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Caudal versus regional block with the use of ultrasound in pediatric analgesia: a systematic review of the main clinical results

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Abstract

Introduction: Regional anesthesia has been gaining prominence in recent decades. A variety of peripheral and central nerve blocks have been developed to ensure that perioperative pain can be effectively controlled. Caudal block is one of the most widely administered techniques of regional anesthesia, and the use of ultrasound has enabled the optimization and precision of the techniques. **Objective:** This study aimed to analyze the main clinical considerations and outcomes of ultrasound-guided caudal and regional block for pediatric analgesia. **Methods:** The systematic review rules of the PRISMA Platform were followed. The search was carried out from May to July 2024 in the Web of Science, Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** A total of 120 articles were found. 75 articles were evaluated and 27 were included in this systematic review. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 5 studies with a high risk of bias and 21 studies that did not meet GRADE. Most studies showed homogeneity in their results, with $I^2 = 18.7\% < 50\%$. All these techniques protect children from perioperative pain and, combined with periprocedural sedation, allow surgical interventions with spontaneous breathing in groups of patients with maximum risk of difficult airways. We consider this specific point the main advantage of regional anesthesia in pediatric patients. Ultrasound-guided caudal epidural, performed under sedation with a non-instrumented airway, is an effective technique in daily clinical routine; however, higher body weight and surgical procedures in the mid-abdomen are risk factors for pain-related block failure. Patients who, regardless of chronological age, were born as extremely premature infants have a higher risk of respiratory events. For bilateral inguinal hernia surgeries, ultrasound-guided caudal epidural block and transversus abdominis plane block showed similar analgesic efficacy in the first six hours postoperatively. Furthermore, ultrasound-guided lower limb peripheral nerve block is a simple and safe method to provide adequate and longer-lasting analgesia compared with ultrasound-guided caudal block for pediatric lower limb surgeries. Ultrasound-guided erector spinae block was safe and effective in pediatric patients undergoing unilateral lower abdominal surgery, as it provided longer-lasting analgesia and fewer analgesic requirements than caudal block and fewer side effects. In children undergoing regional anesthesia, the incidence of infection, hematoma, and local anesthetic toxicity is low.

Keywords: Caudal anesthesia. Regional anesthesia. Abdominal wall block. Ultrasound. Pediatrics.

Introduction

In the setting of pediatric anesthesia procedures, regional anesthesia has gained prominence in recent decades. A variety of peripheral and central nerve blocks have been developed to ensure that

perioperative pain can be effectively controlled. These developments have made it possible to reduce systemic drug concentrations, thus paving the way for periprocedural spontaneous breathing and early ambulation. Furthermore, reduced dose concentrations have improved hemodynamic stability in potentially high-risk patient populations, such as those with cardiopulmonary insufficiency, respiratory depression, or prematurity [1,2].

Despite this, it is still unclear whether any long-term outcome parameters can be affected by regional anesthesia. However, of the neurotoxicity of general anesthesia, regional anesthesia may offer some advantages [2]. Therefore, the caudal block is one of the most widely administered techniques of regional anesthesia in pediatric patients undergoing sub-umbilical interventions [3].

In addition, pediatric caudal epidural block is a simple, safe procedure with a high success rate. It is the preferred mode of analgesia for pediatric inguinal surgeries, but the duration of analgesia is very short when used as a single injection. Many additives have been used with local anesthetics in single-injection caudal epidurals to prolong the duration of analgesia [4]. Dexmedetomidine is a highly selective α2 agonist and has been shown to prolong the duration of caudal analgesia when used in pediatric surgeries [4]. Dexmedetomidine has been shown to prolong the duration of peripheral nerve blocks in children [5,6].

Also, ilioinguinal and iliohypogastric nerve block is another equally effective regional anesthesia technique for inguinal hernia surgeries in children [7]. However, the main disadvantage of ilioinguinal and iliohypogastric block is a high failure rate when performed blindly. Thus, ultrasound-guided ilioinguinal and iliohypogastric blocks are being described with a significantly higher success rate [8,9]. This technique is proving to be as effective as a caudal block for postoperative analgesia in children [7].

Given the above, the present systematic review study analyzed the main considerations and clinical outcomes of ultrasound-guided caudal and regional blocks for pediatric analgesia.

Methods

Study Design

The present study followed the international systematic review model, following the rules of PRISMA (preferred reporting items for systematic reviews and meta-analysis). Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed on: 07/10/2024. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: https://amstar.ca/. Accessed on: 07/10/2024.

Research Strategy and Search Sources

The literature search process was carried out from May to July 2024 and developed in the Web of Science, Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases, covering scientific articles from various periods to the present day. The following descriptors (DeCS / MeSH Terms) were used: "Caudal anesthesia. Regional anesthesia. Abdominal wall block. Ultrasound. Pediatrics", and using the Boolean "and" between the MeSH terms and "or" between the historical discoveries.

Study Quality and Risk of Bias

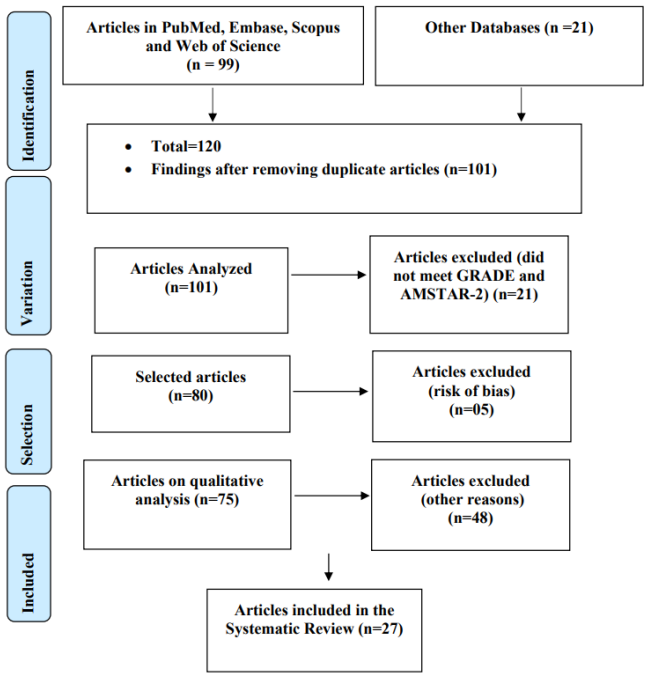
The quality was classified as high, moderate, low, or very low regarding the risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analysis of randomized clinical trials, followed by randomized clinical trials. Low quality of evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument by analyzing the Funnel Plot graph (Sample size versus Effect size), using Cohen's d test.

Results and Discussion

Summary of Findings

As a result of the literature search system, a total of 120 articles were found that were submitted to eligibility analysis, and then 27 of the 75 final studies were selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering in the first instance the level of scientific evidence of studies in study types such as meta-analysis, consensus, randomized clinical, prospective and observational. Biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies presented homogeneity in their results, with I^2=18.7%<50%. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 5 studies with high risk of bias and 21 studies that did not meet GRADE and AMSTAR-2.

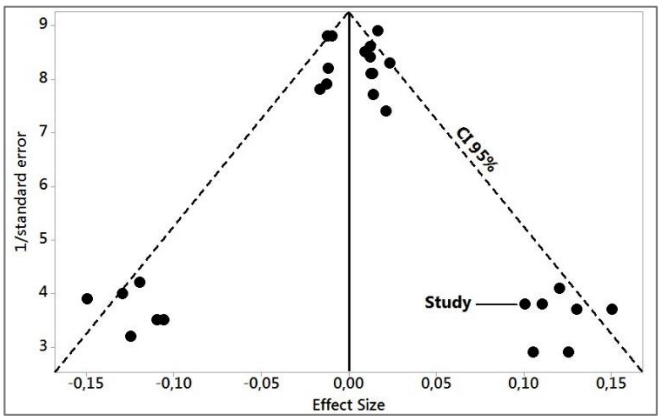
Figure 1. Flowchart showing the article selection process.



Source: Own Authorship.

Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using Cohen's Test (d). Precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph had a symmetrical behavior, not suggesting a significant risk of bias, both among studies with small sample sizes (lower precision) that are shown at the bottom of the graph and in studies with large sample sizes that are shown at the top.

Figure 2. The symmetrical funnel plot does not suggest a risk of bias among the studies with small sample sizes that are shown at the bottom of the graph. Studies with high confidence and high recommendation are shown above the graph (n=27 studies).



Source: Own Authorship.

Key Clinical Findings - Ultrasound-Guided Caudal Versus Regional Block

Caudal epidural block in children is one of the most widely administered regional anesthesia techniques, and the patient selection can be expanded to include preterm infants up to 50 kg body weight. Caudal blocks are an efficient way to provide perioperative analgesia for painful sub-umbilical interventions, allowing not only early ambulation but also periprocedural hemodynamic stability and spontaneous breathing in groups of patients at maximum risk of a difficult airway. These are important advantages over general anesthesia, particularly in preterm infants and in children with cardiopulmonary comorbidities [3]. Although caudal anesthesia produces convincing success rates, it can be prone to block failure [10]. Ultrasound guidance, in contrast, helps to identify small anatomical structures and allows the spread of local anesthetic to be observed [10-12].

Ultrasound guidance also does not impose any special requirements on patient positioning or additional asepsis. The superiority of ultrasound-guided puncture is so obvious that it remains unchallenged, especially in premature infants and in infants whose sacral anatomy is not well understood [13]. However, more large-scale prospective clinical trials are needed to confirm that ultrasound provides better morbidity and long-term outcomes in children of any age treated with caudal anesthesia [10,11]. In this regard, regional anesthesia in children offers a good balance between safety and risks during the perioperative period [14,15]. Data from a European multicenter study suggested that regional anesthesia is safe and has a very low overall complication rate of 0.12% in pediatrics [14].

Furthermore, a large multicenter study in the United States (Polaner and colleagues [16]) showed that factors that appear to significantly increase the risk include age younger than 6 months, central nerve blocks, and catheter use. Nevertheless, caudal blocks are known to involve hemodynamic/systemic or local adverse events. Examples include arrhythmia, hypotension when combined with general anesthesia, respiratory depression resulting from inadvertent anesthetic expansion, toxicity-related seizures, puncture site infection/inflammation, sacral osteomyelitis, or local nerve injury. However, the morbidity associated with any of these events is low. Ecoffey and colleagues [17] analyzed data from 31,132 regional anesthetic procedures and identified only eight patients with complications related to caudal blocks, six dural punctures (without post-dural puncture headache), one nerve injury, and one case of cardiac toxicity. Polaner and colleagues [16] further reported 'no complications in the caudal group', noting that the main periprocedural problems were the inability to place the block and block failure. Although central regional techniques in adults are preferably performed with the patient awake to

obtain instantaneous feedback on paresthesias, pain, or symptoms of systemic toxicity of the local anesthetic, children are usually sedated to ensure immobility during puncture [18]. The literature shows that regional anesthesia is safe during deep sedation or general anesthesia [14,15,18].

Despite the different regional anesthesia techniques used to provide intraoperative and postoperative analgesia in pediatric patients, the analgesic efficacy of peripheral nerve blocks with minimal side effect profiles has not yet been fully determined. Therefore, a randomized controlled clinical trial compared the efficacy of ultrasound-guided transversus abdominis plane (TAP) block, quadratus lumborum (QL) block, and caudal epidural block for perioperative analgesia in pediatric patients aged 6 months to 14 years undergoing elective unilateral lower abdominal wall surgery. A total of 94 patients classified by the American Society of Anesthesiologists (ASA) as ASA I or ASA II were randomly divided into 3 equal groups to undergo TAP, QL, or caudal epidural block using 0.25% bupivacaine solution (0.5 mL/kg). Postoperative analgesic consumption was higher in the TAP block group ($p<0.05$). In the QL block group, Pediatric Pain Objective Scale (POAS) scores were statistically significantly lower after 2 and 4 hours ($p<0.05$). The length of hospital stay was significantly longer in the caudal block group than in the QL block group ($p<0.05$). Therefore, ultrasound-guided QL block analgesia may be considered an option for perioperative analgesia in pediatric patients undergoing lower abdominal surgery [19].

In this sense, a randomized controlled clinical study compared the duration of analgesia provided by local anesthetic (LA) and dexmedetomidine for caudal and ilioinguinal/iliohypogastric block for pediatric inguinal surgeries. A total of 46 children undergoing inguinal hernia repair were selected. After general anesthesia, the children received 0.75 mL/kg of 0.25% bupivacaine with 1 mcg/kg of dexmedetomidine in caudal epidural or 0.25 mL/kg of 0.25% bupivacaine with 1 mcg/kg of dexmedetomidine in ilioinguinal/iliohypogastric block. The pain was assessed up to 24 hours postoperatively using the face, legs, activity, crying, and consolability (FLACC) score. For FLACC ≥4, rescue analgesia was provided with 1 μg/kg intravenous fentanyl up to 2 hours postoperatively and 10 mg/kg oral ibuprofen between 2 and 24 hours postoperatively. There were no significant differences in pain scores or analgesic use between groups. The duration of analgesia for caudal and ilioinguinal/iliohypogastric blocks were similar (720.3±430.1 min and 808.4±453.1 min, respectively). The time taken to perform the block was significantly longer for caudal compared with ilioinguinal/iliohypogastric (547±93 vs. 317±179 s; $p<0.001$). Therefore, both caudal epidural block and ilioinguinal/iliohypogastric block with ultrasound and with dexmedetomidine as an adjunct provided comparable duration of postoperative analgesia without significant side effects [20].

In addition, a retrospective observational study of validated data from April 2014 to December 2020 in a pediatric cohort where the initial plan for anesthetic management was sedation and caudal epidural without general anesthesia or airway instrumentation. In total, 2547 patients ≤ 15 years of chronological age met the inclusion criteria. Among the 2547 cases, including 453 (17.8%) ex-preterm patients, the success rate of caudal epidural plus sedation was 95.1%. The primary anesthesia plan was abandoned for general anesthesia in 124 cases. Pain-related block failure in 83 (3.2%) was the most common cause of conversion. Complications included 39 respiratory events and 9 accidental spinal anesthesias. Higher odds of pain-related block failure were associated with higher body weight as well as with mid-abdominal surgery (such as umbilical hernia repair), while extreme prematurity (<28 weeks), regardless of chronological age, was associated with higher odds for respiratory problems [21].

Furthermore, a prospective randomized trial compared point-guided, neurostimulation-guided, and ultrasound-guided techniques in terms of success rate. A total of 300 children aged 1–5 years scheduled for circumcision, hypospadias repair, and minor lower extremity surgeries were enrolled. Demographic profiles were comparable in terms of age, weight, sex distribution, and types of surgeries. The success rates of point-guided, neurostimulation-guided, and ultrasound-guided were 97%, 97%, and 98%, respectively, which were comparable ($p=0.879$). There was no significant difference in the incidence of blood or cerebrospinal fluid aspiration. Therefore, a similar success rate of caudal epidural block was found [22]. Ultrasound-guided caudal epidural block (CEB) and transversus abdominis plane block (TAPB) are two techniques used for pain control after inguinal hernia (IHR) surgeries. Thus, a randomized controlled clinical trial compared CEB and ultrasoundguided TAPB for postoperative pain scores, additional analgesic requirements, and the development of chronic pain in pediatric bilateral open IHR. A total of 70 patients aged 1 to 7 years who underwent bilateral open IHR were included. Patients were randomized into group T (bilateral TAPB) and group C (CEB). Postoperative FLACC (face, legs, activity, crying, consolability) scores were assessed for pain intensity. The need for additional analgesics and length of hospital stay were also recorded. Postoperative FLACC scores at 15, 30, and 45

minutes, the first and second hours were similar in both groups (p>0.05). In group C, FLACC scores at 6 and 24 postoperative days were significantly higher than in group T. The need for additional analgesics in the postoperative 24 hours was statistically higher in group C (56.7%) than in group T (20%) (p<0.01). The development of chronic pain did not differ between groups (p>0.05). The length of hospital stay was shorter in patients in group T compared with patients in group C (p<0.01). Therefore, for bilateral IHR, US-guided CEB and TAPB have similar analgesic efficacy in the first six postoperative hours [23].

Authors Jain, Hussain, and Ayub, 2022, performed a meta-analysis study to determine the usefulness of ultrasound in caudal blocks in children over the landmark-based technique. Randomized controlled trials comparing ultrasound-guided caudal blocks and landmark-based techniques in pediatrics were searched. A total of 5 studies with 904 participants were included. There was no difference in the success rate between the two techniques (p=0.15). The time to perform the block was similar (p=0.57), while the first puncture success was higher with the ultrasound-guided technique (p=0.0001). Complications such as vascular puncture and needle misplacement were less in the ultrasound group, and no serious complications were observed in any patient. Needle visualization and sacral canal distension were observed in 82% and 97.5% of cases, respectively, in the ultrasound group. Therefore, ultrasound-guided caudal injection does not improve the success rate or time to perform the block, but results in higher first-time success and lower incidence of complications compared to the reference technique [24].

A randomized clinical trial conducted by authors Mahrous, Ahmed, and Ahmed, 2022, compared the efficacy of ultrasound-guided caudal block versus ultrasound-guided peripheral nerve blocks (femoral and sciatic nerve blocks) in providing perioperative analgesia in pediatrics undergoing unilateral lower limb surgery. Children aged 1 to 12 years scheduled for unilateral lower limb surgery during the period January 2020 to December 2021 were randomly allocated into two groups. Group C received an ultrasound-guided caudal block, while Group P, received ultrasound-guided sciatic and femoral nerve blocks after induction of general anesthesia (GA). There was statistical significance at 6, 8, 12, and 24 hours postoperatively, frequency of analgesia, as well as the total postoperative dose of opioids (nalbuphine). The time to the first requirement of analgesia (nalbuphine) was significantly shorter in group C with a mean of (9.6±2.9 h) than in group P with a mean of (15.1±3.5 h). Parents of children in group P were more satisfied than those in group C, with no complications recorded for both techniques [25].

Also, a randomized, controlled, double-blind clinical study evaluated the safety and efficacy of ultrasound-guided erector spinae block and compared its analgesic effect with ultrasound-guided caudal block in pediatric patients. A total of 63 children were included for unilateral lower abdominal surgeries under general anesthesia and were randomly allocated into 3 equal parallel groups: Group I (erector spinae block group – ESB) received an ultrasound-guided erector spinae muscle block at a dose of 0.4 mg/kg of 0.25% bupivacaine between the 10th transverse process and the erector spinae muscles. Group II (caudal block – CB group) received an ultrasound-guided caudal block at a dose of 2.5 mg/kg of 0.25% bupivacaine. The last group, Group III (control group C), did not receive any regional block. The immediate postoperative FLACC score was lower in the ESB group than in the CB group; both were lower than the control group. Erector spinae block had a longer duration of analgesia than caudal block duration of analgesia in the ESB group was 8 (8-12) hours while it was 6 (6-8) hours in the CB group. Both groups had a longer duration of analgesia compared to group C 0.25 (0.17-4) hours. The total amount of analgesia was less in the ESB group than in the CB group. The number of patients who required rescue analgesia with intravenous fentanyl was 14 patients in group C while no patients required intravenous fentanyl in ESB and CB groups [26].

Finally, a joint committee of the European Society for Regional Anaesthesia and Pain Therapy (ESRA) and the American Society for Regional Anaesthesia and Pain Medicine (ASRA) reviewed electronic literature databases on pediatric regional anesthesia to construct evidence-based recommendations. Thus, for epidural anesthesia, lumbar or thoracic placement is preferred. Skin preparation before block placement with chlorhexidine is preferred over povidone-iodine. A tunneled catheter technique is suggested when using the caudal route or if the epidural catheter placement is to be left in situ for more than 3 days. Inspection of the epidural catheter insertion site should be performed at least once daily as part of postoperative management. When the medical and physical examinations are normal, coagulation tests are usually unnecessary, but if coagulation tests are abnormal, neuraxial and deep peripheral nerve blocks are contraindicated. For patients receiving thromboprophylaxis with low molecular weight heparin, a safety interval of two half-lives plus the time required for heparin to reach peak levels is considered an adequate compromise between the risk of bleeding and the risk of thrombosis when removing epidural catheters. Ultrasound-guided peripheral nerve blocks reduce the risk of vascular puncture and therefore the

risk of local anesthetic toxicity is reduced. In children undergoing regional anesthesia, the incidence of infection, hematoma, and local anesthetic toxicity is low [27].

Conclusion

It was concluded that all techniques that protect children from perioperative pain and, combined with periprocedural sedation, allow surgical interventions with spontaneous breathing in groups of patients at maximum risk of difficult airways. We consider this specific point to be the main advantage of regional anesthesia in pediatric patients. Ultrasound-guided caudal epidural block, performed under sedation with a non-instrumented airway, is an effective technique in daily clinical routine; however, higher body weight and surgical procedures in the mid-abdomen are risk factors for pain-related block failure. Patients who, regardless of chronological age, were born as extremely premature infants have a higher risk of respiratory events. For bilateral inguinal hernia surgeries, ultrasound-guided caudal epidural block and transversus abdominis plane block showed similar analgesic efficacy in the first six postoperative hours. Furthermore, ultrasoundguided lower limb peripheral nerve block is a simple and safe method to provide adequate and longer analgesia compared with ultrasound-guided caudal block for pediatric lower limb surgeries. Ultrasound-guided erector spinae block was safe and effective in pediatric patients undergoing unilateral lower abdominal surgery, providing longer-lasting analgesia and fewer analgesic requirements than caudal block and fewer side effects. In children undergoing regional anesthesia, the incidence of infection, hematoma, and local anesthetic toxicity is low.

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Informed Consent

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Data Sharing Statement

No additional data are available.

Conflict of Interest

The authors declare no conflict of interest.

Similarity Check

It was applied by Ithenticate[@].

Peer Review Process

It was performed.

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