



Outcomes following implementation of a pediatric procedural sedation guide for referral to general anesthesia for magnetic resonance imaging studies

[Jocelyn Grunwell](#), *Emory University*
[Neelima K. Marupudi](#), *Emory University*
[Rohan V. Gupta](#), *Mercer University*
[Curtis D. Travers](#), *Emory University*
[Courtney E. McCracken](#), *Emory University*
[Julie Williamson](#), *Emory University*
[Jana Stockwell](#), *Emory University*
[James Fortenberry](#), *Emory University*
[Kevin Couloures](#), *Yale University*
[Joseph Cravero](#), *Harvard University*

Only first 10 authors above; see publication for full author list.

Journal Title: Pediatric Anesthesia
Volume: Volume 26, Number 6
Publisher: Wiley | 2016-04-07, Pages 628-636
Type of Work: Article | Post-print: After Peer Review
Publisher DOI: 10.1111/pan.12903
Permanent URL: <https://pid.emory.edu/ark:/25593/s2zrv>

Final published version: <http://dx.doi.org/10.1111/pan.12903>

Copyright information:

© 2016 John Wiley & Sons Ltd. This is the peer reviewed version of the following article, which has been published in final form. This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Self-Archiving.

Accessed November 20, 2019 8:14 PM EST



Published in final edited form as:

Paediatr Anaesth. 2016 June ; 26(6): 628–636. doi:10.1111/pan.12903.

Outcomes following implementation of a pediatric procedural sedation guide for referral to general anesthesia for magnetic resonance imaging studies

Jocelyn R. Grunwell¹, Neelima K. Marupudi², Rohan V. Gupta³, Curtis D. Travers², Courtney E. McCracken², Julie L. Williamson^{1,4}, Jana A. Stockwell¹, James D. Fortenberry¹, Kevin Couloures⁵, Joseph Cravero⁶, and Pradip P. Kamat¹

¹Division of Critical Care Medicine, Department of Pediatrics, Emory University School of Medicine and Children's Healthcare of Atlanta at Egleston, Atlanta, GA, USA

²Department of Pediatrics, Emory University School of Medicine, Atlanta, GA, USA

³Department of Medicine, Mercer University School of Medicine, Macon, GA, USA

⁴Department of Anesthesia, Emory University School of Medicine, Atlanta, GA, USA

⁵Pediatric Sedation Services, Yale School of Medicine and Yale New Haven Children's Hospital, New Haven, CT, USA

⁶Department of Anesthesia, Harvard School of Medicine and Boston Children's Hospital, Boston, MA, USA

Summary

Background/Aims—Guidelines for referral of children to general anesthesia (GA) to complete MRI studies are lacking. We devised a pediatric procedural sedation guide to determine whether a pediatric procedural sedation guide would decrease serious adverse events and decrease failed sedations requiring rescheduling with GA.

Methods—We constructed a consensus-based sedation guide by combining a retrospective review of reasons for referral of children to GA ($n = 221$) with published risk factors associated with the inability to complete the MRI study with sedation. An interrupted time series analysis of 11 530 local sedation records from the Pediatric Sedation Research Consortium between July 2008 and March 2013, adjusted for case-mix differences in the pre- and postsedation guide cohorts, evaluated whether a sedation guide resulted in decreased severe adverse events (SAE) and failed sedation rates.

Results—A significant increase in referrals to GA following implementation of a sedation guide occurred ($P < 0.001$), and fewer children with an ASA-PS class III were sedated using procedural

Correspondence: Jocelyn R. Grunwell, Division of Critical Care Medicine, Department of Pediatrics, Emory University School of Medicine, Children's Healthcare of Atlanta at Egleston, 1405 Clifton Road NE, Atlanta, GA 30322, USA jgrunwe@emory.edu.

Ethics approval: Children's Healthcare of Atlanta IRB #13-014 expedited approval was obtained for this study. The Pediatric Sedation Research Consortium had no role in the design, collection, analysis, and interpretation of data, writing of the manuscript, or the decision to submit this manuscript for publication.

Conflict of interest: Dr. J.R. Grunwell is supported by T32GM095442. Dr. J. Cravero is a section editor of *Pediatric Anesthesia*.

sedation ($P < 0.001$). There was no decrease in SAE ($P = 0.874$) or in SAE plus airway obstruction with concurrent hypoxia ($P = 0.435$). There was no change in the percentage of failed sedations ($P = 0.169$).

Conclusions—More studies are needed to determine the impact of a sedation guide on pediatric procedural sedation services.

Keywords

pediatric; procedural sedation; adverse events; airway obstruction; laryngospasm; propofol

Introduction

There is a high demand for pediatric procedural sedation services to complete imaging studies and procedures outside of the operating room. The utilization of pediatric procedural sedation results in alleviation of anxiety, adequate sedation to ensure quality imaging, and adequate analgesia for painful procedures (1–3). Our institution performs nearly 2 500 magnetic resonance imaging (MRI) studies with sedation annually; however, there is not enough anesthesia coverage to meet the demand for all pediatric procedural sedation. Because of the demand for pediatric procedural sedation, providers from disciplines such as pediatric emergency medicine and pediatric intensive care provide sedation at our institution. Patient selection for pediatric procedural sedation vs referral to GA is an important issue as last minute cancelations and inappropriate referrals to pediatric procedural sedation result in family dissatisfaction, unproductive use of sedation team time, and inefficient use of the MRI scanner.

There are several single-center and multi-center studies conducted through the Pediatric Sedation Research Consortium that characterize the experience and adverse event profile of pediatric procedural sedation (2,4–16). These studies have overwhelmingly demonstrated a high degree of efficacy and safety when pediatric procedural sedation is provided by nonanesthesiologist sedation providers in coordinated teams (2,6,9,11). In addition, there are several articles detailing risk factors for failing sedation (4,5,8,13). The diverse nature of pediatric procedural sedation services in terms of provider subspecialty, credentialing, services performed, and location of pediatric procedural sedation has precluded development of a pediatric procedural sedation standard to guide patient selection for pediatric procedural sedation. We combined characteristics of children who were unable to complete pediatric procedural sedation, defined as a failed sedation encounter, with the characteristics of children referred immediately to general anesthesia (GA), to develop a pediatric procedural sedation guide for referral of patients to GA for MRI studies. We hypothesized that implementation of a pediatric procedural sedation guide would: (i) increase referrals to GA, (ii) decrease severe adverse events (SAE) during pediatric procedural sedation, and (iii) decrease the rate of failed sedations due to referral of children at higher risk of failed sedations due to SAE to GA for definitive airway management to complete their MRI study.

Methods

Study design and data collection

For development of pediatric procedural sedation guide, we conducted a retrospective chart review, approved by the Institutional Review Board, of patients requiring sedation for MRI at Children's Healthcare of Atlanta at Egleston (CHOA-Eg). CHOA-Eg is a quaternary care, free-standing children's hospital in Atlanta, Georgia that provides inpatient and outpatient procedural sedation to approximately 3 500 pediatric patients per year. Sedation services are provided by sedation physicians trained in pediatric intensive care or pediatric emergency medicine that are credentialed at our institution to provide deep procedural sedation. Almost all patients in the service receive intravenous propofol by bolus dose for induction and maintenance with propofol infusion for the duration of the imaging study or procedure. MRI logs of patients undergoing GA were reviewed from January 2006 to June 2011 to identify reasons for physician referral to GA to complete their MRI study.

Patients were included in this study from the ages of birth to 21 years of age. Characteristics of patients compiled included age, gender, weight, ASA-PS class, genetic disorders, metabolic disorders, and history of prematurity. Some genetic disorders are associated with craniofacial anomalies with the potential for having a difficult airway to intubate as part of rescue maneuvers. Metabolic disorders include obesity in the Pediatric Sedation Research Consortium database, and were included as a risk factor for failing sedation (8,17). Presence of asthma, current upper respiratory infection, gastroesophageal reflux disease, developmental delay, obstructive sleep apnea/snoring, or congenital heart disease were obtained from a standardized presedation history and physical evaluation form. An airway evaluation is performed by the sedation physician at the time of pediatric procedural sedation. Obesity was defined as a weight greater than the 95th percentile for sex and age based on the Centers for Disease Control and Prevention (CDC) growth curves (18). Procedure start and end times, type of procedure or imaging study, medications administered, complications experienced, and interventions performed during sedation were all obtained from a standard anesthesia record that was scanned into an electronic medical record.

To evaluate the impact of a pediatric procedural sedation guide on rate of referral to GA, we examined internal quality data on the number of patients referred to GA from July 2008 to March 2013. To capture the failed sedation rate and the SAE rate, we queried the Pediatric Sedation Research Consortium database to obtain our institution's data from the matching time period. The Pediatric Sedation Research Consortium database is a web-based prospective data collection tool with input from 44 self-selected participating member institutions that has been extensively described in the literature (2,7,9–11,17,19). In November 2011, the Pediatric Sedation Research Consortium changed its online data collection template. As a result, definitions of various adjunctive medications, primary diagnoses, and adverse events changed. Only variables used in the 2007–2011 (prepediatric procedural sedation guide) and the 2011–2013 (postpediatric procedural sedation guide) cohorts were used in this analysis. Implementation of the pediatric procedural sedation guide took place in April 2011 with a 3-month educational run-in period for the nurses trained in

the monitoring and care of children receiving sedation and analgesia to complete imaging studies or other procedures, herein referred to as pediatric procedural sedation. The sedation nurses contact a parent or guardian of the child that is to be sedated within 2–3 days of the scheduled sedation. During this telephone call, the sedation nurses ask the parent/guardian a series of screening questions to determine whether the child is a candidate for pediatric procedural sedation or whether the child should be referred to GA to complete the MRI study.

Outcomes and SAE measures

Successful completion of an MRI study and the incidence of SAE were documented as outcome measures. A severe adverse event was defined as any one of the following events: (i) laryngospasm, (ii) emergent airway intervention, (iii) unplanned hospital admission or increased level of care, (iv) aspiration, (v) emergency anesthesia consult, (vi) cardiac arrest, or (vii) death (2,9). We examined SAE in two ways: (i) SAE as defined above or (ii) SAE plus airway obstruction with concurrent hypoxia. These SAE are readily identifiable in the Pediatric Sedation Research Consortium database. Emergent airway intervention, as defined in the Pediatric Sedation Research Consortium database, includes tracheal intubation, positive pressure ventilation, or placement of another airway device such as a nasopharyngeal tube, an oral airway, or a laryngeal mask airway because of prolonged apnea or oxygen desaturation. Airway obstruction was defined as a lack of air movement in spite of respiratory effort, but may be resolved by repositioning of the patient or with a chin lift/jaw thrust maneuver. Laryngospasm was defined as a complete or near-complete lack of air movement with respiratory effort and/or stridor that was not relieved by chin repositioning or oral/nasal airway. Although multiple SAE could occur within a single course of sedation, the SAE rate was reported as the number of sedations in which at least one severe adverse event occurred out of the total number of sedations. Additionally, patients could have been sedated more than one time and appear multiple times in the dataset. For analysis, multiple sedations on the same patient were considered independent. Information was only available on pre-, intra-, and immediate postprocedure events, and long-term follow-up or any subsequent care related to a severe adverse event could not be obtained.

Statistical methods

Descriptive statistics were calculated using counts and frequencies, medians and interquartile ranges, or means and confidence intervals (CIs) for patient demographics and sedation procedure characteristics. Characteristics of children extracted from the Pediatric Sedation Research Consortium that were sedated prior to implementation of a pediatric procedural sedation guide were compared to those sedated following implementation of a pediatric procedural sedation guide using chi-square tests and Wilcoxon rank-sum tests, as appropriate. Failed sedation and SAE, excluding airway events and including airway events with concurrent hypoxia, were calculated as a rate per 100 sedates with associated 95% CIs. Given that we know the specific point at which the new screening guidelines went into effect, an interrupted time series analysis was performed to quantify the percentage of referrals to GA, failed sedations, and SAE excluding and including airway events. Interrupted time series analysis is a quasi-experimental approach for examining longitudinal effects of interventions. The interrupted time series analysis was performed using segment

regression analysis. The change in the rate of GA referrals pre- and postpediatric procedural sedation guide implementation was assessed by comparing the linear trend (i.e., slope) between time and GA referral rate pre- and postimplementation. Similar analyses were performed for SAE rates. We performed a sensitivity analysis to adjust for differences in patient characteristics and case-mix for pre- and postpediatric procedural sedation guide cohorts. Goodness of fit of the linear relationship is defined by r^2 . Variables controlled in the sensitivity analysis included: (i) weight, (ii) developmental delay, (iii) genetic/metabolic comorbidities (including obesity), (iv) asthma, and (v) seizures. Statistical analyses were performed using SAS 9.4 (Cary, NC, USA) and a P -value <0.05 was considered statistically significant unless otherwise noted.

Results

Development of a pediatric procedural sedation guide

A pediatric procedural sedation guide was developed by consensus of sedation providers based on internal analysis of risk factors of children who failed sedation (8), and are summarized in Figure 1. We also examined the demographics of children referred immediately to GA during the time period prior to implementation of the pediatric procedural sedation guide to determine the reasons for physician referral to GA for pediatric procedural sedation (Table 1). Children referred immediately to GA had an ASA-PS status III (66%), and many of these children were referred to cardiac (25.9%) and brain/spine MRI studies (68.2%). Many children were referred to GA by physician discretion for having single comorbidities or combinations of comorbidities such as being developmentally delayed (50%), having congenital heart disease (37.6%), a history of obstructive sleep apnea/snoring (26.7%), a history of prematurity (26.9%), and being obese (15.6%).

Referrals to GA increased after pediatric procedural sedation guide implementation

We performed an interrupted time series analysis of referrals to GA following implementation of the pediatric procedural sedation guide in the first quarter of 2011 (Figure 2). Prior to implementation of the pediatric procedural sedation guide, the change in the GA referral rate (per quarter) was relatively flat with a baseline rate of 6.4/100 sedations (95% CI: 5.3/100–7.4/100) and showed no trend over the preimplementation time period (slope: -0.18 , $P = 0.176$, $r^2 = 0.146$). Following the implementation of the pediatric procedural sedation guide, there was a steady increase in GA referrals as indicated by the increasing trend seen in Figure 2. The postpediatric procedural sedation guide rate of change in GA referrals was significantly higher compared to the prepediatric procedural sedation guide (slope: 0.89 , $P = 0.0003$, $r^2 = 0.865$).

Effects of pediatric procedural sedation guide implementation on SAE and failed sedation rates

We analyzed the percentage of children who had at least one severe adverse event during pediatric procedural sedation or a failed sedation during their MRI study pre- and postpediatric procedural sedation guide implementation. The overall rate of SAE and failed sedations are around 1% and 0.5%, respectively, indicating that SAE and failed pediatric procedural sedation are relatively infrequent. We examined SAE (defined in Methods) in two

ways: (i) SAE and (ii) SAE plus airway obstruction with concurrent hypoxia. Figure 3a shows that the test for trend prepediatric procedural sedation guide showed a decrease in the SAE rate that excluded airway events (slope: -0.100 ; $P = 0.029$, $r^2 = 0.256$). Interrupted time series analysis showed that the slope did not significantly change postpediatric procedural sedation guide (slope: 0.016 ; $P = 0.87$, $r^2 = 0.057$, overall model $r^2 = 0.528$). Figure 3b shows that the test for trend prepediatric procedural sedation guide also showed a decrease in the SAE rate that included airway events (slope: -0.118 ; $P = 0.01$, $r^2 = 0.397$); however, there was no change in trend postpediatric procedural sedation guide (slope: 0.074 ; $P = 0.435$, $r^2 = 0.222$, overall model $r^2 = 0.429$). The interrupted time series analysis for failed sedation is shown in Figure 3c. Because the sedation failure rate starts at $<1\%$, there is no detectable difference in failure rate despite examination of over 11 000 local sedation records (prepediatric procedural sedation guide: $r^2 = 0.104$, postpediatric procedural sedation guide: $r^2 = 0.004$, overall model $r^2 = 0.118$).

Characteristics of children before and after pediatric procedural sedation guide implementation

Finally, we examined the demographics and characteristics of children before and after implementation of a pediatric procedural sedation guide using prospectively collected the Pediatric Sedation Research Consortium data (Table 2). Following implementation of the pediatric procedural sedation guide, the percentage of children with an ASA-PS status III declined according to pediatric procedural sedation guide recommendations. Because the manner in which obstructive sleep apnea/snoring was reported in the Pediatric Sedation Research Consortium database changed after November 2011, we chose to exclude this variable from analysis due to discrepancies in data capture in the Pediatric Sedation Research Consortium database. We saw a slight decrease in children with a primary diagnosis of seizure disorder and a history of prematurity and no decline in the percentage of children with upper respiratory infections, cardiovascular, or gastrointestinal primary diagnoses undergoing pediatric procedural sedation following implementation of the pediatric procedural sedation guide. In addition, we are sedating a slightly higher percentage of children with developmental delay, metabolic/genetic syndromes (including obese patients), and asthmatics following implementation of the pediatric procedural sedation guide.

Discussion

Pediatric procedural sedation is a necessary component to successfully accomplish MRI studies in children. While the safety and efficacy of pediatric procedural sedation has been demonstrated in multiple studies from the Pediatric Sedation Research Consortium, there may be some children who would benefit from referral to pediatric anesthesia. There is little published information on GA referral patterns for MRIs in children, and no guidelines exist for referral of children to GA. We approached the matter of referral of children to GA by combining risk factors for failing sedation with the examination of reasons for referral of children to GA to complete MRI studies at our institution. The pediatric procedural sedation guide was devised using a consensus approach due to the paucity of evidence to determine specific referral criteria. An interrupted time series analysis demonstrated a significant

increase in referrals to GA for an MRI study following implementation of a pediatric procedural sedation guide; however, when we examined prospectively collected observational data using the entries into the Pediatric Sedation Research Consortium database from CHOA, we did not see an impact of our pediatric procedural sedation guide on SAE or failed sedation outcomes.

Several publications from the Pediatric Sedation Research Consortium have demonstrated the overall low risk of pediatric procedural sedation (2,7,9). The overall incidence of failing pediatric procedural sedation for an MRI study is 0.5–0.7% making it extremely difficult to detect a significant change in failed sedation rates as a consequence of an intervention. Previous Pediatric Sedation Research Consortium reports indicate that the failed sedation rate for all-comers and all procedures and imaging studies is <0.01% when propofol is used (9). In the largest Pediatric Sedation Research Consortium cohort studies to date (>90 000 pediatric procedural sedations), Kamat *et al.* reported that the adverse event rate for pediatric procedural sedation using propofol is 5% and the SAE rate (including airway events) is 2.2% (9). In the current study, looking at pediatric procedural sedation for MRI studies alone, the SAE rate excluding airway events is lower at 0.6% postpediatric procedural sedation guide vs 1.1% prepeditric procedural sedation guide. When SAE including airway obstruction with concurrent hypoxia are counted, the rate is *still* lower than previously reported at 1.1–1.3%. We postulate that the overall severe adverse event rate may be lower for pediatric procedural sedation patients undergoing MRI because sedation providers may be more selective for these patients due to the lack of immediate contact with their patients while in the MRI scanner. The physical isolation from the patient makes the provider more dependent on monitoring systems and physically delays patient management changes such as airway repositioning, chin lift/jaw thrust, providing supplemental oxygen, and administration of additional medications to maintain depth of sedation.

Determining the appropriateness of a patient for pediatric procedural sedation vs GA for an MRI study is a critical area under current discussion. Risk factors for failing sedation have been examined in several single-center studies (4,5,8,13). Our previous work identified several characteristics that placed children at higher odds for failing sedation including: (i) older age, (ii) current upper respiratory infection, (iii) obesity, (iv) a history of obstructive sleep apnea/snoring, and (v) ASA-PS status of III (8). Others, including the recent policy statement by the American Academy of Pediatrics on pediatric anesthesia, have shown that younger children are at higher risk for complications during pediatric procedural sedation (20,21). These characteristics are in agreement with multi-center studies from the Pediatric Sedation Research Consortium database recently published that also indicate that in addition to ASA-PS status III and a primary diagnosis of an upper respiratory infection, that a primary diagnosis of a lower respiratory infection, prematurity, weight < 5 kg, and addition of adjunct medications were also associated with increased risk of adverse events and SAE (9). Despite institution of a pediatric procedural sedation guide comprising screening questions inclusive of the aforementioned risk factors that resulted in increased referrals of ASA-PS III status patients to GA, we did not detect a significant decrease in our failed sedation or severe adverse event rates. The lack of change in failed sedation or severe adverse event rates may be due to several reasons such as: (i) a pediatric procedural sedation guide does not help reduce SAE, (ii) the incorrect pediatric procedural sedation guide

criteria were used, (iii) the pediatric procedural sedation guide was not adhered to with enough stringency to help reduce failed sedations or severe adverse event rates, (iv) the sample size was not large enough to detect a change in low occurrence events. In addition, although our data did not find a change in failed sedation or severe adverse event rates, in other situations screening guidelines aid in selecting patients appropriate for procedures and in improving the efficiency of anesthesia services (22–25).

The pediatric procedural sedation guide was developed utilizing risk factors reported to be associated with failing sedation for pediatric sedation and input from multi-disciplinary team of experienced sedation physicians based upon retrospective observations. However, the occurrence and impact of these risk factors was not assessed individually. It is possible that the failed sedation and/or severe adverse event rates would have been higher postpediatric procedural sedation guide implementation; however, because we performed an interrupted time series analysis without a direct comparison cohort, we cannot determine whether this possibility is correct. Data from the Pediatric Sedation Research Consortium are de-identified and as such children referred to the GA service following a failed sedation cannot be tracked with our current system. Children referred to GA, either directly or because of the inability to complete the study with procedural sedation, are not entered in to the Pediatric Sedation Research Consortium database and therefore the severe adverse event and failed sedation rates for these referrals cannot be determined at this time.

Although the pediatric procedural sedation guide was developed and tested at a single-center, during the time period studied, CHOA-Eg contributed nearly a third of the data in the Pediatric Sedation Research Consortium database. As a high-volume center with an ethnically mixed population, we believe our outcomes are representative of a general cohort of sedation patients. Despite showing an increase in referral to GA following implementation of a prepediatric procedural sedation guide, we did not prospectively collect feedback from anesthesiologists regarding whether the referral to GA was appropriate and whether the child required GA to complete the MRI study. In general, anesthesiologists do not comment on the appropriateness of the referral to GA in their documentation; therefore, a retrospective review of charts postpediatric procedural sedation guide implementation is not likely to contain information needed to answer this question. Prospective collection of these data, that includes a detailed airway evaluation, will be required in future studies.

We queried our institution's Pediatric Sedation Research Consortium data to determine whether any changes in SAE and failed sedation rates were seen following screening implementation. Participation in the Pediatric Sedation Research Consortium is voluntary and centers that participate may have a higher level of motivation and organization that could lead to higher performance compared to centers that do not participate in the Pediatric Sedation Research Consortium. After adjusting for case-mix differences by performing a sensitivity interrupted time series analysis, we did not detect a decrease in SAE or failed sedation rates following pediatric procedural sedation guide implementation. It is possible that the granularity of the Pediatric Sedation Research Consortium data is not detailed enough to determine how well we adhered to our own pediatric procedural sedation guide. In addition, we excluded the risk factor of obstructive sleep apnea/snoring from our analysis because there was a change in the manner in which this variable was entered into the

Pediatric Sedation Research Consortium database following implementation of our pediatric procedural sedation guide. The exclusion of obstructive sleep apnea/snoring is a weakness that cannot be overcome in the current study, and future work on the prospective analysis of a pediatric procedural sedation guide should take the evaluation of obstructive sleep apnea, verified by a sleep study, into account.

Conclusions

In summary, we describe the development of a pediatric procedural sedation guide for referral of children to GA for MRI studies and demonstrated an increase in GA referrals following implementation of our guidelines. We suggest that future work should focus on designing a multi-center study implementing a pediatric procedural sedation guide to study the impact of the guidelines on sedation service work-flow, severe adverse event rate, and the appropriateness of referrals to the GA service.

Acknowledgments

We acknowledge the Emory+Children's Biostatistics Core for help with statistical analysis.

Funding: The study received no external funding.

References

1. Havidich JE, Cravero JP. The current status of procedural sedation for pediatric patients in out-of-operating room locations. *Curr Opin Anaesthesiol.* 2012; 25:453–460. [PubMed: 22732423]
2. Couloures KG, Beach M, Cravero JP, et al. Impact of provider specialty on pediatric procedural sedation complication rates. *Pediatrics.* 2011; 127:e1154–e1160. [PubMed: 21518718]
3. Cote CJ, Wilson S. American Academy of P, American Academy of Pediatric D; Work Group on S. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures: an update. *Pediatrics.* 2006; 118:2587–2602. [PubMed: 17142550]
4. Cote CJ, Karl HW, Notterman DA, et al. Adverse sedation events in pediatrics: analysis of medications used for sedation. *Pediatrics.* 2000; 106:633–644. [PubMed: 11015502]
5. Cote CJ, Notterman DA, Karl HW, et al. Adverse sedation events in pediatrics: a critical incident analysis of contributing factors. *Pediatrics.* 2000; 105(Pt 1):805–814. [PubMed: 10742324]
6. Cravero JP. Risk and safety of pediatric sedation/anesthesia for procedures outside the operating room. *Curr Opin Anaesthesiol.* 2009; 22:509–513. [PubMed: 19512915]
7. Cravero JP, Blike GT, Beach M, et al. Incidence and nature of adverse events during pediatric sedation/anesthesia for procedures outside the operating room: report from the Pediatric Sedation Research Consortium. *Pediatrics.* 2006; 118:1087–1096. [PubMed: 16951002]
8. Grunwell JR, McCracken C, Fortenberry J, et al. Risk factors leading to failed procedural sedation in children outside the operating room. *Pediatr Emerg Care.* 2014; 30:381–387. [PubMed: 24849275]
9. Kamat PP, McCracken CE, Gillespie SE, et al. Pediatric critical care physician-administered procedural sedation using propofol: a report from the Pediatric Sedation Research Consortium Database. *Pediatr Crit Care Med.* 2015; 16:11–20. [PubMed: 25340297]
10. Mallory MD, Baxter AL, Kost SI. Pediatric Sedation Research C. Propofol vs pentobarbital for sedation of children undergoing magnetic resonance imaging: results from the Pediatric Sedation Research Consortium. *Pediatr Anesth.* 2009; 19:601–611.
11. Mallory MD, Baxter AL, Yanosky DJ, et al. Emergency physician-administered propofol sedation: a report on 25,433 sedations from the pediatric sedation research consortium. *Ann Emerg Med.* 2011; 57:462–468 e1. [PubMed: 21513827]

12. Malviya S, Voepel-Lewis T, Eldevik OP, et al. Sedation and general anaesthesia in children undergoing MRI and CT: adverse events and outcomes. *Br J Anaesth.* 2000; 84:743–748. [PubMed: 10895749]
13. Malviya S, Voepel-Lewis T, Tait AR. Adverse events and risk factors associated with the sedation of children by nonanesthesiologists. *Anesth Analg.* 1997; 85:1207–1213. [PubMed: 9390581]
14. Monroe KK, Beach M, Reindel R, et al. Analysis of procedural sedation provided by pediatricians. *Pediatr Int.* 2013; 55:17–23. [PubMed: 23062205]
15. Vespasiano M, Finkelstein M, Kurachek S. Propofol sedation: intensivists' experience with 7304 cases in a children's hospital. *Pediatrics.* 2007; 120:e1411–e1417. [PubMed: 18055659]
16. Wheeler DS, Vaux KK, Ponaman ML, et al. The safe and effective use of propofol sedation in children undergoing diagnostic and therapeutic procedures: experience in a pediatric ICU and a review of the literature. *Pediatr Emerg Care.* 2003; 19:385–392. [PubMed: 14676486]
17. Scherrer PD, Mallory MD, Cravero JP, et al. The impact of obesity on pediatric procedural sedation-related outcomes: results from the Pediatric Sedation Research Consortium. *Pediatr Anesth.* 2015; 25:689–697.
18. Centers for Disease Control and Prevention, National Center for Health Statistics; 2000. United States Growth Charts: Percentile Data Files with LMS Values. Available from: http://www.cdc.gov/growthcharts/percentile_data_files.htm [Accessed 10 October 2015]
19. 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. [PubMed: 19224786]
20. Biber JL, Allareddy V, Allareddy V, et al. Prevalence and predictors of adverse events during procedural sedation anesthesia-outside the operating room for esophagogastroduodenoscopy and colonoscopy in children: age is an independent predictor of outcomes. *Pediatr Crit Care Med.* 2015; 16:e251–e259. [PubMed: 26218257]
21. Cote CJ, Wilson S. American Academy of P, American Academy of Pediatric D; Work Group on S. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures: an update. *Pediatr Anesth.* 2008; 18:9–10.
22. Varughese AM, Hagerman N, Townsend ME. Using quality improvement methods to optimize resources and maximize productivity in an anesthesia screening and consultation clinic. *Pediatr Anesth.* 2013; 23:597–606.
23. Knape JT, Adriaansen H, van Aken H, et al. Guidelines for sedation and/or analgesia by non-anaesthesiology doctors. *Eur J Anaesthesiol.* 2007; 24:563–567. [PubMed: 17568472]
24. Morton NS, Oomen GJ. Development of a selection and monitoring protocol for safe sedation of children. *Paediatr Anaesth.* 1998; 8:65–68. [PubMed: 9483601]
25. Hoffman GM, Nowakowski R, Troshynski TJ, et al. Risk reduction in pediatric procedural sedation by application of an American Academy of Pediatrics/American Society of Anesthesiologists process model. *Pediatrics.* 2002; 109:236–243. [PubMed: 11826201]

What is already known

- Pediatric subspecialists provide sedation outside the operating room; however, not all children can be sedated and some children are best served by an anesthesiologist. There are no clear guidelines in the literature as to which patients need to be referred to an anesthesiologist.

What this article adds

- This study analyzes the use of a pediatric procedural sedation guide for referral of children to an anesthesiologist for their sedation.

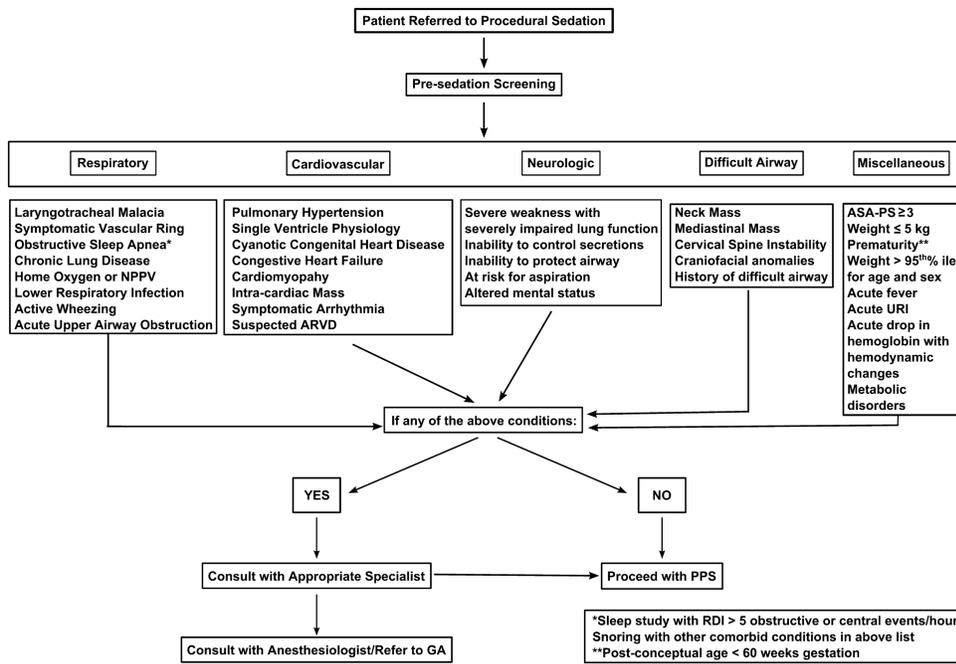


Figure 1.

Flow diagram of pre-sedation screening guide for pediatric procedural sedation. Once children are referred to pediatric procedural sedation, they undergo a screening interview with a trained sedation nurse by phone prior to pediatric procedural sedation. Children at risk for having the potential for sedation-related complications are categorized by respiratory, cardiovascular, neurologic, difficult airway, and other characteristics or conditions listed. Consultation with specialists and an anesthesiologist are recommended prior to pediatric procedural sedation. This list is a suggested list of conditions, and it is not exhaustive. ARVD, arrhythmogenic right ventricular dysplasia; ASA-PS, American Society of Anesthesiologists-physical status; GA, general anesthesia; PPS, pediatric procedural sedation; RDI, respiratory disturbance index; URI, upper respiratory infection.

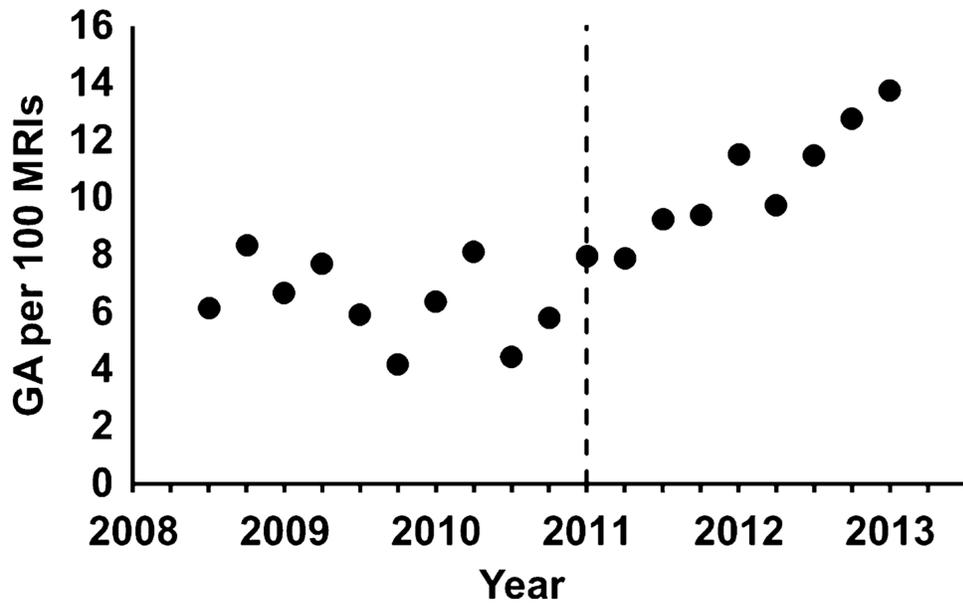


Figure 2. Interrupted time series analysis shows an increase in referrals to GA. The graph represents the number of children referred to GA per quarter per 100 MRIs. The vertical dashed line represents the implementation of the pediatric procedural sedation guide. There is a significant ($P < 0.001$) increase in referrals to GA following guideline implementation.

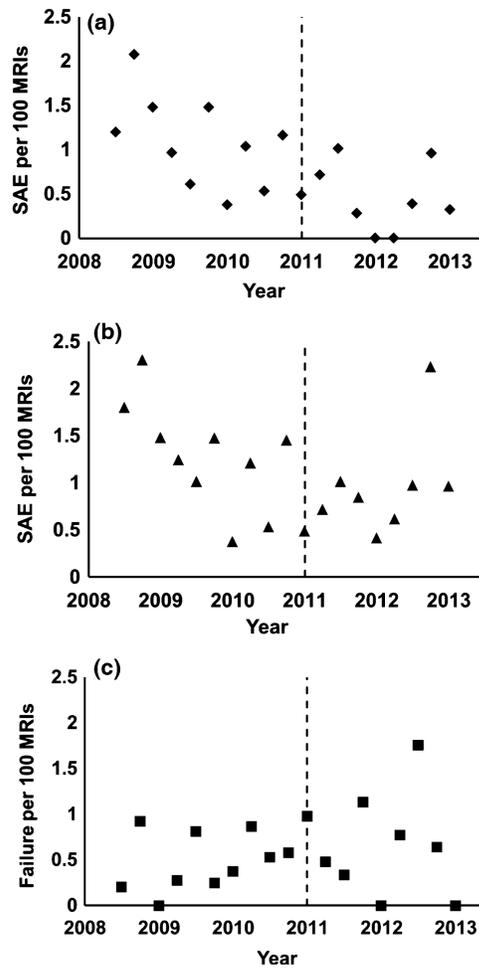


Figure 3.

Interrupted time series analysis of severe adverse events (SAE) and failed sedations. The graphs represent the number of children with severe adverse events or failed sedations per quarter per 100 MRIs. The vertical dashed line represents the implementation of the pediatric procedural sedation guide. (a) SAE (b) SAE plus airway obstruction with concurrent hypoxia. The interrupted time series analyses of both categories of SAE began trending downward prior to pediatric procedural sedation guide implementation and plateaued postpediatric procedural sedation guide implementation. (c) The number of failed sedations for MRIs per quarter per 100 MRIs. The pediatric procedural sedation failure rate is low making the detection of decreases in failed sedations difficult despite examination of over 11 000 sedation records.

Table 1
Demographic and clinical characteristics of children referred to general anesthesia

Characteristic	General anesthesia (<i>n</i> = 221)
Age (year), median (IQR)	4.5 (1.1–10.3)
Female, <i>n</i> (%)	94 (43.9%)
Weight (kg), median (IQR)	16.5 (8.7–34.6)
Duration of sedation (min), median (IQR)	97 (79–129)
Type of MRI, <i>n</i> (%)	
Brain/Spine	150 (68.2%)
Cardiac	57 (25.9%)
Chest	1 (0.5%)
Abdomen/Pelvis	7 (3.2%)
Extremity	5 (2.3%)
Orbits/Face/Neck/Sinus	0 (0%)
ASA-PS Score, <i>n</i> (%)	
I	7 (3.4%)
II	64 (30.6%)
III	133 (63.6%)
IV	5 (2.4%)
Anesthetic used, <i>n</i> (%)	
Propofol	168 (76.4%)
Brevital	1 (0.5%)
Nitrous Oxide/Sevoflurane	189 (85.9%)
Other	9 (4.1%)
Upper respiratory infection, <i>n</i> (%)	37 (17.6%)
Developmental delay, <i>n</i> (%)	105 (50.0%)
Congenital heart disease, <i>n</i> (%)	79 (37.6%)
Obstructive sleep apnea/Snoring, <i>n</i> (%)	56 (26.7%)
Prematurity ^a , <i>n</i> (%)	7 (26.9%)
Gastroesophageal reflux disease, <i>n</i> (%)	73 (34.8%)
Obesity, <i>n</i> (%)	33 (15.6%)
Asthma, <i>n</i> (%)	3 (1.4%)

IQR = 25th–75th interquartile range.

Obesity is defined as a weight >95 percentile for sex and age.

^aPrematurity was counted only for children < 6 months of age, and thus, % are not out of the total *n* for the category of patient listed.

Table 2
Demographic and clinical characteristics of CHOA-Eg Pediatric Sedation Research Consortium subjects

Characteristic	Preguideline (<i>n</i> = 5276)	Postguideline (<i>n</i> = 6254)	<i>P</i> -value
Age (year), <i>n</i> , (%)			
2	2081 (39.4%)	2023 (32.4%)	<0.001
3–5	1429 (27.1%)	1843 (29.5%)	
6	1766 (33.5%)	2388 (38.2%)	
Female, <i>n</i> (%)	2307 (43.7%)	2691 (43.0%)	0.451
Weight (kg), median (IQR)	16.6 (11.4–25.0)	18.2 (12.6–26.8)	<0.001
Intensivist provider, <i>n</i> (%)	2727 (51.7%)	3570 (57.1%)	<0.001
ASA score, <i>n</i> (%)			
I	1103 (20.9%)	1098 (17.6%)	<0.001
II	2635 (49.9%)	3869 (61.9%)	
III	1442 (27.3%)	1258 (20.1%)	
IV	96 (1.8%)	29 (0.5%)	
Propofol use, <i>n</i> (%)	4973 (94.3%)	6143 (98.2%)	<0.001
Upper respiratory infection, <i>n</i> (%)	241 (4.6%)	258 (4.1%)	0.245
Cardiovascular, <i>n</i> (%)	350 (6.6%)	395 (6.3%)	0.489
Developmental delay, <i>n</i> (%)	579 (11.0%)	792 (12.7%)	0.005
Metabolic/Genetic, <i>n</i> (%)	207 (3.9%)	305 (4.9%)	0.013
Prematurity, <i>n</i> (%)	44 (0.8%)	25 (0.4%)	0.003
Seizure, <i>n</i> (%)	1094 (20.7%)	1097 (17.5%)	<0.001
Gastrointestinal, <i>n</i> (%)	355 (6.7%)	448 (7.2%)	0.361
Asthma, <i>n</i> (%)	369 (7.0%)	591 (9.5%)	<0.001

IQR = 25th–75th interquartile range.

Chi-square statistic was performed on categorical data. Wilcoxon rank-sum test was performed on continuous data.

Metabolic category includes obesity. Obesity is defined a BMI > 99th percentile for age and sex.