Ultrasound-Guided versus Conventional Landmark Caudal Epidural Block in Pediatrics: A Narrative Review of Success Rate, Safety, and Clinical Considerations

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Abstract

Introduction: Caudal blockade remains a widely utilized regional anesthetic technique in pediatric practice, employed both for the provision of surgical anesthesia and for the management of perioperative pain. Caudal block is a safe and easily administered regional technique in children, associated with low postoperative pain scores. When combined with general anesthesia, it reduces the need for inhaled medications, opioids, improved

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postoperative analgesia, and more rapid endotracheal tube removal. Historically, the landmark-guided approach has served as the standard method for this block, offering ease of performance and acceptable efficacy, albeit with recognized complications including unintentional dural perforation and vascular injection. Ultrasound-guided caudal blockade, by contrast, is associated with superior success rates and a lower incidence of these complications.

Materials and Methods: This narrative review synthesizes evidence comparing ultrasound-guided and landmark-based techniques for caudal block in pediatric patients, with respect to success rate, safety, and complications.

Results: Current clinical data and meta-analyses indicate that while overall success rates can be high for both, ultrasound offers significant advantages in precision**.** Ultrasound consistently results in a higher first-puncture success rate and a reduced number of needle manipulations. Regarding safety real-time visualization significantly lowers the risk of vascular punctures, accidental dural punctures, and rectal perforation**.** Clinical considerations highlight that ultrasound is especially beneficial for patients with obesity or anatomical anomalies where palpable landmarks are unreliable. Although the landmark technique is sometimes faster by a matter of seconds, the immediate confirmation of injectate spread provided by ultrasound enhances overall reliability.

Conclusion: ultrasound provides superior accuracy and safety**,** supporting its routine use to optimize pediatric anesthetic outcomes.

Keywords

- Regional anesthesia
- Caudal block
- Pediatric
- Ultrasound-guided
- Landmark technique

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Introduction

Anesthesia is indispensable to contemporary surgical practice, facilitating complex, life-preserving interventions that would otherwise be insufferable. Its primary objective is to achieve a controlled, reversible state of sensory ablation while safeguarding patient well-being, comfort, and operative conditions.[1] Recent decades have brought substantial progress to pediatric anesthesia, yet perioperative pain management in children continues to represent a significant clinical challenge.[2-3] Effective pain management enhances patient well-being, promotes early ambulation, diminishes the incidence of perioperative adverse events, and expedites the restoration of functional status.[4] Caudal epidural analgesia is one of the most frequently utilized regional anesthesia techniques in children, especially for infra-umbilical and lower limb procedures.[5-6] Its clinical popularity is underpinned by procedural simplicity, predictable anesthetic spread, and effective analgesia across the intraoperative and postoperative periods.[7-8] General anesthesia combined with caudal block could reduce opioid consumption, enable earlier tracheal extubation, and facilitate the resumption of spontaneous ventilation.[9-10]

Traditionally, regional anesthesia has been performed using anatomical landmark-based techniques.[11-12] These techniques utilize surface landmarks and tactile feedback, including the classic "pop" felt when piercing the sacrococcygeal ligament, to guide needle insertion.[11-13] While widely practiced, landmark techniques are associated with variability in success rates and a higher incidence of complications such as nerve injury and vascular puncture.[11-12] However, the pediatric sacral hiatus is small, shallow, and subject to significant anatomical variability, which makes the blind approach challenging.[14] Consequently, landmark techniques are associated with failure rates reported between 4% and 25% and a higher incidence of complications, such as accidental dural puncture and vascular injection.[15]

The advent of ultrasound-guided regional anesthesia (UGRA) has revolutionized this field.[16-17] Ultrasound allows direct visualization of nerves, surrounding structures, and needle trajectory, thereby improving accuracy and reducing complications.[16-18] Studies have shown that

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UGRA increases block success rates, and decreases onset time and local anesthetic volume requirements.[10-18]

This narrative review aims to synthesize and critically appraise the evidence comparing ultrasound-guided and landmark-based caudal epidural block in children. Beyond reporting success rates and complications, this review seeks to identify the specific clinical scenarios including obesity, anatomical variability, and young infancy, in which ultrasound offers clinically meaningful advantages.It ultimately provides a practical, evidence-based framework to guide technique selection and optimize perioperative outcomes.

Materials and Methods

This review was conducted using a structured literature search strategy. Electronic searches were performed in PubMed, Scopus, and Google Scholar up to 2026 for relevant literature. Search terms were used alone or in combination and included "ultrasound," "caudal block," "pediatric," "children," "landmark technique," "success rate," and "safety". Peer-reviewed articles were considered, including randomized controlled trials, observational studies, systematic and narrative reviews, meta-analyses, and relevant preclinical mechanistic studies. Studies were excluded if they focused solely on adult populations and were not available in English. As this was a narrative review, no formal risk-of-bias assessment or quantitative synthesis was performed.

Result

The results of various studies are as follows:

The conventional landmark technique

The blind nature of the procedure

The conventional landmark (LM) technique for caudal epidural block (CEB) is a blind procedure that has been the cornerstone of pediatric regional anesthesia for decades.[11] It relies on the identification of superficial surface anatomy, specifically the sacral cornua and the sacral hiatus**,** which form an equilateral triangle with the posterior superior iliac spines in older children.[19] The primary tactile endpoint for successful entry into the caudal space is the characteristic "pop" or "give-way" sensation felt as the needle pierces the sacrococcygeal ligament. Once this "pop" is detected, the needle is typically redirected at a lower angle (20–30 degrees) and advanced 2–3 mm into the sacral

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canal.[11] Because this method is inherently subjective, clinicians must rely on the absence of blood or cerebrospinal fluid (CSF) on aspiration and negative "whoosh" or "swoosh" tests to infer correct needle placement.[11-15] This reliance on tactile feedback is particularly challenging in children due to their soft connective tissues**,** which can limit the distinctiveness of the loss-of-resistance sensation.[19]

Defining success and failure

Success in landmark-based CEB is traditionally defined by clinical indicators rather than direct visualization.[15] The most common definition of a successful block is the absence of a significant hemodynamic response, such as a >15-20% increase in heart rate or blood pressure, to surgical incision, as well as low postoperative pain scores on scales like EVENDOL or Wong-Baker FACES.[20-21] While overall success rates for the LM technique can reach up to 96% in some series, other studies report failure rates ranging from 4% to 25%.[22] High failure rates are often associated with anesthesiologist experience; studies on learning curves indicate that residents may require at least 32 supervised procedures to achieve a consistent 80% success rate.[23] Furthermore, a prospective analysis using ultrasound to verify blind placement found that providers incorrectly judged the needle to be in the caudal space in approximately 21.1% of cases.[24]

Safety profile and specific complications

Despite its utility, the blind nature of the LM technique presents a specific spectrum of risks, often referred to as the "Big Three" complications:

Accidental Dural Puncture: This risk is significantly higher in neonates and young infants because the dural sac terminates at a lower level (S3–S4 at birth) compared to older children and adults (S2).[11] If the needle is advanced more than a few millimeters past the sacrococcygeal ligament, there is a substantial risk of accidental subarachnoid injection, which can lead to life-threatening total spinal anesthesia and subsequent apnea.[25]

Intravascular Injection: The pediatric sacral canal contains a rich epidural venous plexus that also terminates low, often around the S4 level in infants.[11] Landmark-based techniques have reported vascular puncture (blood tap) rates as high as 11% to 23.8%.[12] Such inadvertent punctures increase the risk of local anesthetic systemic toxicity (LAST), a grave concern

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in small children with immature metabolic pathways.[11]

Bony Contact and Rectal Perforation: Misdirection of the needle can lead to frequent bony contact, reported in 24.1% of landmark cases, which may cause trauma to the ossification nuclei of the sacrum.[12] A rare but catastrophic risk involves the needle being directed anteriorly through the sacrococcygeal membrane into the pelvis, potentially resulting in rectal perforation or pelvic organ injury.[12, 26] Real-time imaging is critical to avoid these misadventures, particularly in children with obesity or anatomical anomalies where palpable landmarks are indistinct.[12, 27]

Ultrasound-Guided Caudal Block

The transition from the conventional landmark technique to UGRA represents a shift from a blind, tactile-based procedure to one based on direct, real-time visualization.[27-28] Ultrasound provides critical anatomical information that standard palpation cannot, such as the exact distance from the skin to the epidural space, the presence of anatomical variations, and the immediate behavior of the injectate within the sacral canal.[12, 27]

Sonographic anatomy: The "Frog-Eye Sign" and landmarks

The pediatric sacrum remains largely cartilaginous, providing an excellent acoustic window for ultrasound waves to penetrate and visualize internal structures.[29-30] In the transverse (short-axis) view, the two sacral cornua appear as two prominent hyperechoic (bright) structures, which together with the underlying sacral bone form the characteristic frog-eye sign or frog's face sign. Spanning between these cornua is the sacrococcygeal ligament (SCL), which appears as a distinct hyperechoic band or hump.[29, 31] Immediately deep to the SCL is an anechoic (black) space representing the sacral hiatus, the gateway to the caudal epidural space.[11, 29]

In the longitudinal (long-axis) view, the SCL is visualized as a thick linear hyperechoic structure covering the anechoic caudal space.[29] The sacral vertebrae appear as a series of curved hyperechoic lines, and in infants, the termination of the dural sac and the conus medullaris can be clearly identified within the canal.[30]

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Primary technical approaches Two primary methods are utilized for performing ultrasound-guided caudal blocks:

Real-Time In-Plane Technique: This is the most widely recommended method for maximizing safety.[32] The ultrasound probe is typically oriented longitudinally between the sacral cornua. The needle is inserted in-plane with the ultrasound beam, allowing the clinician to visualize the entire needle path, including the tip as it pierces the SCL and enters the caudal epidural space.[33] This method is most associated with improved safety outcomes because it allows for precise needle placement while ensuring the tip does not advance too far cephalad, thereby avoiding inadvertent dural or vascular puncture.[32-33]

Out-of-Plane Technique (Surrogate Guidance): In this approach, ultrasound is used as a preprocedural tool to identify landmarks and measure the depth to the sacral hiatus from the skin surface.[33] Once the landmarks are marked and the depth is confirmed, the puncture is performed using the conventional technique. While less precise than real-time guidance, this method serves as a valuable bridge for difficult anatomy, such as in obese patients where surface landmarks are impalpable.[34-35]

Confirmation of correct injection: shifting the paradigm

The critical advantage of ultrasound is the shift from subjective clinical impressions, such as the tactile "pop" or the unreliable "whoosh" test, to objective visual evidence (35, 11). Successful caudal placement is objectively confirmed by observing several real-time indicators.[37-38]

Anterior Displacement of the Dura Mater: During injection, the hyperechoic posterior dura mater can be seen moving ventrally (anteriorly) as it is displaced by the local anesthetic entering the epidural spac.[37]

Unidirectional Injectate Spread: Ultrasound allows for the visualization of hypoechoic drug spread and subsequent distension of the sacral canal.[37-38]

Absence of Complication Patterns: Clinicians can immediately identify subcutaneous bulging or the lack of epidural spread, which signals incorrect placement even if a tactile "pop" was felt.[11, 39] Furthermore, ultrasound can help ensure the absence of vascular injection by confirming correct epidural spread rather

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than observing venous dilation or swirling patterns that might suggest intravascular uptake.[11, 40]

This visual paradigm virtually eliminates technical failures by allowing immediate correction of needle position before a full dose of local anesthetic is administered.

Comparative effectiveness: success rate and procedural precision

The comparative effectiveness of ultrasound-guided (USG) versus landmark-based (LM) techniques is defined by a trade-off between technical precision and procedural speed.[41-42] While both methods are highly effective in expert hands, current evidence suggests that ultrasound significantly enhances the reliability of the initial puncture and reduces the need for repeated needle manipulations.[43-44]

First-puncture success rate

The strongest evidence for the superiority of ultrasound lies in its ability to achieve successful entry into the caudal space on the first attempt.[12, 45] A meta-analysis of five randomized controlled trials (RCTs) involving 904 participants demonstrated that the first-puncture success rate is significantly higher with the ultrasound-guided technique.[28] Individual studies corroborate this finding; for instance, Gautam et al. reported a 92% first-puncture success rate with USG compared to 76% with the LM technique.[46] Similarly, Wang et al. found that USG achieved a 92.8% first-attempt success rate, whereas the landmark group reached only 60%.[47] By minimizing needle passes, ultrasound reduces traumatic tissue disruption and the associated risk of inflammatory responses or hematoma.[11, 28]

Overall block success and effectiveness

When evaluating overall clinical success, defined as the absence of hemodynamic response to surgical incision, the evidence is more nuanced. Meta-analytical data indicate no statistically significant difference in the final overall success rate between the two techniques when performed in controlled trials.[28] This suggests that for uncomplicated, normal-weight children, experienced clinicians can achieve high success rates (93%–96%) using either method.[46, 48]

However, the blind nature of the LM technique often leads to a false impression of success.[15, 49] Prospective observational studies using ultrasound to verify blind needle placement found that providers incorrectly judged the needle to be in the caudal space in 21.1% of cases.This technical failure rate of approximately 20%

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in landmark-based procedures highlights a significant reliability gap that ultrasound-guided real-time visualization effectively bridges.[49] Furthermore, ultrasound has demonstrated higher overall success rates in specific cohorts; Nanjundaswamy et al. reported 92.1% success with USG versus 81.8% with LM.[12]

Procedural time trade-off

There is a documented paradox regarding procedural time.[50-51] The actual puncture time, the interval from needle contact to drug administration, is frequently shorter with the landmark technique, as it avoids the time required for equipment setup and probe manipulation.[45, 50] Erbüyün et al. found that the LM technique was faster by a matter of seconds (26.08s vs. 41.60s), concluding that this difference is clinically negligible.[52] Conversely, when factoring in total procedural efficiency, ultrasound may be faster.[11, 28] Titus et al. observed that the total time taken to perform the block was actually shorter in the ultrasound group due to the reduction in failed attempts and needle redirections.[53]

Learning curve

The adoption of USG is often hindered by the perceived difficulty of mastering sonoanatomy.[28] However, evidence suggests the USG learning curve is relatively steep and manageable.[54] Novice residents can achieve a plateau in landmark identification skills after only 9 procedures and basic technical proficiency in performing the US-CEB after 11 supervised attempts.[54] This compares favorably to the conventional landmark technique, where studies on resident learning curves indicate that at least 32 procedures are required to reach a consistent 80% success rate.[23] Consequently, USG may facilitate faster skill acquisition for trainees while providing a safety net of visual confirmation.[55-56]

Clinical considerations: stratifying care for challenging populations

While the overall success of the CEB is high, its reliability diminishes significantly in specific patient populations where surface landmarks are either obscured or developmentally unreliable.[11] In these challenging cohorts, USG techniques are not merely an alternative but often an essential requirement for procedural success and safety.[12, 46]

Obesity in children

The conventional landmark technique is notoriously unreliable in children with high

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body mass indexes. Excessive subcutaneous fat often renders the sacral cornua impalpable, making it difficult to identify the sacral hiatus.[11, 36] Research indicates that in obese patients, ultrasound can provide 30%–60% higher success rates compared to the palpation method.[12] Specifically, Opfermann et al. found that for every 1-kg increase in weight, the odds of pain-related block failure increased by a factor of 1.063.[25] Furthermore, in children with higher weight and more adipose tissue, local anesthetic injected outside the caudal space can go completely undetected by the clinician until large, potentially toxic volumes have been administered, whereas USG allows for immediate identification of incorrect spread.[11, 49]

Sacral anatomical anomalies

Ultrasound serves as a critical pre-puncture screening tool to identify anatomical variations that would render a blind approach both traumatic and likely to fail.[11] Studies have shown that USG can successfully identify the sacral hiatus even when it is difficult to detect by palpation due to anatomical abnormalities.[57] These variations can include blunt or asymmetric cornua, or a closed sacral hiatus due to complete fusion of the laminae.[11, 30] Most importantly, children with urogenital anomalies have a higher prevalence of occult spinal dysraphism (OSD), such as a tethered spinal cord with lipoma. In these vulnerable patients, a preprocedural ultrasound survey is essential to assess spinal structures and avoid catastrophic needle-induced neural injury.[58]

Infants and neonates

In infants and neonates, the period of highest pharmacokinetic and complication risk, ultrasound offers a unique developmental advantage. Because the pediatric sacrum is incompletely ossified and remains largely cartilaginous, it provides an excellent acoustic window that offers remarkably clear visualization of neuraxial structures, including the dural sac and the conus medullaris.[37, 59] This clarity is vital because the dural sac terminates at a lower level (S3–S4)in infants than in older children, significantly increasing the risk of accidental subarachnoid injection during blind landmark-based attempts.[59] USG visualization has been rated as easy in this age group, providing a visual safety net that facilitates precise needle placement while avoiding the rich, low-terminating epidural venous plexus.[37, 55]

Opioid-sparing and enhanced recovery

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The enhanced reliability provided by ultrasound translates directly into optimized clinical outcomes.[10] When a caudal block is successfully performed as an adjunct to general anesthesia, it significantly reduces the requirement for volatile agents and intraoperative opioids.[60] By ensuring a higher first-puncture success rate, USG minimizes the physiological stress response to surgery and promotes earlier tracheal extubation. In a prospective cohort, the use of ultrasound to confirm successful block placement resulted in a reduction of postoperative rescue opioid administration from 16.1% to only 5.6%.[49] This opioid-sparing effect is a cornerstone of enhanced recovery after surgery (ERAS) pathways, facilitating a rapid and smooth recovery that is particularly beneficial for pediatric day-case surgical procedures.[10]

Discussion

The evidence synthesized in this review suggests a compelling case for a paradigm shift in pediatric regional anesthesia. USG-CEB has demonstrated superior precision and a significantly enhanced safety profile, particularly in mitigating the Big Three complications: vascular puncture, accidental dural puncture, and needle misplacement.[12, 53] While some meta-analyses indicate that overall success rates may be comparable between ultrasound and landmark techniques when performed by experts in ideal conditions, the technological ability to visualize the dural sac, the needle trajectory, and real-time drug spread provides a safety net that the landmark technique cannot replicate.[28, 61] In high-risk populations, such as neonates with low-lying dural sacs terminating at S4-S5 or obese children with impalpable anatomy, ultrasound is no longer merely an alternative but is increasingly positioned as the standard of care where resources and training permit.[19, 36] By replacing subjective tactile impressions with objective visual confirmation, USG-CEB essentially eliminates the technical uncertainty inherent in the blind approach.[15, 37]

Despite the clear advantages of imaging, the conventional landmark technique maintains an enduring role in clinical practice.[28, 48] Ultrasound guidance has conventionally served to enhance needle precision and procedural safety. However, these benefits are offset by the need for dedicated equipment, skilled personnel, and extended procedural durations, factors that may contribute to higher costs.[62] The

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LM approach is time-tested, simple, and requires no specialized equipment, making it highly efficient for high-volume, straightforward cases in patients with clear anatomical markers.[12, 46] Furthermore, in resource-limited settings where ultrasound technology is unavailable or cost-prohibitive, the landmark technique remains the primary method for providing essential perioperative analgesia.[12] Mastery of the landmark technique also remains a critical competency for all pediatric anesthesiologists, serving as avital rescue technique in the event of equipment failure or in environments where sonographic visualization is technically impossible.

A scholarly critique of the existing literature reveals several challenges in establishing definitive clinical guidelines. Many randomized controlled trials in this field are limited by small sample sizes, which often lack the statistical power to detect rare but catastrophic complications.Additionally, true blinding of the proceduralist is impossible, as the presence or absence of an ultrasound probe is immediately evident, potentially introducing performance bias. There is also a notable lack of uniformity in how "success" is defined across studies, with some researchers relying on hemodynamic responses to incision and others using objective pain scores or direct visualization of injectate spread.[15, 63] Furthermore, many registries suffer from low adoption rates for ultrasound, making it difficult to extract large-scale safety data that compares USG and LM techniques head-to-head.[15, 37]

The future of pediatric caudal anesthesia lies in the integration of advanced technology and standardized education. Beyond needle guidance, ultrasound allows for predicting successful puncture and catheterization using surrogate markers, such as dura mater displacement, epidural space widening due to drug injection, or mass movement of the drug within the caudal space.[37] Finally, the use of simulation-based training will be essential in standardizing curricula and establishing objective competency assessments for trainees.[64] As these technologies mature, the goal remains to move beyond a "one technique fits all" approach toward a personalized anesthetic strategy that optimizes safety and recovery for every pediatric patient.[25]

While the conventional landmark technique for caudal epidural block has served as a cornerstone of pediatric regional anesthesia with a historically

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effective and remarkable safety record, contemporary evidence demonstrably supports the transition toward ultrasound guidance. Ultrasound-guided techniques significantly enhance procedural efficacy by providing higher first-pass precision and a marked reduction in needle redirections and traumatic manipulations compared to the blind approach. Furthermore, ultrasound guidance provides a superior safety profile by replacing subjective tactile endpoints with objective visual confirmation, allowing for the real-time avoidance of the dural sac, epidural venous plexus, and anterior pelvic structures.

Consequently, ultrasound should be strongly considered as the preferred technique for pediatric caudal blocks to minimize technical failures and potential local anesthetic toxicity. This direct visualization is particularly critical for younger infants and patients with challenging anatomy, such as obesity or sacral anomalies, where traditional surface landmarks are unreliable or misleading. Finally, to ensure the consistent delivery of high-quality anesthetic care and optimize patient outcomes, structured training and the achievement of proficiency in ultrasound-guided techniques should become a core component of modern pediatric anesthesia curricula.

Ethical Consideration

This review article does not require a code of ethics .

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