by intramuscular route is 4 mg/kg [50]. It is contraindicated for use in children less than 3 months of age, in those with tracheal stenosis or recent tracheal surgery, and those with increased intracranial pressure, acute psychosis, porphyria and diseases of the thyroid gland. Ketamine stimulates hypersalivation, although prospective trials have not supported the use of concomitant anticholinergics to attenuate hypersalivation [52]. Dysphoric emergence reactions are infrequent in children and do not warrant prophylactic administration of benzodiazepines. Emesis occurs in as much as 20% of patients who receive ketamine. It is more common in older children, and usually occurs late during the recovery phase [50]. The only disadvantage with the use of ketamine for PSA is the prolonged recovery period (50–110 min when given intravenously, 60–140 min when given intramuscularly) [53].

Nonpharmacological interventions

A recent publication has emphasized the importance of nonpharmacologic interventions in the relief of pain and anxiety in children [54]. Family-member presence is not only comforting for the child, but also does not adversely affect the clinicians' ability to provide safe and effective care. Cognitive and behavioral approaches are an invaluable adjunct in reducing anxiety and altering pain perception. The child can be distracted during the painful procedure by asking them to breathe rhythmically or having the parents sing or tell a story to them. Since children have vivid imaginations, hypnosis has been advocated for acute management of painful conditions in children, although its use in ED settings has not been rigorously studied. Child-life specialists can be very helpful in preparing the child prior to the procedure and can often offer a variety of interventions to reduce the child's anxiety. A child near nap time will need less medication and it is prudent to schedule elective outpatient procedures depending around the child's sleep time.

Conclusion & future perspective

Administration of analgesics and sedatives by trained and credentialed physicians is safe, effective and offers optimum pediatric care, with improvement of patient and family satisfaction. Future research should focus on further improving the safety and efficacy of sedation in children with investigation of newer agents and expansion of adjuncts for PSA in the form of regional anesthesia, psychological techniques and ancillary services, such as the use of child-life specialists. Research is also needed to study post-discharge sedation-related side effects. Definitions of what constitutes a successful sedation from the perspective of the patient, family and healthcare professional involved in sedation needs to be determined [55].

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Executive summary

- Procedural sedation and analgesia (PSA) for children – the use of sedatives, analgesics or dissociative drugs to overcome pain and anxiety associated with diagnostic and therapeutic procedures – has evolved tremendously over the last two decades, with a rapid rise in the number of procedures performed outside the operating room.
- Expertise in PSA has become a fundamental skill set for physicians providing acute care to children.

Pre-sedation assessment & monitoring

- Pre-sedation assessment should include a directed medical history, risk stratification using the American Society of Anesthesiologists classification and a focused physical examination, which includes, most importantly, assessment of the airway.
- Although there is no clear relationship between pre-procedural fasting and increased sedation-related adverse outcomes, documentation of the *nil per os* status is required.
- Heart rate, respiratory rate, blood pressure, oxygen saturation and the patient's level of consciousness should be monitored and documented prior to sedation, during sedation and until the patient has returned to his/her baseline function.
- Informed consent should be obtained prior to administration of PSA.

Sedation-related adverse events

- Serious adverse events related to sedation are rare and mostly respiratory in nature.
- The majority of them occur during the procedure.
- Adherence to published sedation guidelines has been shown to decrease the incidence of adverse events.
- The studies regarding the risk factors that predispose to sedation-related adverse events are inconclusive.
- Reported post-discharge side effects have also been in the form of motor imbalance, gastrointestinal side effects and restlessness.

Future perspective

- Further research is needed to improve the safety and efficacy of PSA in children, to study the delayed sedation-related side effects and to define a 'successful' sedation from the viewpoint of the patient, family and healthcare personnel involved in sedation.

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