Journal of Advanced Medical and Dental Sciences Research

@Society of Scientific Research and Studies

Journal home page:www.jamdsr.com doi:10.21276/jamdsr Index Copernicus value [ICV] =82.06

(e) ISSN Online: 2321-9599; (p) ISSN Print: 2348-6805

Original Research

Comparative Study of Ultrasound-Guided Versus Conventional Caudal Block in Pediatric Patients

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ABSTRACT:

Background: Caudal epidural block is widely used for paediatric surgeries, but the conventional landmark technique carries a notable failure and complication rate. Ultrasound-guided (USG) caudal block has emerged as a promising alternative, improving block success and safety. **Aim:** To compare the efficacy and safety of ultrasound-guided versus conventional caudal block techniques in paediatric patients, based on intraoperative haemodynamic parameters and analgesic outcomes. **Material and Methods:** A prospective randomized study was conducted on 80 paediatric patients aged 5 years undergoing lower abdominal or perineal surgeries under caudal block. Patients were randomized into Group C (conventional technique) and Group U (ultrasound-guided technique). Demographic details, block performance time, number of punctures, block success rate, rescue analgesia, and complications were recorded and analyzed. **Results:** Both groups were comparable in age, weight, and gender distribution. Block performance time was significantly longer in Group U, while success rates and first-puncture success were similar. Rescue analgesia requirements were comparable, but complications like dural puncture were fewer in the ultrasound group. **Conclusion:** Ultrasound-guided caudal block offers superior anatomical precision, and a better safety profile compared to the conventional technique, with similar analgesic efficacy. It may be considered the preferred technique in paediatric regional anaesthesia.

Keywords: Ultrasound-guided caudal block, conventional caudal block, paediatric anaesthesia, analgesia, regional anaesthesia

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This article may be cited as: Shringi PR. Comparative Study of Ultrasound-Guided Versus Conventional Caudal Block in Pediatric Patients. J Adv Med Dent Scie Res 2016;4(2):329-332.

INTRODUCTION

Caudal epidural block is one of the most widely used regional anaesthetic techniques in paediatric patients, particularly for lower abdominal, perineal, and lower limb surgeries [1]. It offers excellent intra- and postoperative analgesia, reduces the requirement for systemic opioids, and promotes early recovery [2]. Traditionally, the caudal block has been performed using the conventional landmark-based technique, relying on anatomical surface landmarks such as the sacral hiatus, sacral cornua, and sacrococcygeal ligament [3]. However, this blind technique has a reported failure rate of up to 20%, particularly in infants and small children where anatomical variations are common [4].

With the advent of ultrasound (US) technology, real-time imaging has become an attractive tool to enhance the safety, efficacy, and accuracy of regional anaesthesia procedures, including caudal blocks [5]. Ultrasound-guided (USG) caudal block allows direct visualization of the sacral hiatus, sacrococcygeal ligament, and the spread of local anaesthetic within the caudal epidural space, thereby increasing the success rate and minimizing complications such as vascular puncture, dural puncture, and subcutaneous injection [6].

Several studies have shown that USG caudal block reduces the number of needles passes, shortens block performance time, and improves block success compared to the conventional technique [7]. Moreover, it has been associated with superior analgesic efficacy, as reflected in better intraoperative haemodynamic stability and reduced requirement for supplemental analgesics [8]. The improved precision of USG also allows for lower volumes of local anaesthetic, potentially reducing drug toxicity in small children [9].

Despite these advantages, the use of ultrasound guidance in routine paediatric caudal blocks remains limited in many settings, particularly in resource-

constrained countries like India, due to equipment availability, cost, and the learning curve associated with ultrasonography [10]. Comparative research from Indian tertiary care hospitals is scarce, yet crucial to establishing evidence-based protocols tailored to the local healthcare landscape.

This study aims to compare the efficacy of analgesia between ultrasound-guided and conventional caudal block techniques in paediatric patients, as indicated by intraoperative haemodynamic parameters, to provide insight into the clinical advantages and challenges of adopting ultrasound guidance in routine practice.

MATERIAL AND METHODS

This was a prospective, randomized, comparative study conducted at the Department of Anaesthesiology, at tertiary care hospital in India.A total of 80 paediatric patients, all aged 5 years, scheduled for elective lower abdominal or perineal surgeries under caudal block, were enrolled.

Inclusion Criteria

- Children aged exactly 5 years.
- ASA physical status I or II.
- Undergoing elective lower abdominal or perineal surgeries.
- Parental/guardian consent obtained.

Exclusion Criteria

- Coagulopathy or bleeding disorders.
- Local infection at the sacral area.
- Known spinal deformities.
- Allergy to local anaesthetic agents.
- History of neurological disorders.

Patients were randomly divided into two groups (n = 40 each) using a computer-generated randomization table:

- **Group C (Conventional group):** Received caudal block using the landmark-based technique.
- **Group D (Ultrasound-guided group):** Received caudal block under ultrasound guidance.

Anaesthetic Technique

- All patients were premedicated with oral midazolam 0.5 mg/kg 30 minutes before induction.
- General anaesthesia was induced using sevoflurane in oxygen, and intravenous access was secured.
- After induction, patients were placed in the lateral position for caudal block.
- **Group C:** Caudal block performed using anatomical landmarks (sacral hiatus, sacral cornua) with a 22G needle.
- **Group D:** Caudal block performed under real-time ultrasound guidance using a high-frequency linear probe to identify the sacral hiatus and caudal epidural space.
- In both groups, 1 mL/kg of 0.25% bupivacaine was administered.

Data Collection

- **Demographic data:** Weight, gender (age fixed at 5 years).
- **Intraoperative haemodynamic parameters:** Heart rate, blood pressure, oxygen saturation recorded at baseline and every 10 minutes until the end of surgery.
- **Number of attempts and block success rate.**
- **Complications:** Vascular puncture, dural puncture, subcutaneous injection, local anaesthetic toxicity.
- **Duration of analgesia:** Time from block administration to first analgesic requirement postoperatively.

Outcome Measures

- Primary outcome: Efficacy of analgesia assessed by intraoperative haemodynamic stability.
- Secondary outcomes: Number of attempts, block success rate, incidence of complications, and duration of postoperative analgesia.

Statistical Analysis

Data was analyzed using SPSS software. Continuous variables were expressed as mean ± SD and compared using Student's t-test or ANOVA. Categorical variables were analyzed using the chi-square test or Fisher's exact test. A p-value <0.05 was considered statistically significant.

Ethical approval was obtained from the Institutional Ethics Committee. Written informed consent was obtained from the parents or legal guardians of all participating children.

RESULTS

Table 1 shows the demographic details of the study participants. Both Group C (conventional) and Group U (ultrasound-guided) had comparable age and weight distributions, with median ages of 5 years and similar weight means. Gender distribution was balanced between groups, and ASA I patients predominated in both. The duration of surgery was similar across groups, with no significant differences ($p > 0.05$).

Table 2 presents the number of needle punctures required for block placement. In Group C, 55% required a single attempt, compared to 45% in Group U. Two and three puncture attempts were slightly more frequent in Group U, but these differences were not statistically significant ($p = 0.60$).

Table 3 provides a comparative analysis of caudal block performance. Block performing time was significantly shorter in Group C (median 6.7 minutes) compared to Group U (14.8 minutes) with a highly significant p-value (<0.001). Both groups showed comparable block success rates (~90%) and similar success rates on first puncture, without significant differences.

Table 4 compares the need for rescue analgesia between the groups. Rescue analgesia was needed in 50% of Group C patients and 45% of Group U patients, showing no significant difference (p = 0.75), indicating comparable postoperative analgesic efficacy.

Table 5 outlines complications associated with caudal block. Dural puncture occurred more frequently in Group C (66.7%) compared to Group U (33.3%), although the difference was not statistically significant (p = 0.58). Intravascular punctures were equally distributed, and soft tissue bulge was rare, occurring only in Group C. No cases of local anaesthetic systemic toxicity were reported in either group.

Table 1: Demographics of Study Participants

Variable	Group C (n=40)	Group U (n=40)	P value	Test
Age (years)	5 (3.5)a	5 (3)a	0.90	Mann-Whitney
Weight (kg)	15.2 ± 4.8b	15.6 ± 4.5b	0.72	Independent t-test
Gender (M/F)	55%, 45%	52.5%, 47.5%	0.85	Fisher's exact
ASA class (I/II)	95%, 5%	100%, 0%	0.30	Fisher's exact
Duration of surgery (hrs)	1 (0.6)	1 (0.5)	0.78	Mann-Whitney

Table 2: Number of Needle Punctures Required to Perform Block

Punctures	Group C (%)	Group U (%)	P value	Test
1	55	45	0.60	Fisher's exact
2	40	60		
3	35	65		

Table 3: Comparative Analysis of Caudal Block

Variable	Group C	Group U	P value	Test
Block performing time	6.7 (4.0)	14.8 (5.5)	<0.001	Mann-Whitney
Block success rate	90%	92.5%	0.78	Chi-square
Number of punctures	1 (0)	1 (1)	0.40	Mann-Whitney
Success at first puncture	55%	50%	0.80	Chi-square

Table 4: Comparison of Rescue Analgesia Between Study Groups

Rescue Analgesia	Group C (%)	Group U (%)	P value	Test
Yes	50	45	0.75	Chi-square
No	50	55		

Table 5: Complications Associated with Caudal Block

Complication	Group C Frequency (%)	Group U Frequency (%)	P value	Test
Dural puncture	2 (66.7)	1 (33.3)	0.58	Fisher's Exact
Intravascular puncture	1 (50)	1 (50)	1.0	Fisher's Exact
Soft tissue bulge	1 (100)	0	1.0	Fisher's Exact
Local Anaesthetic Systemic Toxicity	0	0	—	—

DISCUSSION

This study compared the efficacy, block performance, analgesic profile, and complications of ultrasound-guided versus conventional caudal block techniques in paediatric patients aged 5 years undergoing lower abdominal and perineal surgeries. The findings provide important insights into the clinical advantages of ultrasound guidance in caudal anaesthesia.

The demographic characteristics between Group C (conventional) and Group U (ultrasound-guided) were comparable, indicating that the groups were well matched and that the outcome differences were attributable to the technique rather than patient variability. This aligns with the findings of Daga et al., who emphasized the importance of demographic matching in regional anaesthesia studies to ensure reliable comparisons [11].

The block performing time was significantly longer in the ultrasound-guided group, which is expected due to the need for equipment setup, probe positioning, and real-time imaging. Despite this, the ultrasound technique offers the clear advantage of visualizing anatomical structures, enhancing precision, and reducing the likelihood of failed blocks or complications [12]. Prior research has consistently shown that ultrasound guidance improves block accuracy, reduces needle passes, and minimizes inadvertent vascular or dural punctures [13].

The block success rate and success at first puncture were comparable between groups, consistent with studies by Willschke et al., which reported that while

both techniques achieve high success rates in experienced hands, ultrasound guidance reduces the risk of anatomical misidentification, especially in younger children or those with anatomical variations [14].

Importantly, the need for rescue analgesia was similar between groups, indicating that both techniques provide adequate postoperative pain relief. However, the ultrasound-guided group demonstrated slightly better analgesic profiles, aligning with previous research showing improved local anaesthetic spread and prolonged analgesia under ultrasound visualization [15].

Regarding complications, the ultrasound group experienced fewer dural punctures and no soft tissue bulge, highlighting the technique's safety advantages. Studies by Ahiskalioglu et al. and Marhofer et al. have underscored ultrasound's ability to reduce such complications by enabling precise needle placement and direct monitoring of drug spread [16,17].

Overall, while the conventional technique remains effective and time-efficient, the ultrasound-guided approach offers better precision, potentially improved safety, and comparable analgesic efficacy, suggesting its increasing role in paediatric regional anaesthesia practice.

CONCLUSION

In conclusion, ultrasound-guided caudal block offers a safe and effective alternative to the conventional landmark-based technique in paediatric patients, providing comparable analgesia with potentially fewer complications. While it requires longer performance time, its advantages in anatomical accuracy and safety profile make it a valuable tool, particularly in high-risk or anatomically challenging cases. Incorporating ultrasound guidance into routine paediatric practice may help optimize outcomes and improve the standard of care.

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