5 Sedation Scales and Discharge Criteria: How Do They Differ? Which One to Choose? Do They Really Apply to Sedation?

Dean B. Andropoulos

Abstract

Assessing the depth of sedation in children is critically important to determine whether the goals of sedation are met without exposing the patient to the risk of adverse outcomes. In Cravero's model of pediatric sedation, the patient's state ranges from fully awake undergoing a painful procedure without sedation or analgesia to apnea, hypoxia, and death from oversedation. Clearly, having the sedated child's state in the goal zone is important, and objective tools to assess sedation depth are necessary to standardize depth of sedation. Additionally, having objective assessment scales available to rate a child's readiness for discharge from a sedation recovery area is also important, as premature discharge may lead to adverse events and even death. This chapter will review commonly used pediatric sedation scales, focusing on procedural sedation. Then methods of sedation assessment using processed EEG will be reviewed and compared to pediatric sedation scales.

Keywords

Pediatric • Sedation scales • Ramsay Sedation Scale (RSS) • Observer's Assessment of Alertness/Sedation Scale (OAA/S) • Modified Observer Assessment Sedation Score (MOAA/S) • COMFORT Scale • University of Michigan Sedation Scale (UMSS) • Dartmouth Operative Conditions Scale • Modified Aldrete Score • Bispectral index (BIS) • Aldrete Score • Maintenance of Wakefulness Test • Modified Maintenance of Wakefulness Test (MMWT) • Auditory evoked potentials (AEP)

Introduction

Assessing the depth of sedation in children is critically important to determine whether the goals of sedation are met without exposing the patient to the risk of adverse outcomes. In Cravero's model of pediatric sedation [1], the patient's state ranges from fully awake undergoing a painful procedure without sedation or analgesia to apnea, hypoxia, and death from oversedation (Figure 5.1). Clearly, having the sedated child's state in the goal zone is important, and objective tools to assess sedation depth are necessary to standardize depth of sedation. Additionally, having objective assessment scales available to rate a child's readiness for discharge from a sedation recovery area is also important, as premature discharge may lead to adverse events and even death [2–4]. This chapter will review commonly used pediatric sedation scales, focusing on procedural sedation. Then methods of sedation assessment using processed electroencephalography (EEG) will be reviewed and compared to pediatric sedation scales. Finally, commonly used scales to assess recovery from sedation and readiness for discharge from sedation will be discussed.

D.B. Andropoulos, M.D., M.H.C.M. (✉)
Department of Anesthesiology, Texas Children's Hospital, Baylor College of Medicine, 6621 Fannin, WT 17417, Houston, TX 77030, USA
e-mail: dbandrop@texaschildrens.org; dra@bcm.tmc.edu

K.P. Mason (ed.), *Pediatric Sedation Outside of the Operating Room: A Multispecialty International Collaboration*,
DOI 10.1007/978-1-4939-1390-9_5,

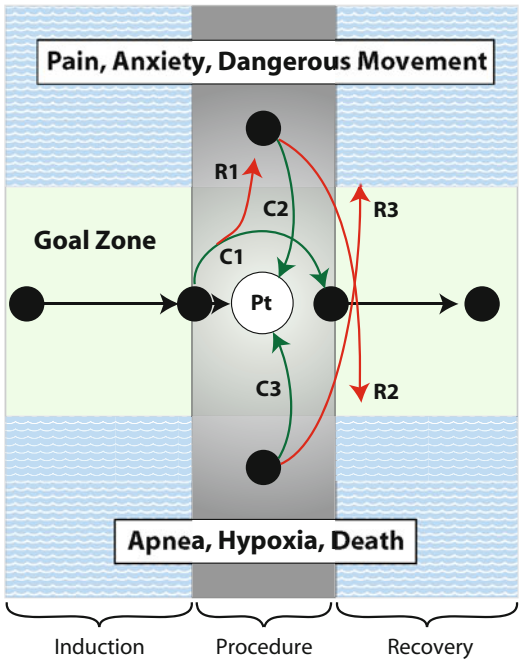

Fig. 5.1 A working model of pediatric sedation. The *x*-axis is the time of phase of sedation. The *y*-axis is the depth of sedation, ranging from inadequate to oversedation. A sedation scale should be able to accurately assess the depth of sedation and maximize the chance that the patient is in the goal zone. The *black dots* are the patient at a single point in time, ranging from preprocedure, through intra- and postprocedure. C designates the work done by the provider to counteract the adverse effects of sedation or accomplish a task. C1 is the procedure control loop, C2 the procedural pain and anxiety control loop, and C3 the sedation-related respiratory depression control loop. R1 is the undesired side effects of therapeutic action: R1 undersedation and pain, R2 oversedation, and R3 rescue from oversedation (Adapted from Cravero JP, Blike GT, Surgenor SD, Jensen J. Development and validation of the Dartmouth Operative Conditions Scale. Anesth Analg. 2005;100:1614–21, with permission from Lippincott Williams & Wilkins)

Table 5.1 American Academy of Pediatrics/Joint Commission/American Society of Anesthesiologists Definitions of Levels of Sedation

Minimal sedation (*anxiolysis*)	A drug-induced state during which patients respond normally to verbal commands
	Although cognitive function and coordination may be impaired, ventilatory and cardiovascular functions are unaffected
Moderate sedation (previously called conscious sedation or sedation/analgesia)	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 patent airway, and spontaneous ventilation is adequate
	Cardiovascular function is usually maintained
Deep sedation	A drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully after repeated or painful stimulation. (*Note*: reflex withdrawal from a painful stimulus is not considered a purposeful response)
	The ability to independently maintain ventilatory function may be impaired
	Patients may 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 to 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 depressed spontaneous ventilation or drug-induced depression of neuromuscular function
	Cardiovascular function may be impaired

Source: Data from American Society of Anesthesiologists. ASA Standards, Guidelines and Statements, October

Sedation Scales

The Joint Commission, the American Academy of Pediatrics, and the American Society of Anesthesiologists have recently revised their definitions of the levels of pediatric sedation [5, 6] (Table 5.1, Figure 5.2). The four levels of sedation are now minimal, moderate, deep, and general anesthesia. The previously used term "conscious sedation" has been eliminated because it was misleading, and particularly in pediatric patients, they can change rapidly from minimal to deep levels of sedation. Any assessment of levels of sedation needs to take these basic considerations into account.

Sedation scales are indeed necessary for pediatric procedural sedation, particularly when practiced by nonanesthesiologists. For example, Reeves et al. [7] studied 16 children undergoing propofol sedation for bone marrow aspiration by nonanesthesiologists, and found that for all children, their level of consciousness, motor activity score, and bispectral index score was consistent with either deep sedation or general anesthesia at some point during the procedure. In the largest pediatric procedural cohort reported to date, Cravero et al. assessed 49,836 propofol sedations. Complications were noted in 5.92 % of patients, including an airway or pulmonary complication in 1.17 %, yet there was no assessment of depth of sedation reported [8]. Sedation scales are essential to minimize complications from sedation by providing early warning of sedation that is deeper than intended, to allow the practitioner to intervene proactively, instead of having to rescue the patient from an episode of hypoxemia from airway obstruction or apnea. The ideal sedation scale would be applicable to children of all ages, easy and rapid to administer to allow repeated objective assessment, and correlate both with depth of sedation necessary for successful completion of the procedure and with adverse effects of sedation, i.e., airway obstruction, hypoxemia, hypotension,

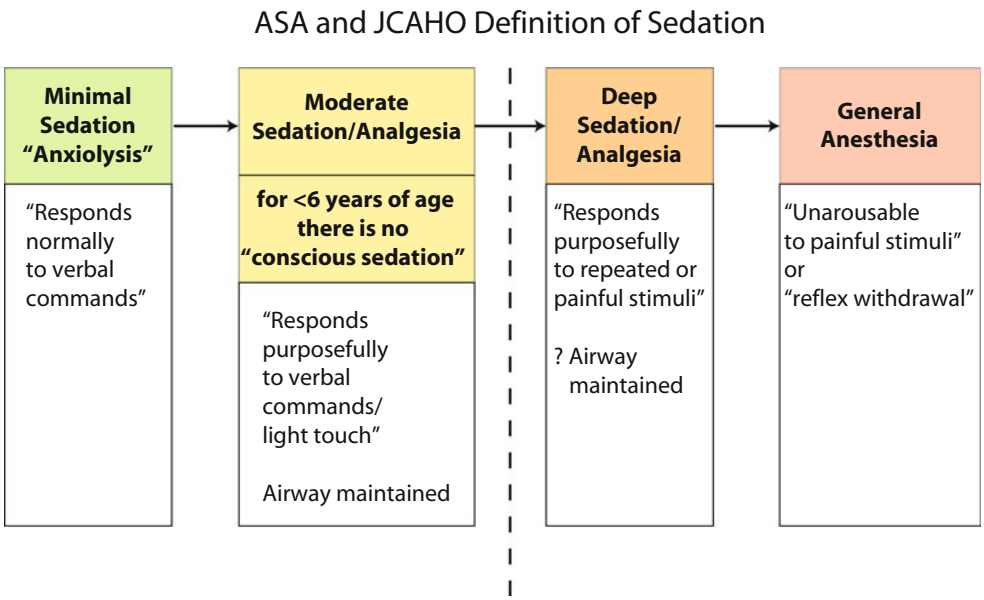

Fig. 5.2 The sedation continuum. A patient may readily pass from a light level of sedation to deep sedation or general anesthesia. Healthcare providers must be prepared to increase vigilance and intensity of monitoring consistent with the depth of sedation. One should consider all children younger than the age of 6 years as deeply sedated because "conscious sedation" in this age group for most children is an oxymoron (*ASA, American Society of Anesthesiologists; JCAHO, Joint Commission on Accreditation of Healthcare Organizations*) (Adapted from [6].)

Table 5.2 Ramsay Scale

Level	Characteristics
1	Patient awake, anxious, agitated, or restless
2	Patient awake, cooperative, orientated, and tranquil
3	Patient drowsy, with response to commands
4	Patient asleep, brisk response to glabellar tap or loud auditory stimulus
5	Patient asleep, sluggish response to stimulus
6	Patient has no response to firm nail-bed pressure or other noxious stimuli

Source: Data from Ramsay et al. [9]

Table 5.3 Modified Ramsay Sedation Scale with American Academy of Pediatrics/Joint Commission/American Society of Anesthesiologists designation

Score	Characteristics
1	Awake and alert, minimal or no cognitive impairment
2[a]	Awake but tranquil, purposeful responses to verbal commands at conversation level
3[a]	Appears asleep, purposeful responses to verbal commands at conversation level
4[b]	Appears asleep, purposeful responses to verbal commands but at louder than usual conversation level or requiring light glabellar tap
5[b]	Asleep, sluggish purposeful responses only to loud verbal commands or strong glabellar tap
6[c]	Asleep, sluggish purposeful responses only to painful stimuli
7[d]	Asleep, reflex withdrawal to painful stimuli only (no purposeful responses)
8[d]	Unresponsive to external stimuli, including pain

Source: Data from Ramsay et al. [9]
GA general anesthesia
[a] Minimal
[b] Moderate
[c] Deep
[d] GA

and bradycardia. It would be validated against other accepted scales, and also an objective method of assessment such as a processed EEG technique. And, it would be further validated in very large numbers of patients to determine that the scale did correlate with outcomes. Unfortunately, no such ideal sedation scale exists. However, there are a number of objective and semiobjective methods, some validated, to assess depth of sedation.

The Ramsay Scale

The Ramsay Sedation Scale (RSS) was described by Ramsay and colleagues in 1974 for the purpose of monitoring sedation with alphaxalone/alphadolone [9] (Table 5.2). It has been validated by several methods including a modified Glasgow Coma Scale and the Sedation-Agitation Scale [10]. The Ramsay Scale was one of the earliest sedation scales, and although not strictly validated in children, it is one of the most widely used scales for assessing and monitoring pediatric sedation in daily practice, as well as in clinical research. It spans the continuum of sedation but does not clearly separate purposeful from nonpurposeful responses.

A later modification of the Ramsey scale more clearly coincides with the AAP and Joint Commission guidelines (Table 5.3) [6]. A score of 2–3 is anxiolysis, 4–5 is moderate sedation, 6 is deep sedation, and 7–8 is general anesthesia.

Table 5.4 The Observer's Assessment of Alertness/Sedation Scale

Assessment categories				
Responsiveness	Speech	Facial expression	Eyes	Composite score level
Responds readily to name spoken in normal tone	Normal	Normal	Clear, no ptosis	5 (alert)
Lethargic response to name spoken in normal tone	Mild slowing or thickening	Mild relaxation	Glazed or mild ptosis (less than half the eye)	4
Responds only after name is called loudly and/or repeatedly	Slurring or prominent slowing	Marked relaxation (slack jaw)	Glazed and marked ptosis (half the eye or more)	3
Responds only after mild prodding or shaking	Few recognizable words	–	–	2
Does not respond to mild prodding or shaking	–	–	–	1 (deep sleep)

Source: Data from Chernik et al. [11]

The Observer's Assessment of Alertness/Sedation Scale and Modified Observer's Assessment of Alertness/Sedation Scale

The Observer's Assessment of Alertness/Sedation Scale (OAA/S) [11] was developed to measure the alertness of adult subjects who are sedated with benzodiazepines. It assesses consciousness level in four areas: responsiveness, speech, facial expression, and eyes (Table 5.4). The OAA/S was validated in 18 healthy males 19–44 years of age, who received intravenous midazolam, initial dose 0.035 mg/kg, followed by additional doses of 0.015 mg/kg every 60–90 s until one of two levels of sedation was reached: light or heavy. A placebo group was also used, and two raters determined the depth of sedation using the OAA/S and 100 mm visual analog scale (VAS) rating patients from 0 (very sedated) to 100 (completely alert). Each subject was tested three separate times in a crossover design to assess the OAA/S reliability, criterion, and construct validity. The scale was found to be reliable with high correlations between raters, to have strong criterion and behavioral validity with consistently decreasing scores for placebo, light, and heavy sedation. The construct validity among the four components was also strong, as was the validity for subsequent administration to the same subject in the crossover phase. Finally, the investigators also used two performance tests—the Digit Symbol Substitution Test and the Serial Sevens Subtraction Test—to compare to OAA/S scores and again found strong correlation.

Despite this thorough validation of the OAA/S in adult patients, and its use in several sedation research studies in children [12, 13], the OAA/S has not been separately validated in children. The OAA/S has been used in the validation of the University of Michigan Sedation Scale [14], and in assessments of the reliability of the bispectral index monitor in children [15].

The Modified Observer Assessment Sedation Score (MOAA/S) uses only the responsiveness category of the OAA/S. This category was separately validated in the original study [11] but, as with the OAA/S, has not been separately validated in children.

The COMFORT Scale

The COMFORT Scale is a physiologically based scale that was originated and validated in children receiving intensive care, and as such is not completely applicable to the procedural sedation environment [16] (Table 5.5). It was tested and validated in 37 ventilated pediatric patients, and interrater agreement and internal consistency were very strong. Criterion validity, assessed by comparison with concurrent global ratings of pediatric intensive care unit (PICU) nurses, was also high. It is included here as an example of such a physiologically based scale. An added dimension is the assessment of pain or discomfort. Generally, a COMFORT score between 18 and 26, with each area scored as 2–3, is desirable to signify appropriate levels of sedation in the ICU setting. It is clear that this scale is complex and will require several minutes to assess, and as such is appropriate for ICU care where the scale is performed no more frequently than every hour. In the context of most procedural sedation, this scale will be inappropriate.

The University of Michigan Sedation Scale

The University of Michigan Sedation Scale (UMSS) is an assessment tool that has been shown to be valid when compared to the OAA/S Scale and other scales of sedation (Table 5.6) [14]. It is a level of consciousness tool that readily separates patients into the sedation categories defined by the AAP, ASA, and Joint Commission. It does not explicitly rate pain, and does not include an assessment of vital signs. In a study of 32 children aged 4 months to 5 years undergoing computed tomography (CT) scanning with oral chloral hydrate, 50–75 mg/kg, Malviya et al. [14] validated the UMSS by comparing the scores assessed every 10 min before, during, and after the procedure by the clinical sedation nurse, with assessments made by trained, blinded observers of the videotaped assessments, which were edited and viewed in random order. UMSS was compared to a 10-point VAS and the OAA/S. One hundred sixty-four observations

Table 5.5 The COMFORT Score

Domain	Characteristics	Score
Alertness	Deeply asleep	1
	Lightly asleep	2
	Drowsy	3
	Fully awake and alert	4
	Hyperalert	5
Calmness/agitation	Calm	1
	Slightly anxious	2
	Anxious	3
	Very anxious	4
	Panicky	5
Respiratory response	No coughing and no spontaneous respiration	1
	Spontaneous respiration with little or no response to ventilation	2
	Occasional cough or resistance to ventilator	3
	Actively breathes against ventilator or coughs regularly	4
	Fights ventilator; coughing or choking	5
Physical movement	No movement	1
	Occasional slight movement	2
	Frequent slight movement	3
	Vigorous movement limited to extremities	4
	Vigorous movement including torso and head	5
Blood pressure	Blood pressure below baseline	1
	Blood pressure consistently at baseline	2
	Infrequent elevations of 15 % or more (1–3 observations)	3
	Frequent elevations of 15 % or more (more than three episodes)	4
	Sustained elevation of >15 %	5
Heart rate	Heart rate below baseline	1
	Heart rate consistently at baseline	2
	Infrequent elevations of 15 % or more (1–3 observations)	3
	Frequent elevations of 15 % or more (more than three episodes)	4
	Sustained elevation of >15 %	5
Muscle tone	Muscle totally relaxed	1
	Reduced muscle tone	2
	Normal muscle tone	3
	Increased muscle tone and flexion of fingers and toes	4
	Extreme muscle rigidity and flexion of fingers and toes	5
Facial tension	Facial muscles totally relaxed	1
	Facial muscle tone normal; no facial muscle tension evident	2
	Tension evident in some facial muscles	3
	Tension evident throughout facial muscles	4
	Facial muscles contorted and grimacing	5

were made, and the UMSS showed an excellent correlation with VAS ($r=0.955$) and OAA/S ($r=0.929$), $p<0.0001$ for both. There was excellent inter-rater agreement between sedation nurse and trained observers at UMSS 0 and 1, and good agreement at UMSS 3 and 4, as well as excellent agreement in a test–retest scenario where 75 videotaped observations were rescored at a later date. Thus it would appear that the UMSS meets several of the requirements for the ideal sedation scale, in that it is validated, rapid to administer, and allows repeated observations. A problem shared with other scales is the need to arouse the patient to make an assessment; this is not possible during a procedure such as a magnetic resonance imaging (MRI) scanning sequence, and may be undesirable if the patient remains aroused, interfering with the procedure.

Table 5.6 University of Michigan Sedation Scale (UMSS)

Score	Characteristics
0	Awake and alert
1	Minimally sedated: tired/sleepy, appropriate response to verbal conversation and/or sound
2	Moderately sedated: somnolent/sleeping, easily aroused with light tactile stimulation or a simple verbal command
3	Deeply sedated: deep sleep, arousable only with significant physical stimulation
4	Unarousable

Dartmouth Operative Conditions Scale

The Dartmouth Operative Conditions Scale [1] was designed by three experienced pediatrician/anesthesiologists, and then refined by videotaping 12 common procedures including MRI, CT scan, voiding cystourethrogram, cardiac catheterization, fracture reduction, and bone marrow biopsy (Table 5.7). Then the Dartmouth scale was validated by videotaping 95 procedures with sedation provided by a variety of providers including radiology nurses, pediatricians, pediatric residents, cardiologists, oncologists, and anesthesiologists. The scale allows quantification of children based on observable behavior. It rates level of sedation in four areas: pain or stress, movement, consciousness, and sedation side effects. In this manner the completeness of the quality of sedation can be assessed comprehensively. Inter- and intra-rater reliability, construct validity, and criterion validity were all excellent. Thus the Dartmouth scale is a well-validated tool, best suited for research because of its comprehensive nature but nonetheless applicable to routine use for procedural sedation. Assessment of this scale at frequent intervals allows for careful tracking of state of sedation, effectiveness of sedation, uncontrolled side effects, and the timing of induction of sedation and recovery. These data can be helpful in quantifying the quality of sedation and best practices. The Dartmouth scale was validated against the COMFORT score (see above), a previously well-validated scale of pain and sedation in pediatric intensive care patients. Scores range from 5 (inadequate sedation with high levels of pain, stress,

Table 5.7 The Dartmouth Operative Conditions Scale

Patient state	Observed behaviors/points			
Pain/stress	Eyes closed or calm expression: 0	Grimace or frown: 1	Crying, sobbing, or screaming: 2	–
Movement	Still: 0	Random little movement: 1	Major purposeful movement: 2	Thrashing, kicking, or biting: 3
Consciousness	Eyes open: 0	Ptosis, uncoordinated, or "drowsy": −1	Eyes closed: −2	–
Sedation side effects	SpO_2 <92 %: −1	Noise with respiration: −1	Respiratory pauses: >10 s: −1	BP decrease of >50 % from baseline: −1

Source: Data from Cravero et al. [1]

and undesired movement) to −4 (dangerously oversedated). Scores in the +2 to −2 range are desired, with more negative scores associated with deeper levels of sedation needed for more painful procedures. These scores correlate with the goal zone desired during sedation (Figure 5.1).

Modified Aldrete Score as a Sedation Scale

The modified Aldrete score has been in widespread use as a postanesthesia recovery score for many years (see below). Because of its near universal use for this purpose it is familiar to many sedation practitioners, and although not designed specifically for this purpose, it is also in wide use as both a sedation scale during the procedure itself, and as a recovery and discharge scale for procedural sedation in children. This score has not been independently validated either in children or for procedural sedation.

Processed EEG Monitors: The Bispectral Index

Several investigators have studied whether the Bispectral Index (BIS, Aspect Corporation, Newton, MA), a single-lead processed EEG that uses a proprietary algorithm to assign a number from 100 (completely awake) to 0 (isoelectric EEG), is meant to objectively assess the depth of sedation or anesthesia (Figure 5.3). The appeal of processed EEG methods is that they are continuous, objective, and do not require awakening of the patient for assessment. Problems with BIS include that the sensor, when applied to the forehead, must be secured with firm pressure to yield a valid signal, and this in itself may awaken the patient. And, its ferromagnetic electrode array is not compatible with MRI magnetic fields. Malviya et al. [17] pooled data from four studies comparing UMSS to BIS values for 3,373 observations for 248 children aged 1 month to 18 years. The patients underwent a variety of diagnostic and therapeutic procedures, with a number of different agents including chloral hydrate, midazolam, pentobarbital, propofol, ketamine, and opioids. There was a moderate inverse correlation between BIS and UMSS in all age groups; however, there was not a difference between BIS values and UMSS 3 and 4 (moderate and deep sedation) in all age groups, and UMSS 0 and 1 (awake versus light sedation) in infants. Furthermore, there was a poor correlation between BIS and UMSS with ketamine or opioid use. The authors concluded that BIS values must be interpreted with caution during procedural sedation in infants and children, with particular attention needed to the age of patient and agents used.

Haberland et al. [18] also compared BIS values and UMSS scores in 35 pediatric dental patients undergoing sedation with nasal mask nitrous oxide in addition to various other regimens, including oral hydroxyzine or chloral hydrate, transmucosal fentanyl, or intravenous (IV) meperidine or midazolam. Mean age of patients was 4.2 years, and duration of sedation was 2.5 h. BIS and UMSS values were recorded every 5 min during sedation, and during the 1-h recovery they were assessed every 15 min, resulting in 455 paired observations. There was a significant decline in BIS and UMSS from baseline to start of the dental procedure, and increase after the procedure, ($p<0.0001$), and moderate kappa coefficient of the percentage agreement between BIS values and UMSS scores 0, 1, 2, and 3–4 (0.26, 95 % confidence interval 0.21–0.20, $p<0.0001$). However, there was no difference in BIS values between UMSS 2 and 3, 2 and 4, or 3 and 4. Therefore, as in the Malviya study [17] cited previously, the authors concluded that BIS did not distinguish between moderate and deep sedation, and was best utilized to distinguish between mild and moderate sedation.

Mason et al. [19] compared BIS values immediately after an MRI or CT scan in 86 children greater than 1 year of age undergoing sedation with pentobarbital as a sole agent, who had achieved Ramsay scores of 4 or 5 (moderate or deep sedation). There was no significant difference between the sedation scores and BIS values (63 ± 12 and 64 ± 15 for RSS 4 and 5, respectively, $p=0.64$). There was a wide variation in BIS values of 31–90. The authors concluded that the BIS had limited ability to distinguish moderate from deep sedation levels.

These studies and other data suggest that BIS has limited utility in assessing sedation level in children [20].

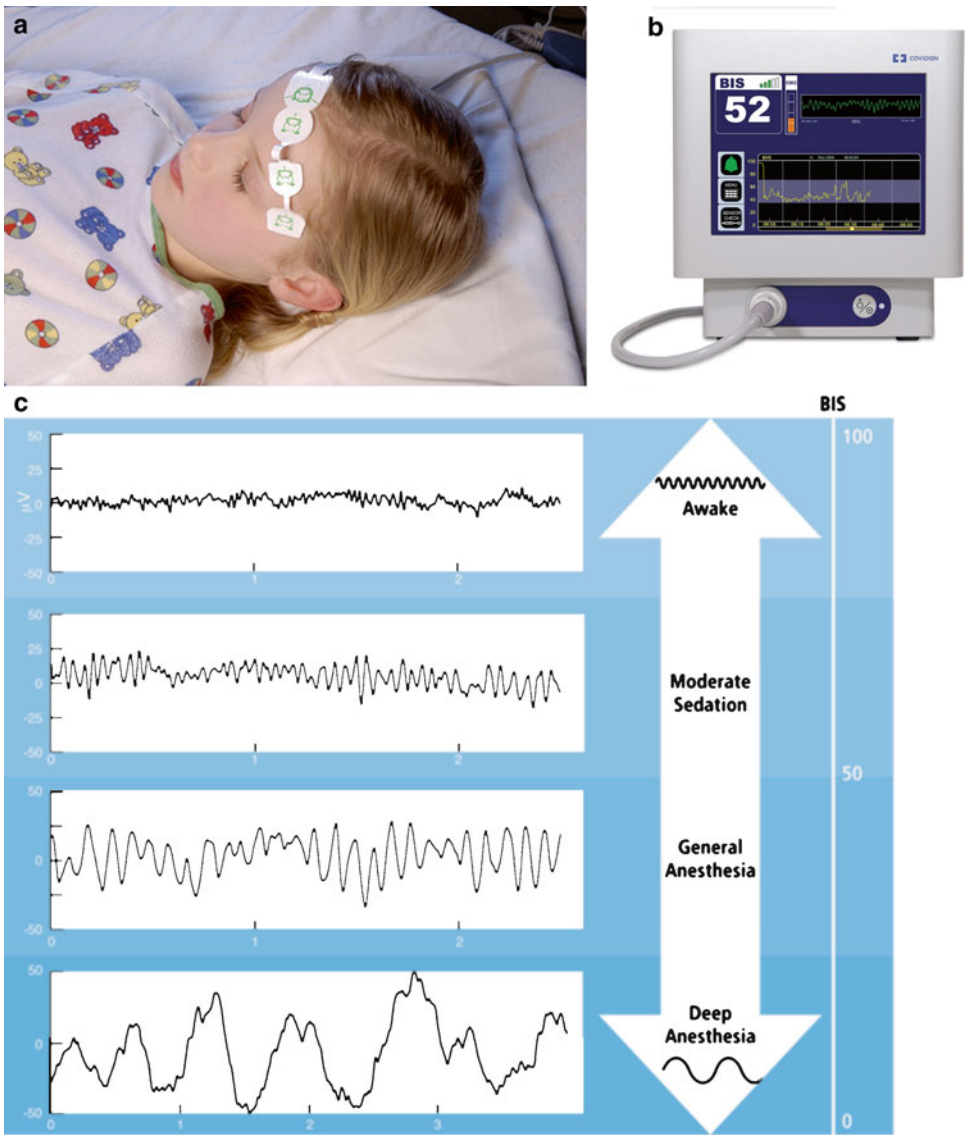

Fig. 5.3 (**a**) The bispectral index® (BIS™) pediatric sensor. A one-channel EEG monitor with reference electrode applied to the forehead. (**b**) The BIS™ monitor displays a single processed EEG number from 0 to 100, as well as the raw EEG waveform, and signal strength indicator. (**c**) The sedation continuum using the BIS algorithm. See text for details (Copyright ©2013 Covidien. All rights reserved. Used with the permission of Covidien)

This is due to several factors, including the age-related developmental differences in the EEG between infants, children, and adults; and the different values achieved with similar levels of sedation with different agents [21].

Auditory Evoked Potentials

Auditory evoked potentials (AEP) demonstrate a correlation with depth of hypnosis in adult patients, and these monitors are becoming available for clinical use. In a study of 75 children aged 1–16 years undergoing urologic surgery with propofol-remifentanil anesthesia, Chueng et al. measured mid-latency AEP produced by a 90 dB click delivered through headphones at a frequency of 6.9 Hz [22]. They compared AEP to BIS during anesthesia, and to the UMSS during emergence. Propofol target-controlled infusion levels were tested, and the BIS demonstrated a stronger correlation than AEP with predicted propofol plasma levels during the intraoperative period (BIS 0.36, AEP 0.21, $p = 0.010$). The BIS and AEP performed similarly in predicting UMSS ≤ 1 (sedated versus awake) during emergence from anesthesia. However, the AEP was inferior to BIS at UMSS 2, 3, or 4 (distinguishing light, moderate, or deep sedation). Additional study of this modality in sedated children is necessary to determine its utility for procedural sedation.

Other Sedation Scales

There are a number of additional sedation scales, such as the Harris, modified Glasgow Coma Scale, Cambridge,

Bloomsbury, Neurobehavioral Assessment Scale, Richmond Agitation-Sedation Scale, PRST (pressure, rate, sweat, tearing), Vancouver Sedative Recovery Scale, Motor Activity Assessment Scale, and many others [10]. These scales are largely not applicable to pediatric procedural sedation because they were designed either for adult or for pediatric ICU care, and many have not been validated. None were designed primarily for procedural sedation. Most also measure physiologic variables as part of the assessment, and thus are long and cumbersome to apply for procedural sedation. To underscore the difficulty in selecting and employing valid subjective sedation scales, Robinson et al. performed a formal psychometric analysis of 11 sedation scales for critically ill adults. [23] A 0–20 scoring system was applied using published data from each scale to assess quality of development of each scale, including item selection and content validation, reliability, construct validity, feasibility of use, and scale relevance/impact. The Richmond Sedation–Agitation Scale had "very good" psychometric properties, with a score of 19.5. The Vancouver Scale (14.3) and Ramsay Scale (13.2) had "moderate" psychometric properties, and the OAA/S Scale (3.7) had a "very low" score. Similar assessment has not been performed for pediatric procedural sedation scales.

Objective, Physiologically Based Sedation Scales

As is evident from the prior discussion, the ideal sedation scale for pediatric patients undergoing procedural sedation does not exist at this time. Limitations of all scales include the inherent subjectivity in assessing the patient's response to verbal or tactile stimulation, which is included in most of the scales. In addition, the arousal of the patient necessary for assessment can interfere with both the sedation level itself, and interrupt the procedure. Also, many scales have not been validated, and interobserver reliability is thus in question. Finally, the ability to discriminate safe from dangerous levels of sedation (i.e., deep sedation from general anesthesia) is limited and has not been demonstrated for most of the scales, or for processed EEG monitoring, and thus the goal of preventing airway and cardiovascular complications is also problematic using current schema. Recently, Green and Mason [24] have advocated a reformulation of the sedation continuum. Instead of basing the scale on subjective or semiobjective criteria, scales based on objective physiologic monitoring would be devised (Table 5.8). Because most sedation-related adverse events begin with airway and ventilatory problems, capnography would be able to detect abnormalities (i.e., upper airway obstruction from lax pharyngeal muscle tone and tongue resulting in cessation of airflow) at its earliest occurrence (Figure 5.4). This is substantially before arterial desaturation is detected by pulse oximetry, or bradycardia or hypotension from prolonged hypoxia. Portable capnographic monitoring is easily performed via widely available divided nasal cannulae made in infant, pediatric, and adult sizes, and can be used in all situations, including the MRI suite [25]. Indeed, capnography monitoring for procedural sedation has been demonstrated to improve safety in children. Lightdale et al. [26] reported 174 moderate sedations in children for gastrointestinal endoscopy procedures, with half receiving capnographic monitoring and an intervention protocol and the other half blinded capnography with only rescue intervention, in a prospective randomized study design. Eleven percent of patients in the intervention arm had $SpO_2 < 95$ % for greater than 5 s, versus 24 % in the control arm ($p < 0.03$).

In a meta-analysis of five randomized trials in adults undergoing procedural sedation in 332 patients, Waugh et al. [27] found that respiratory depression events were 6.5–17.6 times more likely to occur without capnographic monitoring, providing significant support for the concept that capnographic monitoring is effective at detecting dangerous increases in depth of sedation. Additional controlled study would be desirable in the pediatric population, but it is highly likely that this principle would have the same strong evidence as in the adult population.

Potential capnographic criteria for increasing levels of sedation would include age-appropriate respiratory rate determined by the capnograph (slower means deeper sedation), significant decreases in end-tidal CO_2 values (signifying smaller tidal volumes or partial airway obstruction, or in worst case scenario low cardiac output), or complete absence of end-tidal CO_2, associated with complete airway obstruction. Specific, focused research would be required to stratify levels of risk based on capnographic and other parameters. A multidisciplinary effort would be required to develop updated guidelines.

Recovery and Discharge Scales

The concept of postanesthesia recovery after a surgical procedure has been expanded to procedural sedation, and scales originally designed to assess anesthesia recovery readiness for discharge to a hospital ward (Aldrete, Steward—see later) have also been expanded to include recovery from sedation, and readiness for discharge to home after procedural sedation without a painful operative procedure, e.g., an outpatient brain MRI for assessment of seizure disorder or developmental delay. Obviously the requirements for discharge can be very different in these two circumstances. The outpatient should be able to resume quiet "normal" activities before discharge from sedation, i.e., spontaneous wakefulness, eating, voiding, drinking, and ambulating with assistance. The inpatient may not need to meet all these requirements. This raises the question of whether these types of recovery scales have ever been validated for the purpose of discharge readiness, and in the case of the postanesthesia

Table 5.8 Preliminary sample schematic for an Objective Risk Assessment Tool for Sedation (ORATS). The choice of four levels here is arbitrary and for illustration purposes only; the final tool would contain the minimum number of discrete levels with independent predictive value

New levels (as yet unnamed)	Escalating risk of serious adverse event	Physiological monitoring parameters (singular or combination)[a]	Recommended sedationist skill set	Recommended resources[b]
1	≤1:10,000	Consistent with normal awake pattern and frequency	Ability to observe and interpret the agreed-upon physiological monitoring parameters	Appropriate for risk level
2	1:1,000	← Objective monitoring predicts this level of risk	Skills appropriate for maintaining sedation at this risk level and for rescuing from the subsequent level	Appropriate for risk level
3	1:100	← Objective monitoring predicts this level of risk	Skills appropriate for maintaining sedation at this risk level and for rescuing from the subsequent level	Appropriate for risk level
4	≥1:10	← Objective monitoring predicts this level of risk	Skills appropriate for maintaining a patient at this risk level	Appropriate for risk level

[a]Focused research would be required to validate the specific variables, parameters, and thresholds that predict the progressive levels of serious adverse event risk. Evaluation of capnography, for example, could include but not be limited to evaluation of waveform, frequency, pattern, and/or numerical value on inspiration or expiration

[b]To be determined at each level by consensus panel and would include but not be limited to recommendations on adjuvant personnel, intravenous access, availability of rescue medications, and airway equipment

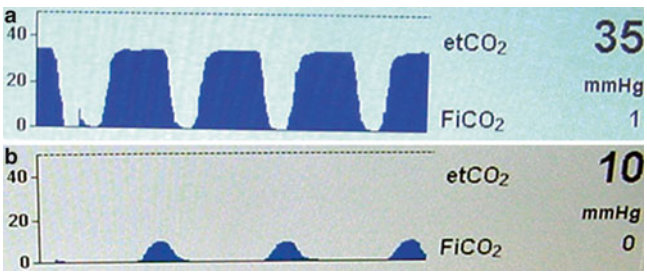

Fig. 5.4 (**a**) Normal capnograph in a sedated patient, obtained with divided nasal cannula. Respiratory rate of 16, and end-tidal CO_2 of 35 mmHg with full "area under the curve" waveform with long plateau signifies unobstructed airway and adequate tidal volumes in this patient. (**b**) Capnograph from a patient with significant respiratory depression. Respiratory rate is 10 per minute, and end-tidal CO_2 is only 10 mmHg, likely signifying small tidal volumes

recovery scales, they have not. Besides assessing readiness to resume "normal" activities, the purpose of discharge and recovery scales is to prevent adverse events. Respiratory and cardiac events, including death, have occurred after premature discharge following procedural sedation [2]. These events have mostly occurred when a long-lasting (long half-life) sedative such as chloral hydrate has been given. This can result in the child being unable to spontaneously unobstruct his or her airway.

The Aldrete score was introduced in 1970 [28], validated in adults, and quickly became the standard for PACU discharge from surgery for both adults and children. It rates five domains: activity, respiration, circulation, consciousness, and color. A point score of 0, 1, or 2 is given in each domain for a maximum score of 10 (Table 5.9). With the introduction of pulse oximetry, the score was modified to include SpO_2 instead of color [29]. Because of its familiarity, it has been used as a score for discharge from sedation as well. A score of 9 or 10 is standard to determine readiness for discharge.

The Maintenance of Wakefulness Test was devised to assess daytime somnolence in patients with sleep disorders. Polysomnography is used to measure the time taken for an adult patient to fall asleep in a dark, quiet room, after they have been instructed to stay awake [30]. The Modified Maintenance of Wakefulness Test (MMWT) is a new modification of the original test, which was devised to help

Table 5.9 The modified Aldrete Scale

Domain	Response	Points
Activity	Able to move four extremities voluntarily or on command	2
	Able to move two extremities voluntarily or on command	1
	Unable to move extremities voluntarily or on command	0
Respiration	Able to breathe deeply and cough freely	2
	Dyspnea or limited breathing	1
	Apneic	0
Circulation	BP ± 20 % of preanesthetic level	2
	BP ± 20–49 % of preanesthetic level	1
	BP ± 50 % of preanesthetic level	0
Consciousness	Fully awake	2
	Arousable on calling	1
	Not responding	0
O_2 saturation	Able to maintain $SpO_2 > 92$ % on room air	2
	Needs O_2 inhalation to maintain $SpO_2 > 90$ %	1
	$SpO_2 < 90$ % even with O_2 supplement	0
Total		

Table 5.10 The Steward simplified postanesthetic recovery score

Domain	Level	Points
Consciousness	Awake	2
	Responding to stimuli	1
	Not responding	0
Airway	Coughing on command or crying	2
	Maintaining good airway	1
	Airway requires maintenance	0
Movement	Moving limbs purposefully	2
	Nonpurposeful movements	1
	Not moving	0
Total		

Source: Reprinted from Steward DJ. A simplified scoring system for the postoperative recovery room. Can Anaesth Soc J. 1975;22:111–3, with kind permission of Springer Science + Business Media

determine discharge readiness in children. In this score, the patient has to maintain a state of wakefulness or alertness in a quiet room for a minimum of 20 min after last being awakened. Malviya et al. studied 29 infants receiving either chloral hydrate or midazolam/diphenhydramine oral sedation for echocardiogram. The modified wakefulness test was combined with the UMSS sedation scale (see above) to devise new, modified discharge criteria, which were compared with the standard hospital sedation discharge criteria. A UMSS of 0 or 1 (awake or minimally sedated), combined with a modified wakefulness test of 20 min, was required to meet these criteria. These data were compared with the bispectral index, with a value of 90 or higher signifying adequate wakefulness for discharge. Standard discharge criteria were stable vital signs, oxygen saturation, and level of consciousness compared to presedation baseline. Also, the patient must maintain a patent air way, manage oral secretions independently, or demonstrate the ability to swallow or demonstrate a gag reflex. In addition, the patient should be able to move or ambulate safely consistent with their presedation baseline. Combining the MMWT and UMSS criteria correctly identified infants with BIS values >90.88 % of the time, compared with only 55 % of children assessed as "street ready" according to usual hospital discharge criteria [30]. In addition, time in recovery to discharge was only 16 ± 13 min using the standard discharge criteria versus 75 ± 76 min ($p \leq 0.007$) using the revised criteria. This very interesting study reveals that many children discharged using standard criteria may indeed not truly be back to their baseline status, and thus be potentially at risk for delayed complications. These more objective discharge criteria would need to be studied in a much larger group of patients to determine whether late complications were truly reduced.

Steward [31], citing the difficulty of assessing patient color (pulse oximetry was not available at the time), and the sometimes inconsistent relationship of blood pressure to recovery from anesthesia, proposed a simplified score (Table 5.10). The original publication was a short description of the scale, and its rationale, but there was no actual patient data attempting to validate it as had been done in the original Aldrete score paper. Despite its use in a number of pediatric studies [32, 33] it has not been independently validated.

In a recent comprehensive review of assessment of recovery from anesthesia or sedation in infants, Sury et al. [34] cited all of the above-noted recovery scales, and several others including the Behavioral Arousal Threshold Scale, Children's Hospital of Wisconsin Sedation Scale, and Simple Pediatric Analog Sedation Score. They concluded that besides the UMSS and MMWT, none of the many other recovery/discharge scales were specifically validated in infants. Additional research to develop criteria for awakening from anesthesia and sedation specific to infants is needed.

Table 5.11 summarizes the sedation, recovery, and discharge scales reviewed above including parameters assessed, utility in various phases of the sedation process, and strengths and limitations.

A Practical Approach to Sedation Scales and Discharge Scores

Synthesizing the concepts presented in this chapter, and considering the demands of a busy sedation service that must be efficient as well as safe, I propose a practical approach to sedation scales and recovery and discharge scores. If moderate or deep sedation by a nonanesthesiologist is planned (the vast majority of pediatric sedations, as only older children undergoing non-painful procedures, will undergo light sedation), one suggested approach is to use a validated simple level of consciousness scale (Ramsay, UMSS, or Aldrete), at least every 15 min or when a change in level of sedation occurs, i.e., after an additional dose of sedative. In addition

Table 5.11 Characteristics of sedation and recovery/discharge scales

Scale	Parameters measured	Sedation, recovery, or discharge scale	Strengths	Limitations	Validated?	References
Ramsay Sedation Scale	Level of consciousness	S, R, D	Simple	No physiologic parameters, must awaken patient	Adults	[6, 9, 10]
OAA/S	Responsiveness, speech, facial expression, eyes	S, R, D	Well validated, relatively simple	No physiologic parameters, must awaken patient	Adults	[11–13]
Modified OAA/S	Responsiveness only	S, R, D	Simple	No physiologic parameters, must awaken patient	Adults	[11]
COMFORT	Alertness, agitation, and multiple physiologic parameters	S	Comprehensive, well validated	Very complex, time consuming, not appropriate for routine procedural sedation	Children	[16]
UMSS	Level of consciousness	S, R, D	Relatively simple	Does not rate pain or physiologic parameters, must arouse patient	Children	[14]
Dartmouth	Pain, movement, consciousness, physiologic parameters	S	Comprehensive, rates pain and movement	Relatively complex	Children	[1]
Modified Aldrete	Activity, respiration, circulation, consciousness, oxygen saturation	S, R, D	Widespread use and familiarity	Not designed as a sedation scale	Adults	[26, 27]
Modified Maintenance of Wakefulness	Maintenance of alertness	R, D	Simple	Requires at least 20 min to administer	Children	[28]
Steward	Consciousness, airway, movement	S, R, D	Simple	No assessment of oxygen saturation	No	[29]
Bispectral Index®	Processed electroencephalogram	S, R, D	Semiobjective; one simple number reported	Continuous, no need to awaken patient	Adults, incomplete validation in young children; not compatible with MRI	[17–20]
Capnography based	End-tidal CO_2	S, R	Objective; sensitive indicator of respiratory depression/obstruction	Many artifacts; equipment not always available	Adults and children, as monitor	[22–24]

S sedation phase, *R* recovery phase, *D* discharge phase, *OAA/S* Observer's Assessment of Alertness/Sedation Scale, *UMSS* University of Michigan Sedation Scale

to standard monitoring with continuous ECG and SpO_2, automated oscillometric blood pressure measurement at least every 5 min, the use of end-tidal CO_2 monitoring via a divided nasal cannula is encouraged. The sedation scale is not assessed if it would arouse the patient such that it would interrupt the procedure (i.e., MRI sequence) and the patient has not exhibited any signs of oversedation (i.e., hypotension or respiratory depression). In this way, the frequent physiologic monitoring is used instead of a more extensive and difficult to administer scale that scores the vital signs, i.e., COMFORT scale. A recovery and discharge score is also used—a modified Aldrete score of 9 or 10, a UMSS of 0 or 1, or a modified wakefulness test of 20 min. It may be simplest to use the same scale for both the sedation and the recovery phases, i.e., the Ramsey, UMSS, or modified Aldrete could be used throughout. The exact tests and scales are determined by institutional preferences. The sedation and recovery personnel must also be familiar with the patient's baseline heart rate, blood pressure, respiratory rate, and oxygen saturation, as well as the age-related normal ranges. Whatever scales are decided upon, they are not a substitute for well-trained sedation practitioners' exercising skill and vigilance, combined with continuous physiological monitoring to ensure the best outcomes.

Conclusion

Regular use of a sedation, recovery, and discharge scales for pediatric procedural sedation is essential, given the wide variety of practitioners involved, as well as the variety of procedures and agents used. Uniform assessment will minimize

oversedation and complications, but also ensure that adequate levels of sedation and analgesia are achieved. In addition, only by more objective measurement of sedation will hospitals and departments have accurate data to improve the quality and outcomes of their programs. In the future, more objective physiologically based scales, utilizing capnography, should be devised. Any research on new agents or approaches must be validated using sedation scores that are objective and allow scientific comparison of different methods.

References

1. Cravero JP, Blike GT, Surgenor SD, Jensen J. Development and validation of the Dartmouth Operative Conditions Scale. Anesth Analg. 2005;100:1614–21.
2. Cote CJ, Karl HW, Notterman DA, et al. Adverse sedation events in pediatrics: analysis of medications used for sedation. Pediatrics. 2000;106:633–44.
3. 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):e42.
4. Malviya S, Voepel-Lewis T, Tait AR. Adverse events and risk factors associated with sedation of children by non-anesthesiologists. Anesth Analg. 1997;85:1207–13.
5. Cote CJ, Wilson S; the Work Group on Sedation. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures: an update. Pediatrics. 2006;118:2587–602.
6. Kaplan RF, Cravero JP, Yaster M, Cote C. Sedation for diagnostic and therapeutic procedures outside the operating room, Chap. 48. In: Cote CJ, Lerman J, Todres ID, editors. A practice of anesthesia for infants and children. Philadelphia: Saunders Elsevier; 2009. p. 1023–48.
7. Reeves ST, Havidich JE, Tobin DP. Conscious sedation of children with propofol is anything but conscious. Pediatrics. 2004;114:e74–6.
8. Cravero JP, Beach ML, Blike GT, et al. The incidence and nature of adverse events during pediatric sedation/anesthesia with propofol for procedures outside the operating room: a report from the Pediatric Sedation Research Consortium. Anesth Analg. 2009;108:795–804.
9. Ramsay MA, Savege TM, Simpson BR, Goodwin R. Controlled sedation with alphaxalone-alphadolone. BMJ. 1974;2:656–9.
10. De Jonghe B, Cook D, Appere-De-Vecchi C, et al. Using and understanding sedation scoring systems: a systematic review. Intensive Care Med. 2000;26(3):275–85.
11. Chernik DA, Gillings D, Laine H, et al. Validity and reliability of the observer's assessment of alertness/sedation scale: study with intravenous midazolam. J Clin Psychopharmacol. 1990;10:244–51.
12. Shannon M, Albers G, Burkhart K, et al. Safety and efficacy of flumazenil in the reversal of benzodiazepine-induced conscious sedation. J Pediatr. 1997;131:582–6.
13. Madan R, Kapoor I, Balachander S, et al. Propofol as a sole agent for pediatric day care diagnostic ophthalmic procedures: comparison with halothane anesthesia. Paediatr Anaesth. 2001;11:671–7.
14. Malviya S, Voepel-Lewis T, Tait AR, et al. Depth of sedation in children undergoing computed tomography: validity and reliability of the University of Michigan Sedation Scale (UMSS). Br J Anaesth. 2002;88:241–5.
15. Sadhasivam S, Ganesh A, Robison A, et al. Validation of the bispectral index monitor for measuring the depth of sedation in children. Anesth Analg. 2006;102:383–8.
16. Ambuel B, Hamlett KW, Marx CM, Blumer JL. Assessing distress in pediatric intensive care environments: the COMFORT scale. J Pediatr Psychol. 1992;17:95–109.
17. Malviya S, Voepel-Lewis T, Tait AR, Watcha MF, Sadhasivam S, Friesen RH. Effect of age and sedative agent on the accuracy of bispectral index in detecting depth of sedation in children. Pediatrics. 2007;120:e461–70.
18. Haberland CM, Baker S, Liu H. Bispectral index monitoring of sedation depth in pediatric dental patients. Anesth Prog. 2011;58:66–72.
19. Mason KP, Michna E, Zurakowski D, et al. Value of bispectral index monitor in differentiating between moderate and deep Ramsay Sedation Scores in children. Paediatr Anaesth. 2006;16:1226–31.
20. Malviya S, Voepel-Lewis T, Tait AR. A comparison of observational and objective measures to differentiate depth of sedation in children from birth to 18 years of age. Anesth Analg. 2006;102:389–94.
21. Davidson AJ. Monitoring the anaesthetic depth in children—an update. Curr Opin Anaesthesiol. 2007;20:236–43.
22. Cheung YM, Scoones GP, Hoeks SE, et al. Evaluation of the aepEX™ monitor of hypnotic depth in pediatric patients receiving propofol-remifentanil anesthesia. Paediatr Anaesth. 2013;23:891–7.
23. Robinson BR, Berube M, Barr J, et al. Psychometric analysis of subjective sedation scales in critically ill adults. Crit Care Med. 2013;41(9 Suppl 1):S16–29.
24. Green SM, Mason KP. Reformulation of the sedation continuum. JAMA. 2010;303:876–7.
25. Mason KP, Burrows PE, Dorsey MM, et al. Accuracy of capnography with a 30 foot nasal cannula for monitoring respiratory rate and end-tidal CO2 in children. J Clin Monit Comput. 2000;16:259–62.
26. Lightdale JR, Goldmann DA, Feldman HA, et al. Microstream capnography improves patient monitoring during moderate sedation: a randomized, controlled trial. Pediatrics. 2006;117:e1170–8.
27. Waugh JB, Epps CA, Khodneva YA. Capnography enhances surveillance of respiratory events during procedural sedation: a meta-analysis. J Clin Anesth. 2011;23:189–96.
28. Aldrete JA, Kroulik D. A postanesthetic recovery score. Anesth Analg. 1970;49:924–34.
29. Aldrete JA. The post-anesthesia recovery score revisited. J Clin Anesth. 1995;7:89–91.
30. Malviya S, Voepel-Lewis T, Ludomirsky A, et al. Can we improve the assessment of discharge readiness?: a comparative study of observational and objective measures of depth of sedation in children. Anesthesiology. 2004;100:218–24.
31. Steward DJ. A simplified scoring system for the postoperative recovery room. Can Anaesth Soc J. 1975;22:111–3.
32. Finkel JC, Cohen IT, Hannallah RS, et al. The effect of intranasal fentanyl on the emergence characteristics after sevoflurane anesthesia in children undergoing surgery for bilateral myringotomy tube placement. Anesth Analg. 2001;92:1164–8.
33. Bevan JC, Veall GR, Macnab AJ, et al. Midazolam premedication delays recovery after propofol without modifying involuntary movements. Anesth Analg. 1997;85:50–4.
34. Sury MR, Bould MD. Defining awakening from anesthesia in infants: a narrative review of published descriptions and scales of behavior. Paediatr Anaesth. 2011;21:364–72.