

Regional anesthesia to ameliorate postoperative analgesia outcomes in pediatric surgical patients: an updated systematic review of randomized controlled trials

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Abstract: Regional anesthesia is becoming increasingly popular among anesthesiologists in the management of postoperative analgesia following pediatric surgery. The main objective of this review was to systematically evaluate the last 5 years of randomized controlled trials on the role of regional anesthesia techniques in alleviating postoperative pain associated with various pediatric surgical procedures. Forty studies on 2,408 pediatric patients were evaluated. The majority of the articles published from 2013 to 2017 reported that the use of regional anesthesia minimized postoperative pain and reduced opioid consumption. Only a few surgical procedures (cholecystectomy, inguinal hernia repair, and non-laparoscopic major abdominal surgery) reported no significant difference in the postoperative pain relief compared with the standard anesthetic management. The growing number of randomized controlled trials in the pediatric literature is very promising; however, additional confirmation is needed to reinforce the use of specific regional anesthesia techniques to provide optimal postoperative pain relief for a few surgical procedures (reconstructive ear surgery, chest wall deformity, hypospadias, umbilical hernia, cleft palate repair) in pediatric patients. More randomized controlled trials are needed to establish regional anesthesia as an essential component of postoperative analgesia management in children.

Keywords: regional anesthesia, peripheral nerve block, pediatrics

Introduction

Postoperative pain remains poorly treated in the general surgical population.^{1,2} Specifically in pediatric patients, few clinical trials have evaluated the efficacy of non-opioid analgesic interventions for improving post-surgical analgesic outcomes.³⁻⁵ The lack of established efficacy for multimodal analgesic interventions in pediatric patients can result in an increased use of opioid medications in the postoperative period.⁶⁻⁸ Post-surgical pain is the most common medical encounter associated with opioid prescriptions.⁹ As such, the current call to decrease the use of prescription opioids makes the evaluation of multimodal analgesia (ie, regional anesthesia) in pediatric surgery a very timely topic in perioperative medicine.^{10,11}

Among the different multimodal analgesic strategies, the use of regional anesthesia has substantially increased in pediatric patients.¹²⁻¹⁴ The use of ultrasonography to assist anesthesiologists in the placement of regional nerve blocks may contribute to the increase in the use of regional anesthesia in children.¹⁵⁻¹⁷ The proliferation of large database studies demonstrating the safety of regional anesthesia in children has

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supported the increased use of this technique.^{18–20} Our group has previously performed a qualitative systematic review to assess the efficacy of regional anesthesia in reducing postoperative pain for pediatric patients.²¹ However, many randomized studies have been published since that review, and this more recent knowledge has yet to be evaluated.

The primary goal of the current systematic review was to evaluate the use of regional anesthesia to improve postoperative analgesia in pediatric patients. In addition, we wanted to identify complications associated with regional anesthesia in the same population.

Methods

We followed the same methods previously used in our first qualitative systematic review in order to update the results.²¹ We performed a systematic review in accordance with the PRISMA guidelines.²²

Systematic search

Articles of randomized controlled trials exploring regional anesthesia on postoperative pain in pediatric patients were searched using the PubMed database, Google Scholar, and the Cochrane Database of Systematic Reviews, from May 22, 2013, to December 31, 2017. Our prior review included studies up to May 21, 2013. Free text and MeSH terms “regional,” “blocks,” “pain,” “surgery,” “post-operative,” “opioid,” and “analgesia” were used individually and in a variety of combinations. The inquiry was limited to human subjects younger than 18 years of age. An attempt to identify additional studies that were not found by the primary search methods was achieved by reviewing the reference lists from the identified studies. No restrictions on language were used. There was no search performed for unpublished studies. This initial search yielded 1,552 manuscripts.

Selection of included studies

The inclusion and exclusion criteria were determined in advance before the commencement of the systematic review. Two trained authors (MCK and LJCA) independently evaluated the abstract and results of the 1,552 articles obtained by the primary search. Articles were excluded if they were clearly not pertinent to our inclusion and exclusion criteria. Disagreements on inclusion of the articles were resolved by discussion among the evaluators, and if consensus was not met, then the final decision was determined by the assistance of a third investigator (GSDO) who was blinded regarding the evaluation of the first two authors. The filtered search subsequently resulted in 123 articles.

Inclusion and exclusion criteria

We included randomized controlled trials that compared perioperative regional blocks with local anesthetics and a control group in pediatric patients undergoing various surgical procedures. Trials containing a concurrent use of an alternative multimodal analgesia regimen were rejected if a direct comparison between a regional anesthesia technique and a control could not be determined. Studies that provided a direct comparison between two different regional anesthetic techniques, two different local anesthetics, and/or comparisons involving a block adjunct were included. The trials included in the review had to report on postoperative pain outcomes such as pain scores or opioid consumption. There was no limitation on sample size in the systematic review.

Validity scoring

Two authors (MCK and LJCA) independently reviewed the included articles and assessed their quality using the modified Jadad five-point scale.²³ The Jadad scale evaluates a study using the following criteria: randomization, valid randomization method, double-blind evaluation, concealment of the study group to an evaluator, and completeness of data at follow-up. Disagreements in scoring were resolved by discussion among the evaluators, and if a consensus was not met, then the final decision was determined by the assistance of a third investigator (GSDO). The minimum score of an included randomized trial was 1 and the maximum score was 5. No studies were ruled out based on quality assessment scores.

Data extraction

Two authors (MCK and LJCA) independently evaluated the full manuscripts of all included trials and performed data extraction using a data collection form specifically developed for this review. Discrepancies were resolved by discussion among the evaluators, and if consensus was not met, then the final decision was made by the third investigator (GSDO). The data obtained from the trials included nerve block type, sample size, the local anesthetic type and dose, use of ultrasonography, number of patients in treatment groups, type of surgery, early (≤ 4 hour) postoperative pain scores and late (24 hours) postoperative pain scores at rest, cumulative opioid consumption, time to rescue analgesic administration (minutes), follow-up period, and adverse events.

Definition of outcome data

Primary outcomes

Early postoperative pain scores at rest (4 hours after operation); late postoperative pain scores (24 hours after

operation); and cumulative opioid consumption (24 hours) in the postoperative period.

Secondary outcomes

The time to first analgesic administration (minutes) and adverse events including but not limited to: postoperative hypotension, nerve damage, and local anesthetic toxicity.

Meta-analyses

Because the study comparisons were clinically nonhomogeneous and the number of studies with similar comparisons was small (less than three studies), a qualitative description of outcomes was considered more appropriate to assess the included studies. We therefore did not explore the presence of publication bias as we have done in our previous studies.^{24–26}

Results

Our search identified 123 articles and we evaluated 40 studies on 2,408 pediatric patients undergoing various surgical procedures (Figure 1).^{27–66} The median (interquartile range) of the sample size for included studies was 60 (40–70) and the Jadad score was 4 (2–5). Articles that did not meet the inclusion criteria upon further evaluation of full text were omitted^{67–113} and they included incomplete data on analgesic

outcomes,^{114–117} age limit exceeded,^{118–181} trials involving dental procedures,^{182–186} and non-translated articles.^{187–189} The characteristics of the included trials are presented in Table 1.

Appendectomy

One study investigated the use of ultrasound-guided rectus sheath block compared with placebo on postoperative pain scores and opioid consumption.⁵³ The children who received a rectus sheath block reported significantly lower pain scores compared with the control in the first 3 hours following surgery. However, there was no difference in pain scores between groups after 3 hours. Opioid consumption was not different among groups.

Cholecystectomy

One study reported the use of regional anesthesia compared with local anesthetic infiltration at laparoscopic port sites in children scheduled to undergo cholecystectomy.⁵⁸ Intraoperative opioid requirements were less in children receiving the bilateral paravertebral block (PVB) than those who received local anesthetic at the port insertions points. Total postoperative hydromorphone patient-controlled analgesia (PCA) consumption and mean pain scores were no different among groups at 12 hours following surgery. The amount of PCA hydromorphone consumption at 8–12 hours following surgery was greater in the PVB group than in the port infiltration group. At 24 hours, pain scores were greater in the PVB group compared with the port infiltration group. The authors did report that the occurrence of shoulder pain was less pronounced (49%, 95% CI 0.269–0.893) in the PVB group compared with the port infiltration group. Although there were two patients who experienced vascular punctures, none of the incidents presented as symptoms of local toxicity.

Circumcision

Two studies investigated a commonly performed regional anesthesia technique for male circumcision: dorsal penile block. In one study, the authors assessed the analgesic effect of clonidine with bupivacaine in dorsal penile blocks compared with bupivacaine alone.³⁹ Children allocated to the clonidine group requested less additional analgesia compared with control. The Children's Hospital of Eastern Ontario Pain Scale (CHEOPS) score was significantly less in the clonidine group until 24 hours after surgery. In the other study, the authors evaluated a multimodal regimen consisting of a ring block, a eutectic mixture of local anesthetic (EMLA) cream, oral sucrose, and a dorsal penile nerve block.³⁵ The Neonatal Infant Pain Scale (NIPS) score was significantly lower in

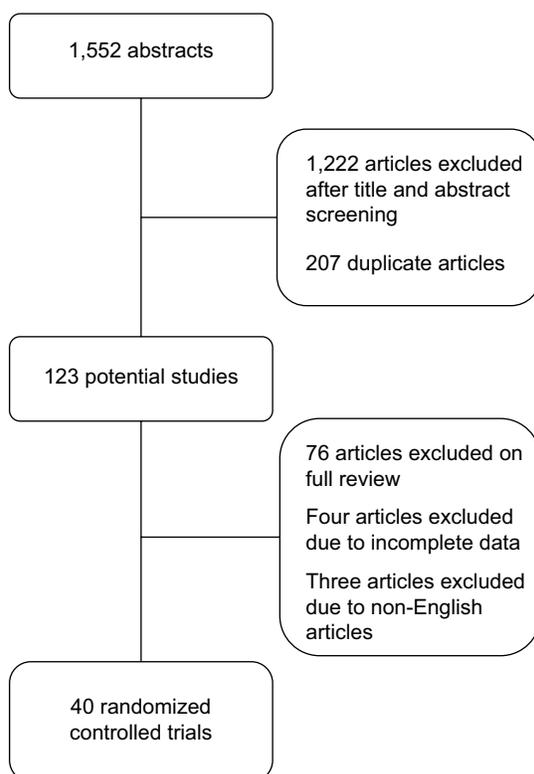


Figure 1 Flow chart outlining systematic review of randomized controlled trials.

Table 1 Summary of included studies

Author	Year	Procedure	USG	Number treatment/control	Block/intervention	Outcomes	Block complications	Modified Jadad score (1-5)
Ince et al ²⁷	2017	Arm/forearm/hand surgery	Y	30/30	Infravascular brachial plexus block	Pain score: no difference	None	4
Litz et al ²⁸	2017	Umbilical hernia repair	Y	30/31	Percutaneous rectus sheath block Intraoperative rectus sheath block	Pain score: no difference in PACU Analgesic use: no difference in PACU	None	3
Luo et al ²⁹	2017	Pectus excavatum surgery	Y	34/28	Bilateral intercostal nerve block IVPCA	Pain score: less in block group first 6 hours Analgesic use: higher in IVPCA group at 24 hours	None	4
Marjanovic et al ³⁰	2017	Orchiopexy/inguinal hernia repair	Y	13/10/17	Caudal block	Analgesic use: no difference	None	2
Ozkan et al ³¹	2017	Soft tissue release for knee/ankle flexion contracture	Y	27/27	Popliteal block	Pain score: less in the popliteal group	None	5
Park et al ³²	2017	Orthopedic lower extremity surgery	Y	30/30	PCA+dexmedetomidine PCA+fentanyl	Pain score: less in dexmedetomidine group at 6 hours Analgesic use: no difference	Neurologic deficit	5
Raof et al ³³	2017	Hernia repair/hydrocelectomy	Y	30/30	TAP block dexmedetomidine	Analgesic use: lower in the dexmedetomidine group	None	5
Sahin et al ³⁴	2017	Lower abdominal surgery	Y	30/30/30	TAP block Ilioinguinal/iliohypogastric blocks Caudal block	Pain score: lower in the TAP and caudal groups at 8 hours Analgesic use: less in TAP and caudal groups	None	1
Sharara-Chami et al ³⁵	2017	Circumcision	Y	20/20/20/10	Dorsal penile nerve block Ring block local anesthetic cream+sucrose	Pain score: lower scores in the intervention group. Analgesia: longer in the ring block group/sucrose/cream	None	5
Uchinami et al ³⁶	2017	Laparoscopic percutaneous extraperitoneal closure	Y	17/17	Rectus sheath block Local anesthetic infiltration	Pain score: no difference at 30 or 60 m	None	3
Abd-Elshafy et al ³⁷	2016	Lower extremity orthopedic surgery	N	30/30/30	Caudal block IV dexamethasone Caudal dexamethasone	Time to first analgesia and number of patients requiring rescue analgesics were less in the IV dexamethasone and caudal dexmedetomidine groups	None	4
Abu Elyazed et al ³⁸	2016	Open inguinal hernia repair	Y	30/30	TAP block	Pain score: lower in TAP block group at 12 hours analgesia use: higher in GA group	None	2
Anouar et al ³⁹	2016	Circumcision	N	20/20	Dorsal penile nerve block Clonidine	Pain scale: lower in clonidine group at 2 to 24 hours Analgesic use: less in clonidine group at 24 hours	None	3

Jarraya et al ⁴⁰	2016	Hernia repair Orchiopexy	N	20/20	Caudal block with clonidine+fentanyl/ Caudal block with fentanyl+placebo	Pain score: less in clonidine group after 6 hours	Residual motor blockade in clonidine group	3
Kendigelen et al ⁴¹	2016	Inguinal hernia	Y	20/20	TAP block Wound infiltration	Pain score: lower in the TAP group Analgesia use: higher at fifth minutes, 1, 6, and 12 hours in the WI group	None	2
Kendigelen et al ⁴²	2016	Hypospadias	N	41/40	Pudendal nerve block Caudal block	Pain score: less in the pudendal group at 24 hours Analgesia use: more in the caudal group	None	5
Marinkovic et al ⁴³	2016	Knee arthroscopy	Y	30/30	Femoral and obturator nerve blocks General anesthesia	Pain score: lower in the block group at 2, 6, and 12 hours Analgesia use: less in the block group	None	2
Niiyama et al ⁴⁴	2016	Microtia surgery	N	24/26	Intercostal nerve block Continuous wound infiltration	Pain control: less in WI group at 12, 36, 48, 60, and 72 hours Analgesia use: less in WI group	None	2
Ohashi et al ⁴⁵	2016	Inguinal hernia repair	Y	19/20	Ilioinguinal/iliohypogastric nerve block	Pain score: no difference at 30 m, 1 hour, 4 hours Analgesic use: not reported	None	5
Sethi et al ⁴⁶	2016	Lower abdominal surgery	Y	36/34	Caudal block TAP block	Pain control: up to 6 hours no difference; was less in TAP block group 6–24 hours Rescue analgesia: no difference	Not reported	3
Shank et al ⁴⁷	2016	Burn reconstructive surgery	Y	5/7/7	Local analgesia infiltration LFCN block FIC block+continuous infusion	Pain score: less in single shot block and catheter group during first 24 hours. Analgesia use: no difference	Not reported	2
Soatda et al ⁴⁸	2016	Renal transplant	N	30/30	Epidural group+multimodal regimen Multimodal regimen	Pain control: was better in epidural group	None	2
Woo et al ⁴⁹	2016	Microtia surgery	Y	30/29	Intercostal nerve block+catheter-based infusion/ IV analgesia	Pain score: less in ICNB group in chest at rest Rescue analgesia use: less in the ICNB group	None	3
Arbi et al ⁵⁰	2015	Open unilateral herniotomy	N	32/32	Caudal IV dexmethasone caudal block	Pain score: less in IV dexmedetomidine group on POD 1 and 2.	None	4
Al-Zaben et al ⁵¹	2015	Lower abdominal and perineal surgery	N	31/30/30	Caudal bupivacaine Caudal bupivacaine + 1 µg/kg dexmedetomidine Caudal bupivacaine + 2 µg/kg dexmedetomidine	Pain score: less in dexmedetomidine groups at 24 hours Analgesic first use: higher in the non- dexmedetomidine group at 24 hours	None	5
Bryskin et al ⁵²	2015	Bilateral ureteral reimplantation	Y	24/21	TAP block Caudal group	Pain scores: lower in the caudal group at PACU Analgesic use: lower in the TAP block group at 24 hours	None	5
Hamill et al ⁵³	2015	Appendectomy	Y	73/73	Rectus sheath block	Pain scores: less in block group at 3 hours Analgesic use: no difference	None	5

(Continued)

Table 1 (Continued)

Author	Year	Procedure	USG	Number treatment/control	Block/intervention	Outcomes	Block complications	Modified Jadad score (1-5)
Lapmahapaisan et al ⁵⁴	2015	Non-laparoscopic major abdominal surgery	Y	18/18/18	TAP block Local anesthetic infiltration Placebo	Pain score: no difference Analgesic use: no difference	None	5
Lundblad et al ⁵⁵	2015	Inguinal hernia repair	Y	21/22	Ilioinguinal/iliohypogastric nerve block with/without dexmedetomidine	Pain score: lower in the dexmedetomidine group at PACU Analgesic first use: prolonged in dexmedetomidine group but no difference	None	5
Suresh et al ⁵⁶	2015	Lower abdominal surgery	Y	18/18	TAP block with bupivacaine 2.5 mg/kg/1.25 mg/kg	Pain scores: no difference Analgesic use: higher in the lower dose group	None	5
Tuzcu et al ⁵⁷	2015	Strabismus	N	20/20	Sub-Tenon's block	Pain scores: less in block group at 30 m Analgesic use: less in block group	None	3
Visoiu et al ⁵⁸	2015	Cholecystectomy	N	41/42	Paravertebral block Port infiltration	Pain score: no difference Analgesic use: no difference	None	5
Al-Zaben et al ⁵⁹	2014	Unilateral orchiopexy	N	35/35	Ilioinguinal/iliohypogastric nerve block IV morphine	Pain scores: lower in morphine group at 1 hour Analgesic use: no difference at 24 hours	None	3
Bharti et al ⁶⁰	2014	Lower abdominal and perineal surgeries	N	20/19/20/19	Caudal block dexmedetomidine (0.5/1.0/1.5 µg/kg)	Pain scores: higher in the plain ropivacaine group at 3-5 hours Analgesic use: more in the plain ropivacaine group	None	5
Chiono et al ⁶¹	2014	Cleft palate repair	Y	30/30	Bilateral suprazygomatic maxillary nerve block	Pain scores: no difference Analgesic use: less in the block group at 48 hours	Bleeding at puncture site; cheek hematoma	5
Flack et al ⁶²	2014	Umbilical hernia repair	Y	20/20	Rectus sheath block Wound infiltration	Pain scores: no difference Analgesic use: less in the block group	None	3
Kim et al ⁶³	2014	Orchiopexy	Y	40/40	Caudal block with/without dexamethasone	Pain scores: less in dexamethasone group at 6 hours and 24 hours Analgesic use: less in dexamethasone group	None	5
Seyedhejazi et al ⁶⁴	2014	Inguinal hernia repair, orchiopexy, hydrocelectomy	N	33/33	Ilioinguinal/iliohypogastric nerve block Caudal block	Pain scores: more severe in the II/IIH group. Analgesic use: no difference	None	2
Qi et al ⁶⁵	2014	Pectus excavatum	Y	15/15	Bilateral thoracic paravertebral block+IVPCA IVPCA	Pain scores: less in the BTPB group at 48 hours Sufentanil use: less in the BTPB group at 24 hours	None	2
Naja et al ⁶⁶	2013	Hypospadias	Y	40/40	Pudendal nerve block Caudal block	Pain scores: lower in the nerve block group at 24 hours Analgesic use: higher in the caudal group at 24 hours	None	4

Abbreviations: BTPB, bilateral thoracic paravertebral block; FC, Fascia iliaca compartment; ICNB, interscostal nerve block; II/IIH, ilioinguinal/iliohypogastric; IV, intravenous; IVPCA, intravenous patient-controlled analgesia; LFCN, lateral femoral cutaneous nerve; PACU, post-anesthesia care unit; PCA, patient-controlled analgesia; POD, postoperative day; TAP, transverse abdominis plane; USG, ultrasound guidance; WI, surgical site local anesthetic infiltration.

the intervention groups compared with those who received the EMLA cream alone. The addition of the ring block with the EMLA cream and oral sucrose provided more effective analgesia than the dorsal penile nerve block, EMLA cream, and oral sucrose. No adverse events were reported.

Cleft palate repair

Orofacial clefts, such as cleft palate, are a common congenital abnormality associated with severe postoperative pain.^{190,191}

One study evaluated the efficacy of bilateral suprazygomatic maxillary nerve blocks on postoperative analgesia outcomes in pediatric patients undergoing cleft palate repair.⁶¹ The authors reported that bilateral suprazygomatic maxillary nerve blocks with ropivacaine lowered the overall morphine consumption compared with placebo after 48 hours following surgery. Interestingly, the postoperative pain scores were not different between ropivacaine and placebo groups. Two minor occurrences related to the nerve block were reported: one patient experienced bleeding at the puncture site while the other patient developed a cheek hematoma in the infrazygomatic area on postoperative day 1. The hematoma resolved spontaneously by postoperative day 5.

Herniotomy

One study investigated the use of a caudal block combined with intravenous dexamethasone on postoperative analgesia in pediatric patients scheduled to have unilateral herniotomy surgery.⁵⁰ The children who received intravenous dexamethasone (0.5 mg/kg) following anesthesia induction reported less pain (Wong-Baker Face Scale) on postoperative days 1 and 2 compared with placebo. There was no pain reported in either group immediately following surgery in the post-anesthesia care unit.

Hypospadias

Two studies investigated the use of regional anesthesia techniques for the pediatric population undergoing hypospadias surgery.^{42,66} Both studies compared pudendal nerve block with caudal block on postoperative analgesic outcomes 24 hours afterward. One study reported that patients who received an ultrasound-guided pudendal nerve block experienced less postoperative pain intensity compared with the caudal group. Moreover, all of the patients who received a caudal block requested additional analgesia medication compared with only 7.5% of the pudendal nerve block group. Taken together, it is not surprising that the patient satisfaction rate was lower in the caudal group. The other study evaluated the efficacy and analgesia duration of a nerve-stimulator

guided pudendal nerve block compared with a caudal block. The postoperative pain scores at 24 hours were less in the pudendal nerve group compared with the caudal group. The total analgesic consumption at 24 hours following surgery was significantly reduced in the pudendal block group compared with the caudal group. Similar to the aforementioned study, the patient satisfaction was higher in the pudendal nerve block group.

Inguinal hernia and groin

Eight studies investigated regional anesthesia and its effect on postoperative analgesia in inguinal hernia and orchiopepy procedures. Three studies evaluated ultrasound-guided transversus abdominis plane (TAP) block on postoperative analgesia.^{33,38,41} One study reported a decrease in opioid consumption at 24 hours in the ultrasound-guided TAP block group compared with general anesthesia alone. The CHEOPS and the Behavioral Objective Pain Score (BOPS) were significantly lower in the TAP block group compared with the control. Another study compared ultrasound-guided TAP block to local anesthetic infiltration. At 24 hours after surgery, the patients who received the TAP block reported significantly lower pain scores and reduced total opioid consumption compared with the patients who received local anesthetic infiltration. Patient satisfaction was higher in the TAP block group. The third study evaluated the effect of adding dexmedetomidine to bupivacaine in pediatric patients scheduled to receive an ultrasound-guided TAP block as part of their postoperative multimodal regimen. The 24 hours total analgesic consumption was significantly higher in the bupivacaine group compared with those who received the combination of bupivacaine and dexmedetomidine.

Three studies assessed the use of ilioinguinal/iliohypogastric nerve blocks in children undergoing inguinal surgeries.^{45,55,64} One study reported postoperative pain (CHIPPS) in the post-anesthesia care unit (PACU) was significantly higher in the local anesthetic group compared with the ilioinguinal/iliohypogastric nerve block group. Another study compared intraoperative ultrasound-guided ilioinguinal/iliohypogastric nerve blocks with those who did not receive a block on postoperative analgesic outcomes. The BOPS was not different between groups at any of the four time points (PACU arrival, 30 minutes, 1 hour, and 4 hours). The next study investigated the addition of clonidine to either caudal blocks or ilioinguinal/iliohypogastric blocks on postoperative outcomes. Patients receiving the ilioinguinal/iliohypogastric blocks experienced more severe postoperative pain compared with the caudal group although

it was not statistically significant. In addition, there was no difference in patients' postoperative analgesic consumption between groups.

Two studies evaluated the efficacy of caudal epidural anesthesia on postoperative analgesia in children undergoing orchiopexy and inguinal hernia repair.^{30,40} One study evaluated three different volumes of 0.25% levobupivacaine (low: 0.6 mL/kg; middle: 0.8 mL/kg; and high: 1.0 mL/kg) and reported that the postoperative analgesic consumption at 6, 12, and 24 hours following surgery did not differ among groups. The postoperative pain was evaluated using the CHIPPS instrument which was not statistically different among groups at any time period. The last study evaluated the efficacy of adding clonidine to a caudal block to alleviate postoperative pain following orchiopexy or hernia repair procedures. No patients requested additional analgesia in either group in the first 6 hours following surgery. The postoperative pain scores (CHEOPS) at 12 and 24 hours were higher in patients who did not receive clonidine compared with those who received clonidine as part of their anesthetic block.

One study compared bilateral ultrasound-guided rectus sheath block with local anesthetic infiltration for laparoscopic percutaneous extraperitoneal closure during inguinal hernia repair in children.³⁶ The pain score (Face, Legs, Activity, Cry, and Consolability [FLACC]) was higher on arrival to the PACU in the local anesthetic infiltration group compared with the rectus sheath block group. However, there was no difference in postoperative pain scores at 30 and 60 minutes between groups. No patients in either of the aforementioned studies experienced immediate or delayed complications.

Lower abdominal procedures

Six studies evaluated regional anesthesia and its effect on postoperative analgesia in lower abdominal procedures including herniorrhaphy, hydrocelectomy, and testicular detorsion.

Four studies examined the efficacy of transversus abdominis plane block for postoperative pain relief in pediatric population undergoing abdominal surgery.^{34,46,54,56} One study compared local infiltration with 0.25% bupivacaine, a control (no block group), and a surgeon-placed bilateral TAP block for non-laparoscopic abdominal procedures. The authors reported no difference in postoperative pain scores and no reduction in cumulative 24 hours opioid consumption among the groups. Suresh et al compared the analgesic efficacy of 1.25–2.5 mg/kg bupivacaine in children scheduled to receive a TAP block for postoperative pain relief.⁵⁶ The pain scores in the PACU were not different between the study groups.

However, the 24 hours total analgesic consumption was higher in the low-dose group compared with the high-dose group. The authors concluded that the higher local anesthetic dose for TAP block in children does not provide benefits in the immediate postoperative recovery period but does seem to decrease the analgesic use 24 hours after surgery.

Another study compared ultrasound-guided TAP block with caudal block for postoperative pain relief after lower abdominal surgery. There was no difference in pain scores between groups in the first 6 hours following surgery. The children who received the caudal block reported a greater incidence of pain 6 hours following surgery than patients allocated to the TAP block group. No statistical difference was reported between groups regarding total opioid consumption.

Sahin et al compared three regional anesthesia techniques in children following elective unilateral lower abdominal surgery.³⁴ The total analgesic consumption was higher in the ilioinguinal/iliohypogastric block compared with the TAP block and caudal block. The pain scores (CHEOPS) during the first 8 hours in the postoperative period were higher in the ilioinguinal/iliohypogastric group compared with the other two groups; however, the pain scores in the ilioinguinal/iliohypogastric group at 16 hours were higher compared with the caudal group. The authors concluded that caudal blocks and TAP blocks are more effective than ilioinguinal/iliohypogastric nerve blocks in the early postoperative period.

One study compared the analgesic efficacy of caudal bupivacaine with two different caudal dexmedetomidine dosages (1 and 2 µg/kg) for postoperative pain relief in pediatric children undergoing lower abdominal and perineal surgery.⁵¹ The time to first analgesic request was longer in children who were allocated to the dexmedetomidine groups compared with the plain bupivacaine group. The 24 hours postoperative analgesic consumption was higher in the plain bupivacaine group compared with either dexmedetomidine groups. However, patients who received dexmedetomidine experienced significantly higher postoperative sedation scores compared with plain bupivacaine group. Two patients who received the 1 µg/kg dexmedetomidine dose developed bradycardia and hypotension and one experienced urinary retention compared with none in the plain bupivacaine group.

A similar study compared caudal ropivacaine to the addition of three different dexmedetomidine dosages (0.5, 1, and 1.5 µg/kg) in caudal ropivacaine on postoperative analgesia in pediatric patients.⁶⁰ The postoperative analgesia was significantly prolonged in all dexmedetomidine groups compared with the plain ropivacaine group. All children receiving plain ropivacaine required opioid analgesia in the

first 6 hours following surgery compared with no opioid requests in all three dexmedetomidine groups. The plain ropivacaine group experienced higher pain scores (FLACC) between 3 and 5 hours following surgery compared with the dexmedetomidine groups. Patients who received 1.5 µg/kg dexmedetomidine experienced higher postoperative sedation scores and significantly prolonged sedation compared with the other groups.

Microtia

Microtia is a congenital deformity of the external ear that requires reconstructive surgery and rib cartilage harvesting. Children often complain of severe postoperative pain during the immediate postoperative period. Two studies examined regional anesthesia in children undergoing auricular reconstruction for postoperative pain relief.^{44,49} One study compared a single-shot intercostal nerve block containing ropivacaine to a 48 hours infusion of ropivacaine into the surgical site on postoperative analgesia outcomes. The supplemental analgesic use was significantly higher in the intercostal nerve block group compared with the surgical site infiltration group. The postoperative pain score (Face Scale; 0=none, 5=severe) was significantly lower in the surgical site infiltration group compared with the intercostal nerve block at 12 to 72 hours after surgery. No patients experienced symptoms of central nervous system or cardiovascular toxicity. The number of patients who experienced postoperative nausea and vomiting (PONV) was not different between groups.

The second study compared the combination of a single-shot intercostal nerve block followed by a catheter-based infusion of ropivacaine to intravenous analgesia on postoperative pain after rib harvesting for auricular reconstruction in children with microtia. The average pain scores (numerical pain rating score) of chest pain at rest and during coughing in the first 48 hours after the surgery was significantly lower in the intercostal nerve block plus infusion group compared with the intravenous analgesia (control) group. Ear pain was also significantly higher in the control group compared with the study group. Rescue medication during the first 48 hours following surgery was significantly less in the block plus infusion group compared with the intravenous analgesia group.

Orchiopexy

Two studies examined the use of regional anesthesia for postoperative pain relief in children undergoing orchiopexy.^{59,63} Orchiopexy is a commonly performed procedure in children with an undescended testicle or testes and is associated with moderate-to-severe postoperative pain lasting up to several

days following surgery.¹⁹² One study compared the analgesic efficacy of caudal ropivacaine with and without dexamethasone (0.1 mg/kg) on postoperative pain and rescue analgesic consumption in children undergoing unilateral orchiopexy. The postoperative pain scores (numeric rating scale [NRS]) were significantly lower in the dexamethasone group compared with the plain ropivacaine group up to 48 hours following surgery. At 48 hours after surgery, there was no difference in the pain scores between groups. Consumption of oral analgesics at 48 hours after surgery was less in the dexamethasone group (28.9%) compared with the plain ropivacaine group (54.1%).

The other study compared ilioinguinal/iliohypogastric nerve block to intravenous morphine in pediatric patients undergoing unilateral orchiopexy surgery. The postoperative pain scores (NRS) were significantly lower in the morphine group compared with the block group in the first hour after surgery. After 60 minutes in the PACU, there was no difference in pain scores between groups. The 24 hours postoperative analgesic consumption was not different between groups. Patients allocated to the morphine group experienced more vomiting and itching compared with the nerve block group.

Orthopedic procedures

Four studies investigated the use of regional anesthesia for postoperative analgesia outcomes in children scheduled to undergo lower extremity orthopedic procedures.^{31,32,37,43} As a component of multimodal anesthesia, regional anesthesia techniques are increasing in popularity for surgical procedures especially in orthopedic surgery.^{193–195} One study compared ultrasound-guided femoral nerve block together with the obturator nerve to a no-nerve block group. The postoperative pain score (Wong-Baker FACE Scale) was significantly lower in the children who received a nerve block compared with those who did not receive a nerve block. In addition, the postoperative analgesic consumption was also significantly less in the block group.

The second study compared the use of a bupivacaine caudal block with and without dexamethasone and intravenous dexamethasone on postoperative pain in pediatric patients undergoing lower limb orthopedic surgery.³⁷ In the first 8 hours and the 12 to 24 hours postoperative period, the postoperative pain scores were higher in the patients who received the caudal epidural with plain bupivacaine compared with those allocated to either dexamethasone groups (caudal or intravenous). There was no difference in pain scores among all three groups at the 12 hours postoperative period. The number of analgesic doses requested was significantly lower in the dexamethasone groups compared with the caudal block

with plain bupivacaine. Moreover, no difference was reported between the plain bupivacaine caudal with intravenous dexamethasone group and the caudal dexamethasone group.

The third study compared the efficacy of epidural adjuvants, dexmedetomidine, and fentanyl to local anesthetics in pediatric orthopedic surgery.³² The median postoperative pain score (revised scale FLACC)¹⁹⁶ was not different among groups at PACU arrival, 12, 24, and 48 hours after surgery. At 6 hours following surgery, the dexmedetomidine group reported significantly lower pain scores compared with the fentanyl group. Rescue analgesic use was not different between groups throughout the 48 hours follow-up period.

Another study evaluated the effects of preoperative ultrasound-guided popliteal block on analgesic outcomes in children with cerebral palsy undergoing lower limb surgery.³¹ The total paracetamol consumption was significantly lower in the popliteal nerve block group compared with the non-block group. The postoperative pain scores (Wong-Baker FACE Scale) were higher in the control group compared with the nerve block group at 10 minutes, 20 minutes, and up to 12 hours postoperatively. There was no difference in pain scores between groups at 24 hours after surgery.

The last study in the group compared ultrasound-guided infraclavicular brachial plexus blocks with two different local anesthetic dosages in children undergoing upper extremity orthopedic surgery.²⁷ The authors detected no statistical difference in postoperative pain scores (Wong-Baker FACE Scale) between local anesthetic volumes of 0.5% bupivacaine (0.25 and 0.50 mL/kg) during the first 24 hours following surgery. No block complications such as pneumothorax or hematoma were reported in either group.

Pectus excavatum

Pectus excavatum is the most common congenital chest wall deformity in children with an incidence of one in 400.¹⁹⁷ The Nuss procedure is a surgical procedure in which a substernal bar is implanted into the anterior chest wall to help stabilize its shape. The procedure is associated with moderate postoperative pain which may affect postoperative rehabilitation and lead to an increased length of hospitalization.^{198,199} Two studies investigated the effectiveness of regional anesthesia in providing postoperative pain in children undergoing the Nuss procedure.^{29,65} One study compared ultrasound-guided bilateral intercostal nerve blocks with intravenous analgesia for postoperative analgesia. The postoperative pain scores (Faces Pain Scale-Revised, FPS-R) in the first 6 hours were significantly decreased in the nerve block group compared with the control group. The 24 hours opioid consumption

was significantly less in the nerve block group compared with the control group.

The other study examined the use of ultrasound-guided bilateral thoracic PVBs and intravenous PCA for postoperative pain. The postoperative pain scores (FLACC; visual analog scale) were significantly reduced in the nerve block group compared with the control group in the first 48 hours following surgery. The 24 hours cumulative opioid consumption was significantly higher in the control group compared with that in the nerve block group. No immediate nerve block complications were reported by the authors in either study.

Umbilical hernia

Two studies investigated the effectiveness of regional anesthesia on postoperative pain for umbilical hernia repair in children. Flack et al compared the use of ultrasound-guided rectus sheath blocks with surgical site infiltration on postoperative opioid consumption and reported that children allocated to the block group consumed significantly less opioids than those in the surgical site infiltration group.⁶² However, there was no difference in the average maximum pain scores between groups.

The second study compared the use of preoperative ultrasound-guided rectus sheath blocks with surgeon-placed rectus sheath blocks for postoperative pain relief.²⁸ The mean postoperative pain scores (Wong-Baker FACE Scale) and analgesia consumption in the post-anesthesia care unit were similar between groups.

Renal transplant

A single study evaluated the effectiveness of a caudal epidural block with and without intravenous fentanyl and paracetamol for postoperative pain relief in children undergoing renal transplantation.⁴⁸ Postoperative pain management after renal transplantation poses a challenge due to the limited kidney function and possible respiratory depression from systemic opioids.^{200–202} The placement of catheters to the thoracic level through the caudal route has been described in many studies and is thought to be safer than direct catheter placement at the lumbar or thoracic levels in children receiving general anesthesia.^{203,204} Soaida et al reported postoperative pain scores that were statistically higher at 6, 12, and 18 hours in the intravenous fentanyl group compared with those who received the caudal epidural block.⁴⁸ Over half of the patients in the control group compared with none in the caudal group received rescue analgesia upon arriving to the post-anesthesia care unit. There were two cases in which

threading the epidural catheter to the thoracic region failed and were excluded from the study.

Strabismus

One study examined regional anesthesia on postoperative pain in pediatric ocular procedures. Strabismus surgery is a common pediatric ocular operation that causes several unpleasant side effects throughout the perioperative period. The most concerning issue is the occurrence of the oculocardiac reflex. It is associated with increased PONV due to the disturbance of the extraocular muscles during surgery.²⁰⁵ Tuzcu et al compared the effectiveness of sub-Tenon's block on postoperative analgesia in children having strabismus surgery.⁵⁷ Patient who received the block reported lower postoperative pain scores (NRS 0–4; 0=no pain, 4=very severe pain) 30 minutes following the procedure compared with those who did not receive the block. In addition, postoperative analgesic use was less in the block group compared with the control group.

Burn reconstructive surgery

One study investigated the use of ultrasound-guided regional anesthesia for postoperative pain control in pediatric burn patients undergoing reconstructive surgery. Burn patients often undergo multiple reconstructive surgeries to regain body function and esthetics.²⁰⁶ Postoperative pain following skin grafting has been challenging and is a main reason for patients to decline reconstructive procedures. Shank et al compared surgical site infiltration (0.25% bupivacaine), ultrasound-guided single-shot lateral femoral cutaneous nerve block, and ultrasound-guided continuous infusion fascia-iliaca compartment block on postoperative pain in children undergoing reconstructive skin grafting.⁴⁷ The authors reported that patients who received regional anesthesia via single-shot lateral femoral cutaneous nerve block (LFCNB) or catheter infusion fascia iliaca compartment block (FICB) experienced less pain than those in the surgical site infiltration group. The patients in the LFCNB group reported significantly less postoperative pain upon arrival to the post-anesthesia care unit until discharge to the floor compared with the FICB group or the control group. However, patients in the FICB group reported significantly lower pain scores on postoperative days 1 and 2 compared with LFCNB and the control group. There was no difference in opioid consumption among all three groups.

Discussion

The current investigation demonstrates that the number of clinical trials supporting the use of regional anesthesia for the

management of postoperative pain has increased in children undergoing surgery. Notably, of the 2,408 patients included in the review, no significant complication attributed to the regional anesthesia techniques such as systemic toxicity or neurological sequelae was reported. The majority of the regional anesthesia techniques were performed using ultrasound guidance, which may be a contributing factor in the observed increased rate of publication of clinical trials in this area. The ability to provide site-specific analgesia while reducing opioid consumption results in targeted pain relief with fewer side effects. Although there has been an increase in the use of regional anesthesia in the pediatric literature demonstrating improvement of postoperative outcomes, our review calls for further examination of the effect of regional anesthesia techniques on postoperative outcomes in pediatric patients.

The strongest evidence to support the use of regional anesthesia for postoperative pain management in children was demonstrated by studies of intercostal nerve blocks (three studies) for reconstructive ear surgery and chest wall deformity. A decrease in postoperative discomfort and analgesic consumption was more pronounced in patients receiving intercostal nerve blocks compared with local anesthetic infusion or infiltration of the surgical site.

Pudendal nerve block is commonly used in adults undergoing obstetric and anorectal procedures. The use of a pudendal nerve block (two studies) for postoperative pain management in pediatric hypospadias surgery provided superior pain relief and reduced 24 hours analgesic consumption compared with caudal blocks, resulting in fewer side effects and improvement in sleep patterns.

Bilateral suprazygomatic maxillary nerve blocks (one study) provided good pain relief by reducing the total opioid consumption 48 hours following cleft palate repair compared with placebo and show promise as an alternative to intravenous opioids. Other regional anesthesia techniques, such as rectus sheath blocks for umbilical hernia surgery, reduced opioid consumption compared with local anesthetic infiltration of the surgical site.

In contrast, several studies have shown a marginal benefit of regional anesthesia in postoperative pain management in children. Similar to our previous study,²¹ ilioinguinal/iliohypogastric nerve blocks for inguinal hernia repair demonstrate mixed results.

Abu Elyazed et al reported a decrease in total opioid consumption at 24 hours following surgery in patients receiving an ultrasound-guided TAP block compared with general anesthesia alone.³⁸ This finding is similar to previous

reports that demonstrated that local anesthetics lowered postoperative analgesic requirements compared with general anesthesia.^{207–209} Compared with TAP block or caudal block, ilioinguinal/iliohypogastric nerve blocks did not provide substantial pain relief or reduce opioid consumption in the early postoperative period.³⁴ However, the use of ilioinguinal/iliohypogastric nerve blocks for unilateral orchiopexy procedures provides short-term pain relief, and patients experience fewer side effects than with intravenous analgesics.⁵⁹

The use of PVBs for postoperative pain relief following cholecystectomy in pediatric patients demonstrated inconclusive results when compared with local anesthetic infiltration at laparoscopic port sites. Similar inconclusive reports on the application of thoracic PVBs and neuraxial anesthesia for cholecystectomy have been published in adult patients.^{210–212} However, patients who received bilateral paravertebral nerve blocks following reconstructive chest wall repair experienced excellent pain relief in the first 48 hours following the procedure.

Caudal epidural blocks are one of the most commonly performed techniques in pediatric regional anesthesia with success rates of above 95%.²¹³ In the present review, we found that almost half of the studies that contained a caudal block arm used ultrasound guidance during catheter placement which is higher than our previous report. Caudal blocks together with dexamethasone provided improved postoperative pain relief (greater than 6 hours), particularly in children undergoing orchiopexy and lower extremity orthopedic surgery. This finding is similar to the report by Hong et al which reported a single dose of intravenous dexamethasone combined with a caudal block prolonged postoperative pain relief in pediatric orchiopexy.²¹⁴

In contrast, all children recovering from hypospadias surgery who received a caudal block requested additional analgesics, suggesting inadequate pain relief. Further investigations involving the safety of regional neuraxial techniques with adjuvants in children are warranted.

Use of additives to local anesthetics for prolongation of the duration of analgesia is common, as this may decrease the total amount of local anesthetic that is necessary.^{215–217} Clonidine has been shown to improve postoperative pain control.^{218,219} Several trials evaluated the use of adjuvants, such as clonidine and dexmedetomidine, together with local anesthetics and reported that patients requested less supplemental medication due to the enhanced analgesia.^{51,55} However, patients who received dexmedetomidine experienced excessive sedation, and two patients experienced side effects, which suggests that appropriate dosing of dexmedetomidine in children deserves further investigation.^{220,221} The use of

adjuvants to local anesthetics in the pediatric population is limited and further studies evaluating its enhanced analgesic effect and safety profile in children are warranted.

Limitations

Our review must be interpreted within the context of the study's limitations. Comparisons in pragmatic trials were heterogeneous (different drugs, adjuvants, or both) and the number of trials for the same surgical procedure was small. We did not carry out a quantitative analysis and limited our review to a qualitative evaluation. We could not assess the existence of publication bias, and it is plausible that negative trials investigating analgesic outcomes were never published. In addition, we did not evaluate if variations of block technique affected pain outcomes.

Conclusion

We performed a systemic review of randomized controlled trials published from 2013 to 2017 in order to assess the effectiveness of regional anesthesia procedures on postoperative outcomes in children after pediatric surgery. Although there are challenges with conducting randomized controlled trials in children, the quantity and quality of the number of pediatric studies published on the topic of regional anesthesia techniques have increased. Still, further trials are needed to improve our knowledge of the benefits and risks of regional anesthesia techniques associated with specific pediatric procedures.

Disclosure

The authors report no conflicts of interest in this work.

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