Burjek *et al.*
Anesthesiology and Perioperative Science (2023) 1:21
https://doi.org/10.1007/s44254-023-00024-4

Anesthesiology and Perioperative Science

PERSPECTIVE

Open Access

Perioperative use of gabapentinoids in pediatric patients

Nicholas E. Burjek[1*], Michael Hafeman[2], David Guthrie[2], Amruta Desai[2], Zhaosheng Jin[2], Megan Brockel[3] and Robert Moore[2]

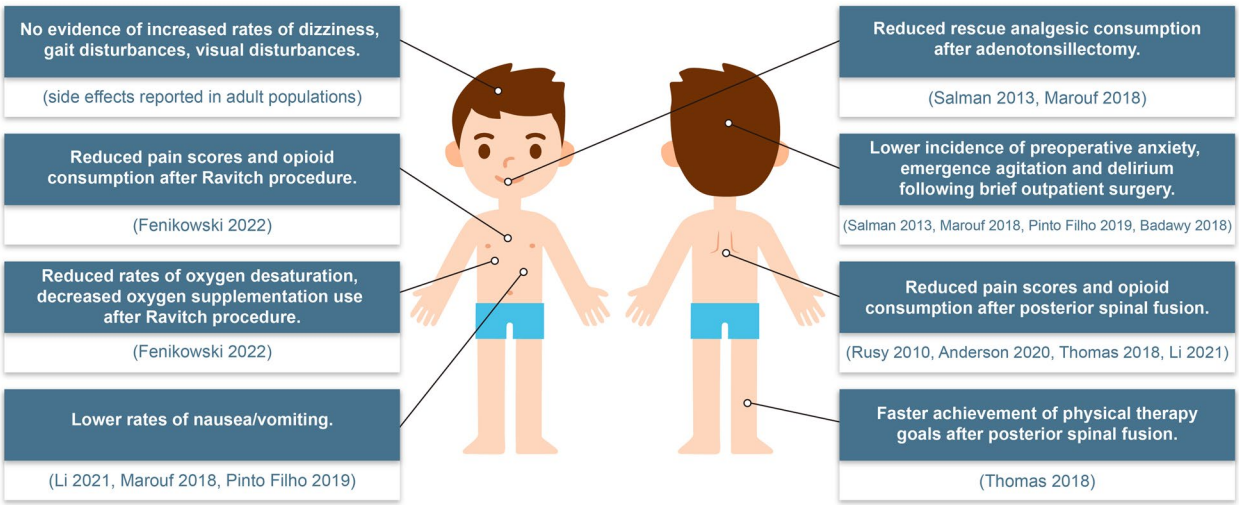
Abstract

Effective management of pediatric perioperative pain is typically goal-directed and multimodal, requiring various imperfect agents in combination to provide analgesia and support recovery. Gabapentinoids are one such class of agents often used in pediatric analgesic and enhanced recovery pathways. In adults, gabapentinoids have been associated with a modest reduction in pain scores but are often avoided due to undesired side effects. Children may be less susceptible to these unwanted effects, and the reduction in pain, agitation, and post-operative nausea and vomiting seen with these medications may confer significant benefit. While further studies are needed, to date there is no evidence to suggest a significantly increased risk of adverse effects in generally healthy children treated with gabapentinoids in the perioperative period. Although current evidence does not support their indiscriminate use, there appears to be a subset of pediatric surgical patients who stand to benefit from perioperative gabapentinoids. Pediatric use should not be abandoned, but rather further investigated to support thoughtful goal-directed application.

Keywords Pediatric, Pain management, Perioperative care, Gabapentin, Acute pain service

*Correspondence:
Nicholas E. Burjek
nburjek@luriechildrens.org
Full list of author information is available at the end of the article

Graphical Abstract



Gabapentin and pregabalin, known collectively as gabapentinoids, are voltage- dependent calcium channel inhibitors. Originally developed as antiepileptics and later approved for the treatment of some chronic neuropathic pain conditions, they have increasingly been used off-label as non-opioid alternatives for the treatment of acute postsurgical nociceptive and neuropathic pain. This off-label use includes numerous pediatric applications.

Acute pain management in pediatrics has the goal of rapidly restoring baseline physiology while minimizing side effects. Often, this requires the use of multiple agents in combination based upon the available evidence for each agent and assumptions about their ability to contribute to overall care goals. This process is exemplified in numerous pediatric enhanced recovery pathways, where multimodal analgesia regimens are used to reduce the need for opioids, an analgesic class with great efficacy and versatility but also side effects (sedation, nausea, reduced bowel motility) which can produce significant discomfort and prolong recovery [1].

Studies of perioperative gabapentinoids in adults have produced mixed results. A 2020 meta-analysis by Verret et al., including 24,682 participants from 281 trials, found a statistically significant reduction in post-operative pain intensity from −3 to −10 on a 100-point scale [2]. Patients receiving gabapentinoids also experienced less nausea and vomiting but more dizziness and visual disturbances. Based on the modest analgesic effect and potential for an increase in clinically meaningful adverse events, these authors and others have recommended against the routine use of perioperative gabapentinoids in *adult* patients [2, 3].

The decision to use any medication is based on the tradeoff between likely risks and benefits. When treating children, a group with unique traits and needs, these choices are typically based on the best available evidence that unfortunately does not always include robust randomized controlled trials (RCT). This can lead to case-specific and nuanced choices based on extrapolation of adult data along with recognition of the unique physiologic and psychologic needs of children with pain. Thus, the benefits of certain treatments in this population may be obscured by a large inclusive meta-analysis such as the effort of Verret et al. [2]. The purpose of this manuscript is to consider potential differences between pediatric and adult surgical patients and review the available literature addressing the use of perioperative gabapentinoids in children.

Children may be less likely to experience the adverse events seen in adults receiving gabapentinoids. Adult surgical patients often have multiple comorbidities, including advanced age, obstructive sleep apnea, and neurologic and respiratory diseases which may make them more susceptible to gabapentinoid side effects such as respiratory depression, sedation, and dizziness. With different physiology and, frequently, fewer comorbidities, children may be somewhat resistant to these drug-related adverse events. Conversely, the reduction in nausea and pain scores highlighted by the meta-analysis would be considered clinically relevant and beneficial in many pediatric settings. These assumptions plus a limited but diverse literature (Table 1) have helped support the use of gabapentinoids in pediatric acute pain management.

Table 1 Pediatric studies examining the use of perioperative gabapentinoids

Study	Study Design	Dosing Regimen	Number of Subjects	Ages	Surgery Type	Primary Outcomes	Secondary Outcomes	Drug-related Adverse Events
Primary outcome: Pain-related								
Rusy et al., 2010 [4]	RCT	Gabapentin 15 mg/kg preoperatively, 5 mg/kg TID × 3 days postoperatively Vs. Placebo	59	9–18 years	Posterior spinal fusion for idiopathic scoliosis	Reduced morphine consumption in PACU, POD 1, POD 2 No difference POD 3 or 4	Reduced pain scores in PACU and morning of POD 1. No difference at later timepoints	No differences, including oxygen requirement or ondansetron use. Did not evaluate sedation
Anderson et al., 2020 [5]	RCT	Gabapentin 15 mg/kg preoperatively, 10 mg/kg TID × 3 days postoperatively Vs. Placebo	50	10–19 years	Posterior spinal fusion for idiopathic scoliosis	Lower pain scores in PACU. No difference at other time points	Reduced hydromorphone use POD 1 and POD 2	No differences, including nausea, sedation
Thomas et al., 2018 [6]	Retrospective review	Gabapentin 400 mg preoperatively and TID × 3 days Vs. Historical controls without gabapentin	101	10–18 years	Posterior spinal fusion for idiopathic scoliosis	Faster achievement of physical therapy goals: logroll, sit, ambulate, stairs	Reduced morphine on POD 1. Lower pain scores on POD 2. No difference at other timepoints	Not reported
Li et al., 2021 [7]	Retrospective review	Intrathecal morphine with mean gabapentin dose 7.8 mg/kg 1 h before operation followed by mean dose 5.1 mg/kg/day starting POD 1 up to POD 2	50	11–18 years	Posterior spinal fusion for idiopathic scoliosis	Lower oxycodone requirements from POD 0–2	Lower pain scores the morning of POD 1. No difference at other time points	Lower rates of nausea and vomiting, and pruritus
Mayell et al., 2014 [8]	RCT	Gabapentin 600 mg preoperatively Vs. Placebo	35	10–17 years	Posterior spinal fusion for idiopathic scoliosis	No difference in postoperative morphine use	No reduction in pain at rest or with movement	No differences, including nausea, dizziness, sedation
Helenius et al., 2020 [9]	RCT	Pregabalin 2 mg/kg preoperatively and BID × 5 days postoperatively Vs. Placebo	63	10–21 years	Posterior spinal fusion for idiopathic scoliosis, Scheuermann kyphosis, or Spondylolisthesis	No difference in oxycodone use for 48 h postoperatively	No difference in pain scores for 48 h postoperatively	No differences, including nausea, sedation

Table 1 (continued)

Study	Study Design	Dosing Regimen	Number of Subjects	Ages	Surgery Type	Primary Outcomes	Secondary Outcomes	Drug-related Adverse Events
Fenikowski et al., 2022 [10]	RCT	Gabapentin 15 mg/kg preoperatively, 7.5 mg/kg BID × 3 days postoperatively Vs. Placebo	56	9–17 years	Ravitch procedure for pectus excavatum, pectus carinatum, or mixed pectus deformities. All patients received postoperative analgesia with morphine, paracetamol, NSAIDs	Reduced average and maximal pain scores on day of surgery, reduced maximal pain score on POD 2	Reduced morphine use on POD 1	Reduced rate of oxygen desaturation with gabapentin and lower median oxygen supplementation time No differences in nausea and vomiting, sedation, pruritus, bradycardia, dizziness, or urinary retention
Tomaszek et al., 2019 [11]	RCT	Gabapentin 15 mg/kg preoperatively, 7.5 mg/kg BID × 3 days postoperatively Vs. Placebo	40	9–17 years	Ravitch procedure for pectus excavatum or carinatum. All patients received postoperative multimodal analgesia, including thoracic epidural infusions of local anesthetic and opioid	No difference in pain scores POD 0–3. Of note, median pain scores at all timepoints were < 1 on the NRS in both groups	No difference in need for rescue analgesia	No differences, including nausea, vomiting, oxygen desaturation, sedation, dizziness Fewer postoperative ondansetron doses in gabapentin group
Primary outcome: Emergence delirium								
Salman et al., 2013 [12]	RCT	Gabapentin 15 mg/kg preoperatively Vs. Placebo	46	3–12 years	Tonsillectomy and adenoidectomy	Lower incidence of emergence delirium on EAS	Reduced postoperative paracetamol consumption in first 24 h Higher parental satisfaction scores	Zero episodes of gait disturbance or dizziness reported by parents
Marouf et al., 2018 [13]	RCT	Pregabalin 1.5 mg/kg preoperatively Vs. Placebo	60	4–10 years	Adenotonsillectomy	Lower scores on EAS	No difference in anesthesia time, wake time, or PACU time Fewer doses of paracetamol for rescue analgesia in gabapentin group	Fewer episodes of vomiting in gabapentin group Zero episodes of dizziness in either group

Table 1 (continued)

Study	Study Design	Dosing Regimen	Number of Subjects	Ages	Surgery Type	Primary Outcomes	Secondary Outcomes	Drug-related Adverse Events
Pinto Filho et al., 2019 [14]	RCT	Gabapentin 30 mg/kg preoperatively Vs. 15 mg/kg preoperatively Vs. Placebo	135	1–6 years	Lumbar puncture and myelogram for oncologic indication	Reduced preoperative anxiety (m-YPAS scale) and emergence delirium scores (PAED) in gabapentin groups vs. placebo. No difference between gabapentin dose groups	Shorter time for inhaled induction of anesthesia in gabapentin group	Fewer episodes of vomiting in gabapentin group Other adverse events not reported
Badawy et al., 2018 [15]	RCT	Gabapentin 5 mg/kg preoperatively Vs. Placebo	70	2–6 years	Strabismus surgery	Lower incidence of emergence delirium on EAS	Fewer doses of meperidine to treat emergence delirium Prolonged duration to emergence and extubation in gabapentin group	No difference in PONV Other adverse events not reported

Abbreviations: RCT Randomized control trial, *TID* Three times a day, *PACU* Post anesthesia care unit, *POD* Postoperative day, *BID* Two times a day, *NRS* Numerical rating scale, *EAS* Emergence agitation scale, *m-YPAS* modified Yale preoperative anxiety scale, *PAED* Pediatric anesthesia emergence delirium, *PONV* Postoperative nausea and vomiting

Several studies highlight benefits in the setting of posterior spinal fusion (PSF) for adolescent idiopathic scoliosis. In an RCT, Rusy et. al demonstrated that a three-day perioperative gabapentin regimen reduces both acute post-operative pain scores (2.5 ± 2.8 vs. 6.0 ± 2.4, $P < 0.001$ in the recovery room; 3.2 ± 2.6 vs. 5.0 ± 2.2, $P < 0.05$ the morning after surgery) and post-operative morphine delivered by patient-controlled analgesia (in mg/kg/hr, 0.044 ± 0.017 vs. 0.064 ± 0.031, $P = 0.003$ in the recovery room; 0.046 ± 0.016 vs. 0.055 ± 0.017, $P = 0.051$ for post operative day 1, 0.036 ± 0.016 vs. 0.047 ± 0.019, $P = 0.018$ for postoperative day 2) following posterior spinal fusion [4]. Anderson et al. published another RCT evaluating three days of gabapentin in the perioperative period and demonstrated significant reductions in visual analog scale (VAS) scores (2.7 vs. 4.1, $P = 0.02$ on the operative day; 2.5 vs. 3.5, $P = 0.09$ on postoperative day 1; 2.4 vs. 3.5, $P = 0.07$ on postoperative day 2) and opioid use (in mg/kg morphine equivalents for the entire perioperative period, 3.58 ± 1.82 vs. 5.33 ± 3.20, $P = 0.02$) with no associated differences in adverse events [5]. A primary goal of multimodal analgesia is to accelerate restoration of function by reducing opioid-related side effects. These two studies did not detect a reduction in opioid-related side effects as a secondary outcome. However, cumulative opioid dose may be considered a surrogate outcome, with the assumption that a reduction in side effects may be seen in an adequately powered study primarily measuring these outcomes.

An additional retrospective cohort study of patients undergoing PSF showed an improvement in time to accomplishment of physical therapy goals once perioperative gabapentin was introduced (completing stairs within 1 day: OR (odds ratio) 5.34, $P = 0.04$, 95% CI (confidence interval) 1.24–37.44) [6]. This outcome is particularly significant, as the value of improved function is easily recognized by patients and providers. A retrospective study by Li et al. compared patients who received intrathecal morphine alone vs. intrathecal morphine with a perioperative gabapentin regimen. Although it did not show improvement in meeting physical therapy goals, the patients receiving gabapentin received less oxycodone (in mg/kg, 0.798 vs. 1.036, $P < 0.015$), and experienced less nausea and vomiting (52% vs. 84%, $P = 0.032$) and pruritus (44% vs. 72%, $P = 0.045$) [7]. Many practices have adopted the use of gabapentinoids following PSF for scoliosis based on this evidence and the assumption that a neuromodulatory agent such as gabapentin is more likely to reduce pain in a procedure which produces neuroinflammation.

Not all data from RCTs in patients undergoing PSF are positive. Mayell compared a single preoperative dose of gabapentin to placebo, while Helenius compared twice daily dosing of pregabalin for five postoperative days to placebo [8, 9]. While neither study showed a clinically or statistically meaningful difference in postoperative pain or opioid use, there was also no difference in drug-related side effects or perioperative adverse events.

The analgesic impact of gabapentinoids in other pediatric surgical populations has also been evaluated. A randomized control trial was performed in children undergoing the Ravitch procedure for pectus excavatum repair. Postoperatively, all patients received an adjustable morphine infusion, scheduled paracetamol and non-steroidal anti-inflammatory drugs (NSAIDs), and were randomized to receive twice-daily gabapentin or placebo. The gabapentin group experienced reduced average and maximal pain scores on the day of surgery (presented as median with upper and lower quartiles, 0.3 [0.1; 0.8] vs. 0.8 [0.3; 1.1], $P = 0.049$; 3.0 [1.0; 4.0] vs. 4.0 [3.0; 5.0], $P = 0.02$), as well as maximal pain scores on post-operative day 2 (0.0 [0.0; 0.0] vs. 0.0 [0.0; 1.5], $P = 0.04$). The gabapentin group also required lower amounts of intravenous morphine on post-operative day 1 (in mg, 21 [19; 24] vs. 25 [21; 32] $P = 0.03$) and experienced lower rates of oxygen desaturation (67.9% vs. 89.3%, $P = 0.05$) [10]. A second RCT from the same group of authors compared adolescents undergoing the Ravitch procedure with a similar analgesic protocol that involved a thoracic epidural infusion of 0.2% ropivacaine and fentanyl in the place of the previously mentioned intravenous morphine infusion, along with randomization to twice daily gabapentin or placebo for three days. [11]. In this study, no statistically-significant difference in postoperative median or maximal pain scores or drug-related side effects was measured. While this study suggests that the relative benefit of gabapentin may be reduced when effective epidural analgesia is used, recent data suggest that despite providing superior pain control, use of an epidural may be associated with longer times to hospital discharge following pectus repair, thus leaving the question of the best analgesic regimen for this painful surgery still unanswered [16].

Gabapentinoids have also been studied as a tool to reduce the incidence of emergence delirium when administered preoperatively in pediatric patients undergoing tonsillectomy, short oncologic procedures, and strabismus surgery with positive results. Salman et al. [12] compared preoperative 15 mg/kg oral gabapentin vs. placebo for children aged 3–12 undergoing adenotonsillectomy and showed reduction in agitation scores after surgery at 10 min (presented as median and range, 4 [1–5] vs. 5 [3–5], $P = 0.053$), 20 min (3 [1–5] vs. 4 [2–5], $P = 0.009$), and 30 min (2 [2–5] vs. 4 [2–5], $P = 0.036$).

They also showed reduced analgesic consumption in the first 24 h postoperatively (mean doses of 15 mg/kg acetaminophen, 1.68 vs. 3.29, $P<0.01$) and improved parent satisfaction scores (mean 3.70 vs. 2.91, $P<0.05$). Marouf [13] compared preoperative oral pregabalin 1.5 mg/kg vs. placebo for children aged 4–10 undergoing adenotonsillectomy and showed reductions in emergency agitation scale at 10 min (2.66 ± 1.18 vs. 3.4 ± 1, $P=0.01$), 20 min (2.2 ± 1.12 vs. 3.16 ± 0.87, $P<0.01$), and 30 min (2 ± 1.01 vs. 3.06 ± 0.78, $P<0.01$) without significant effect on time to open eyes, time to extubate, or post anesthesia care unit (PACU) duration of stay. They also showed a reduction in number of postoperative 15 mg/kg acetaminophen doses (1 ± 0.63 vs. 1.4 ± 0.62, $P=0.045$) and reduced frequency of vomiting (16% vs. 46%, $P=0.02$) with no reported dizziness in either group. Pinto Filho et al. [14] compared oral gabapentin 15 mg/kg and 30 mg/kg vs. placebo for children aged 1–6 undergoing myelogram or lumbar puncture with or without intrathecal chemotherapy and found lower scores in the pediatric anesthesia emergence delirium scale (PAED) (2.61 ± 4.94 for 15 mg/kg, 2.63 ± 5.06 for 30 mg/kg, and 10.33 ± 6.11 for placebo) and lower pain on the children and infants postoperative pain scale (CHIPPS) (0.63 ± 1.43 for 15 mg/kg, 0.65 ± 1.85 for 30 mg/kg, and 2.45 ± 2.45 for placebo). They also found that 30 mg/kg dosing of gabapentin was associated with an odds ratio of 5.259 ($P=0.012$) to not vomit. Badawy et al. [15] studied 2–6 year old children undergoing strabismus surgery and compared 5 mg/kg gabapentin to placebo. They found a reduction in the median emergence agitation score with gabapentin (3 vs. 4, $P=0.006$), with no difference in postoperative nausea and vomiting, and more patients in the control group requiring meperidine for postoperative crying and agitation (30.3% vs. 52.9%, $P=0.03$). While other medications, such as the α2-agonist dexmedetomidine, are better studied for the prevention of emergence delirium and have produced excellent outcomes [17], the lack of adverse effects in the gabapentin studies mentioned here support the observation that they are generally well tolerated by children in the perioperative setting.

The current available evidence for perioperative gabapentinoids in children leaves several questions unanswered. The ideal regimen, including timing of initiation, duration of treatment, and size of individual doses is unknown, with considerable variation in the published literature (Table 1). Mayell et al. administered only a single preoperative dose before spinal fusion and found no difference in postoperative opioid consumption or pain scores, while most of the studies using multi-day pre- and post-operative dosing regimens showed improvement in pain outcomes. This suggests that multiple doses may be required to observe a benefit following painful surgery. Direct comparisons of the analgesic effect and side effect profiles of gabapentin vs. pregabalin are lacking. It is also unknown whether perioperative gabapentinoids reduce the development of chronic pain following certain procedures. One study of patients undergoing scoliosis surgery suggested an opioid-reducing analgesia protocol with ketamine and dexmedetomidine may be associated with reduced incidence of chronic pain [18]. It is possible that gabapentinoids, with their neuromodulatory and opioid-reducing effects, may produce a similar outcome, a question which warrants further study. While most of the studies available investigated gabapentinoids in the setting of major skeletal surgery (scoliosis and pectus excavatum repair), their use for other painful surgeries, including those with large abdominal and thoracic incisions, is understudied. However, at this time gabapentinoids are only available in oral formulations. The fact that many patients having major abdominal surgery may not tolerate oral medications immediately after surgery, combined with the apparent decrease in benefit of preoperative-only dosing of gabapentinoids, may limit their use in this setting. Finally, use in neonates remains unstudied. While some authors have described long-term use for agitation and hyperalgesia in the neonatal intensive care unit, to our knowledge there are no reports of short-term treatment of perioperative acute pain in this population [19, 20].

Despite these limitations and unanswered questions, the evidence available to date suggests that the adverse effects of perioperative gabapentinoids noted in adult patients (dizziness, visual disturbances) may not be as significant in generally healthy pediatric surgical patients. In fact, we are aware of no studies showing an increased risk of these or any other adverse events in this population. Meanwhile, the reduction in pain, agitation, opioid-consumption, and post-operative nausea and vomiting may confer a significant benefit in some circumstances.

Early enthusiasm for gabapentinoids may have led to their wide-spread application despite limited evidence, but a similar rush to change practice could lead to the premature abandonment of a tool which may still have a place in pediatric pain management. The available pediatric evidence certainly does not support the role of gabapentinoids as a panacea with universal applicability. However, in certain pediatric populations they appear to reduce pain, nausea, and emergence delirium. The drugs may also play a valuable role in enhanced recovery pathways (ERPs) where the goal is to improve the overall recovery profile. ERPs are often used for large abdominal surgery in which traditional postoperative care involved multiple days without oral nutrition or medication, limiting the use of enterally-administered medications such as gabapentinoids. However, the adoption of other

strategies to hasten return of bowel function may make early postoperative administration of gabapentinoids possible, thus further reducing opioid requirements and supporting bowel recovery.

Pediatric pain management requires the use of imperfect tools to optimize patients' recovery from surgery. Acetaminophen is virtually the only analgesic agent with negligible side effects when dosed appropriately. Opioids, NSAIDs, and ketamine infusions can be employed but have significant associated adverse effects and may require specific monitoring. Regional analgesia techniques are invasive, have specific contraindications, and require indwelling catheters to prolong benefit. Yet these modalities are used after considering intrinsic risks and benefits in the specific clinical context. Further, while each individual drug may only provide incremental improvement, optimizing the overall balance of analgesia and functional status versus side effects serves as the ultimate goal. Acknowledging the balancing act required for severe and difficult to manage perioperative pain, currently available literature suggests that gabapentinoids should not be indiscriminately prescribed, nor abandoned completely for pediatric patients. Rather, they should be applied judiciously as part of a unified strategy after consideration of their strengths and weaknesses as currently understood.

Abbreviations

BID	Two times a day
CHIPPS	Children and infants postoperative pain scale
CI	Confidence interval
EAS	Emergence agitation scale
ERP	Enhanced recovery pathway
m-YPAS	modified Yale preoperative anxiety scale
NRS	Numerical rating scale
NSAIDs	Non-steroidal anti-inflammatory drugs
OR	Odds ratio
PACU	Post anesthesia care unit
PAED	Pediatric anesthesia emergence delirium scale
POD	Postoperative day
PONV	Postoperative nausea and vomiting
PSF	Posterior spinal fusion
RCT	Randomized controlled trial
TID	Three times a day
VAS	Visual analog scale

Acknowledgements
Not applicable.

Authors' contributions
NB: Review of literature, manuscript conceptualization, and manuscript writing. MH: Review of literature, manuscript conceptualization, and manuscript writing. DG: Manuscript conceptualization and manuscript writing. AD: Manuscript conceptualization and manuscript editing. ZJ: Review of literature, manuscript conceptualization and manuscript editing. MB: Manuscript conceptualization and manuscript editing. RM: Manuscript conceptualization and manuscript editing.

Funding
The authors did not receive support from any organization for the submitted work.

Availability of data and materials
Data sharing not applicable to this article as no datasets were generated or analyzed.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
All authors have approved this submission for publication.

Competing interests
Author Zhaosheng Jin is a member of the Editorial Board of ***Anesthesiology and Perioperative Science*** and recuses himself from every editorial procedure of this submission including peer-review and academic decisions.

Author details
[1]Department of Pediatric Anesthesiology, Ann and Robert H. Lurie Children's Hospital of Chicago, Northwestern University Feinberg School of Medicine, Chicago, IL 60611, USA. [2]Department of Anesthesiology, Stony Brook University Renaissance School of Medicine, Stony Brook, NY 11794, USA. [3]Department of Pediatric Anesthesiology, University of Colorado School of Medicine, Aurora, CO 80045, USA.

Received: 25 October 2022 Revised: 18 January 2023 Accepted: 6 March 2023
Published online: 12 July 2023

References

1. Tøndevold N, Dybdal B, Bari TJ, Andersen TB, Gehrchen M. Rapid discharge protocol reduces length of stay and eliminates postoperative nausea and vomiting after surgery for adolescent idiopathic scoliosis. World Neurosurg. 2022;158:e566–76.
2. Verret M, Lauzier F, Zarychanski R, Perron C, Savard X, Pinard AM, et al. Perioperative use of gabapentinoids for the management of postoperative acute pain: a systematic review and meta-analysis. Anesthesiology. 2020;133(2):265–79.
3. Kharasch ED, Clark JD, Kheterpal S. Perioperative gabapentinoids: deflating the bubble. Anesthesiology. 2020;133(2):251–4.
4. Rusy LM, Hainsworth KR, Nelson TJ, Czarnecki ML, Tassone JC, Thometz JG, et al. Gabapentin use in pediatric spinal fusion patients: a randomized, double-blind, controlled trial. Anesth Analg. 2010;110(5):1393–8.
5. Anderson DE, Duletzke NT, Pedigo EB, Halsey MF. Multimodal pain control in adolescent posterior spinal fusion patients: a double-blind, randomized controlled trial to validate the effect of gabapentin on postoperative pain control, opioid use, and patient satisfaction. Spine Deform. 2020;8(2):177–85.
6. Thomas JJ, Levek C, Quick HD, Brinton JT, Garg S, Cohen MN. Utility of gabapentin in meeting physical therapy goals following posterior spinal fusion in adolescent patients with idiopathic scoliosis. Paediatr Anaesth. 2018;28(6):558–63.
7. Li Y, Swallow J, Robbins C, Caird MS, Leis A, Hong RA. Gabapentin and intrathecal morphine combination therapy results in decreased oral narcotic use and more consistent pain scores after posterior spinal fusion for adolescent idiopathic scoliosis. J Orthop Surg Res. 2021;16(1):672.
8. Mayell A, Srinivasan I, Campbell F, Peliowski A. Analgesic effects of gabapentin after scoliosis surgery in children: a randomized controlled trial. Paediatr Anaesth. 2014;24(12):1239–44.
9. Helenius LL, Oksanen H, Lastikka M, Pajulo O, Löyttyniemi E, Manner T, et al. Preemptive pregabalin in children and adolescents undergoing posterior instrumented spinal fusion: a double-blinded, placebo-controlled, randomized clinical trial. J Bone Joint Surg Am. 2020;102(3):205–12.
10. Fenikowski D, Tomaszek L, Mazurek H, Gawron D, Maciejewski P. The effects of gabapentin on post-operative pain and anxiety, morphine consumption and patient satisfaction in paediatric patients following the ravitch procedure-a randomised, double-blind, placebo-controlled, phase 4 trial. J Clin Med. 2022;11(16):4695.

11. Tomaszek L, Fenikowski D, Maciejewski P, Komotajtys H, Gawron D. Perioperative Gabapentin in Pediatric Thoracic Surgery Patients-Randomized, Placebo-Controlled, Phase 4 Trial. Pain Med. 2020;21(8):1562–71.
12. Salman AE, Camkıran A, Oğuz S, Dönmez A. Gabapentin premedication for postoperative analgesia and emergence agitation after sevoflurane anesthesia in pediatric patients. Agri. 2013;25(4):163–8.
13. Marouf HM. Effect of pregabalin premedication on emergence agitation in children after sevoflurane anesthesia: a randomized controlled study. Anesth Essays Res. 2018;12(1):31–5.
14. Pinto Filho WA, Silveira LHJ, Vale ML, Fernandes CR, Gomes JA. Gabapentin in Improvement of Procedural Sedation and Analgesia in Oncologic Pediatric Patients: A Clinical Trial. Anesth Pain Med. 2019;9(5):e91197.
15. Badawy AA, Kasem SA, Rashwan D, Al Menesy T, Adel G, Mokhtar AM, et al. The role of Gabapentin oral solution in decreasing desflurane associated emergence agitation and delirium in children after stabismus surgery, a prospective randomized double-blind study. BMC Anesthesiol. 2018;18(1):73.
16. Muhly WT, Beltran RJ, Bielsky A, Bryskin RB, Chinn C, Choudhry DK, et al. Perioperative Management and In-Hospital Outcomes After Minimally Invasive Repair of Pectus Excavatum: A Multicenter Registry Report From the Society for Pediatric Anesthesia Improvement Network. Anesth Analg. 2019;128(2):315–27.
17. Fang XZ, Gao J, Ge YL, Zhou LJ, Zhang Y. Network Meta-Analysis on the Efficacy of Dexmedetomidine, Midazolam, Ketamine, Propofol, and Fentanyl for the Prevention of Sevoflurane-Related Emergence Agitation in Children. Am J Ther. 2016;23(4):e1032–42.
18. Julien-Marsollier F, Assaker R, Michelet D, Camby M, Galland A, Marsac L, et al. Effects of opioid-reduced anesthesia during scoliosis surgery in children: a prospective observational study. Pain Manag. 2021;11(6):679–87.
19. Edwards L, DeMeo S, Hornik CD, Cotten CM, Smith PB, Pizoli C, et al. Gabapentin Use in the Neonatal Intensive Care Unit. J Pediatr. 2016;169:310–2.
20. Sacha GL, Foreman MG, Kyllonen K, Rodriguez RJ. The Use of Gabapentin for Pain and Agitation in Neonates and Infants in a Neonatal ICU. J Pediatr Pharmacol Ther. 2017;22(3):207–11.

Publisher's Note