Original Article

Analgesic Efficacy of Erector Spinae Plane Block in Pediatric Abdominal Surgery: Guidance with Conventional Method and NOL: Case Series

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Received: 01-Nov-2022;
Revision: 12-Feb-2023;
Accepted: 03-May-2023;
Published: 14-Jul-2023

Abstract

Background: Erector spinae plane (ESP) block is a regional anesthesia technique that blocks both somatic and visceral nerve fibers. Despite its high analgesic potential, its mechanism of action is not yet fully understood. The ultrasound-guided ESP block, which can be easily performed, makes important contributions to the control of intraoperative pain in pediatric patients undergoing abdominal surgery. The follow-up of pain in the intraoperative period is usually done by evaluating the changes in hemodynamic parameters. Due to physiological differences in pediatric patients, it is more difficult to do this with only hemodynamic changes than in adult patients. **Aim:** The NOL® *(Nociception Level)* monitor calculates the nociception/pain score by evaluating many parameters through a proprietary algorithm. Our primary aim was to demonstrate the effectiveness of ESP block with an advanced pain monitor in this patient group; our secondary aim was to investigate the necessity of pain monitors in the pediatric patient group. **Methods:** In this case series, we applied intraoperative NOL® monitoring in addition to standard monitoring (ECG, SpO2, heart rate, $EtCO_2$) in pediatric patients (16 cases) who were scheduled for abdominal surgery and underwent ESP block. **Results:** Considering the hemodynamic data, NOL values, postoperative pain scores, side effects, and complications, it was concluded that ESP block can be used safely in this patient group. Although the hemodynamic data and the NOL® index were compatible with each other after a nociceptive stimulus, the NOL index was less affected by other variables and gave the clinician clearer information about pain.

Keywords: *Erector spinae plane block, Monitorization, Multimodal analgesia, NOL, Pediatric abdominal surgery*

Introduction

Pain control in the intraoperative and postoperative period is an important parameter in the recovery period of the patient and shortening the hospital stay.[1] Anesthesiologist has a great role in the successful management of this problem.[2,3]

Regional anesthetic techniques are increasingly used in the management of pain. Performing regional anesthesia applications under the guidance of ultrasonography has significantly increased the application of fascial blocks in pediatric anesthesia. Erector spinae plane (ESP) block is a recently described regional anesthesia technique. Although controlled clinical trials are few, numerous case reports have been reported. This interfacial plane block is a good option for multimodal analgesia because of the lower risk of spinal cord injury, epidural hematoma, and infection.[4,5]

Pediatric abdominal surgery is a topic that includes many surgical indications (open inguinal hernia repair,

Access this article online	
Quick Response Code:	**Website:** www.njcponline.com
	DOI: 10.4103/njcp.njcp_754_22

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How to cite this article: Ozdemir C, Isik B, Kurtipek O. Analgesic efficacy of erector spinae plane block in pediatric abdominal surgery: Guidance with conventional method and NOL: Case series. Niger J Clin Pract 2023;26:779-86.

ileostomy, diaphragmatic hernia repair, laparoscopic cholecystectomy, abdominal abscess evacuation, etc). In young children, the incidence of congenital malformation-induced surgeries is high. Malignant diseases of solid organs in older children and inflammatory diseases that are constantly increasing in children and adolescents represent an important issue. The ESP block has gained prominence as a viable option for abdominal surgery as it blocks both somatic and visceral pain.[4-6] As only 9.5% of reported cases of ESP block are in children, the available information is insufficient.[4,6]

Pain assessment is considered a complex and challenging process in children. If perioperative pain management is not done quickly and effectively, the child may experience physical and psychological problems, chronic pain, long hospital stays, and an increased risk of infection.[1] Increased heart rate (HR) and blood pressure (BP), tachypnea, cardiac arrhythmias, mydriasis, and sweating can be considered as physiological indicators of intraoperative pain. These changes can easily mislead the anesthetist as they can also be signs of drug effect, dehydration, and fever.[7,8]

NOL® Index PMD200TM (Medasense Biometrics Ltd, Ramat Gan, Israel) is a recently developed monitor specifically for measuring nociception in adult patients. Using a proprietary algorithm, the monitor calculates a nociception/pain index using data from four sensors (photoplethysmography, galvanic skin response, temperature, and accelerometer) via a non-invasive finger probe[9-13]. Hemodynamic parameters used; pulse rate, pulse rate variability, pulse wave amplitude, skin conductivity, skin temperature, motion and nonlinear random forest regression technique. The NOL index is a single number from 0 to 100. NOL between 0 and 25 represents a suitably suppressed physiological response to noxious stimuli and indicates adequate analgesia.[9-13] An index greater than 25 (constant or fluctuating) for more than one minute indicates that the patient feels pain. Higher values indicate a stronger nociceptive response. An index of less than 10 for more than one minute may indicate excessive anti-nociception, and reduction of analgesics may be considered. Lower NOL values are expected if regional analgesia is used.

Pain monitoring with advanced pain monitors was not performed in children who underwent ESP block. Understanding the analgesic efficacy of the block at the concentrations and volumes commonly used in the literature can help clinicians further improve the performance of the block.

Material and Methods

After obtaining ethical approval from the Gazi University Faculty of Medicine Clinical Studies Ethics Committee (01/2019-50), the data of 20 children aged 5–17 years American Society of Anesthesiology (ASA) class I-II and planned for abdominal surgery were analyzed [Figure 1 and Table 1]. The patients did not have any diseases other than the current surgical indication in their history. In our case series, in addition to standard monitoring (HR, BP, SpO_2, ECG) the NOL monitor was used to monitor pain. Since the finger probe is designed for adults, the probe has been adapted to be compatible with pediatric patients. The data of 16 cases were included in this case series because the data of three cases were missing and unilateral ESP block could be performed in one case.

In our pediatric surgery operation room, standardized anesthesia protocol is used. For premedication, 0.5 mg/kg midazolam is given orally (based on ideal body weight and maximum 15 mg). 15 to 20 minutes later than premedication, intravenous access obtains. After monitorization, anesthesia induction performs with 1 mg/kg lidocaine + 2 − 3 mg/kg propofol + 0.6 mg/kg rocuronium. Sevoflurane inhalation at 1 MAC values+0.2 µg/kg/min remifentanil infusion is used for anesthesia maintenance. Remifentanil doses are determined based on a 20% decrease or increase in blood pressure values [in the range of 0.3 − 0.2 − 0.05 µg/kg/min or stop]. Volume-controlled mechanical ventilation is administered to produce a tidal volume of 6–8 mL/kg. Fluid replacement is calculated with Holliday-Segar formula (0.9% serum saline or 0.9% serum saline and 5% dextrose mixture infusion). At the last quarter of the surgery, remifentanil is discontinued, and 0.05 mg/kg morphine was given intravenously. All patients are given 10 mg/kg paracetamol intravenously every 6 h for the first 24 h. 0.05 mg/kg morphine is used as a rescue analgesic.

Patients is prepared for regional anesthesia. The ESP block is performed by first identifying the erector spinae muscle (ESM) just lateral to the spine under ultrasound guidance by cranio-caudal approach. The linear probe is placed in a parasagittal plane 1 to 3 cm lateral from the midline. A block needle (22G-50 to 21G-100 mm) was advanced into the transverse process (TP). After contacting the TP, the erector spina fascial plane is opened by hydrodissection. Analgesia is provided by injecting a total of 0.4 mL/kg of bupivacaine at a concentration of 0.2% into this area. This process is done bilaterally [Figure 2].

All patients underwent standard monitoring with ECG, non-invasive BP, SpO2, and EtCO2. Intraoperative

NoL values were recorded, but anesthesia management was not changed according to NOL value to detect correlation with hemodynamic data.

The faces pain scale-R scale (less than 8 years old)[14] or the VAS scale (over 8 years old) were used to evaluate postoperative pain. Total score ≤4 was accepted slight pain.

Results

Sixteen patients data are included in this research [Tables 1 and 2].

Diagram of each time point for intraoperative HR, BP, and SPO2 data of cases is shown in Figures 1 and 2. Diagram of each time point for postoperative pain scoring data of cases is shown in Figure 3. Hemodynamic data

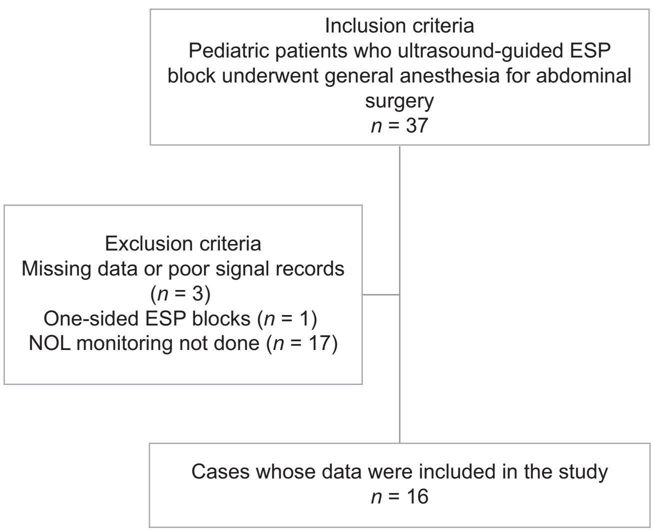

Figure 1: Algorithm of the cases included in this case series

and NOL monitoring were compared with each other at all time points from T0 to T6. Perioperative HR andBP variables are shown in Figures 4 and 5. T1 and T5 time points NOL values are shown in Figure 6. Postoperative pain scores in cases is shown in Figure 7. Although they were correlated with each other at most points, the instantaneous increases and decreases were more in hemodynamic data. However, most of them were corrected by changing the depth of anesthesia or fluid therapy. According to hemodynamic data, only one patient required 0.2 μg/kg/min remifentanil throughout the entire case, and it was given at doses of 0.05 μg/kg/min or less in 11 cases. Remifentanil infusion was not required in four cases. The NOL index showed less instantaneous variability across the whole case and presented consistent data. The index was still stable in interventions for hemodynamic variability. The index was in a decreasing trend from the block making to the end of the surgery. Nausea or vomiting was observed in three patients in the postoperative period. No other side effects or complications were detected in the cases. The patients did not need rescue analgesics. The fact that the NOL index was within the appropriate range in all patients and that no patient needed rescue analgesics postoperatively was an indicator of the success of the ESP block, dose, and volume used.

Discussion

In this pediatric case series, intraoperative and postoperative analgesic effects of the ESP which performed underwent general anesthesia are revealed. This case series is one of the first to evaluate conventional hemodynamic monitoring together with the NOL index in pediatric patients undergoing abdominal surgery.

Table 1: Demographic and operational information of the cases

Age (Year)	Gender F/M	Operation	Time from induction to recovery of the anesthesia (min)	Postoperative opioid as a rescue analgesic
7	F	Abdominal mass	165	-
15	E	Whipple	195	-
14	F	Cist hydatic	170	-
12	F	Cholecystectomy	115	-
12	F	Renal mass	180	-
17	F	Cholecystectomy	120	-
9	F	Pyloroplasty	120	-
7	M	Diverticulosis of vesica urinaria	120	-
7	M	Uretero-pelvic stricture	120	-
6	M	Invagination	150	-
5	M	Intraabdominal mass	160	-
6	F	Pyeloplasty	100	-
5	M	Renal neuroblastoma	120	-
15	M	Cist hidatic	100	-
15	F	Cholecystectomy	80	-
14	M	Cist hidatic	75	-

ESP block properties

Regional anesthesia is often used in conjunction with general anesthesia for perioperative analgesia in children.[15] Regional anesthesia reduces neuroendocrine stress response and postoperative pain, provides a faster recovery, and shortens hospital stay. Despite the large number of research on adult patients, only a few clinical researches were about pediatric patients.

The use of erector spinae plane block for multimodal analgesia has experienced advances in recent years. In the past 5 years, publications referring to ESP block have increased significantly. ESP block appears to be a safe and effective alternative to neuraxial blocks, although it is a newly developed block. The ESP blocks prevent neuraxial risks such as dural puncture or the need for bladder catheterization.[4-6] The ESP block is less likely to cause a hematoma, which is an advantage in patients taking anticoagulants. Studies of dose and duration of analgesia will allow better standardization of ESP block and its integration into standard care. There are also researchers who do not accept the effectiveness of the ESP block because the pain relief mechanism is not fully understood.[16] Most current hypotheses are limited to blockade of the cutaneous nerves located in the plane of the erector spinae and their spread to the paravertebral and epidural spaces. In studies, it has been reported that in addition to the direct effect of the ESP block, it also contributes to analgesia with the systemic effects of the local anesthetic.[6,17,18] De Cassai *et al.*[19] showed that effective analgesic concentration was reached within the first few minutes after a single bolus; however, such concentrations are maintained only for the first few hours.

Table 2: Demographic and ESP block variables of the cases

Number of the patients (F/M), (*n*)	16 (9/7)
Age [Mean (Min-Max)], (year)	10,3 (5–17)
Body weight [Mean (Min-Max)], (kg)	25–92
ESP block level (*n*)	T6 (6), T7 (8), T8 (1), T10 (1)
Mean doses of the local anesthetics [Mean (Min-Max)], (mL)	15.5 (10–28)
Bupivacaine %0.2	0.4 mL/kg
ESP block performance time [Mean (Min-Max)], (min.)	8.3 (4–12)
Block to skin incision time interval [Mean (Min-Max)], (min.)	16.3 (10–30)
Number of cases with 20% increase in HR after surgical incision (*n*)	0
Number of cases who required 0.2 µg/kg/min remifentanil infusion (*n*)	1
Do not need intraoperative remifentanil usage (*n*)	4
Surgery time [Mean (Min-Max)], (min.)	130 (55–215)
Rescue analgesic in early postoperative period (*n*)	0
NOL values at surgical incision time point (Min-Max), (0 to 100)	(5–25)
Number of cases with NOL >25 at surgical incision	0
Postoperative VAS values ≤4 (*n*)	16

Analgesic efficacy of ESP

Tsui B.C.H. *et al.*[5] examined 242 ESP block cases data in between 2016 and 2018 from published literature. They reported use as part of 90.9% multimodal analgesia and reduction in opioid use in 76.0% of cases. Only one of these patients developed pneumothorax, and there were no other significant complications.

Noxious stimulus is damaging or threatens to normal tissues like surgical skin incision. The anterior abdominal wall incision is responsible for most of the pain experienced after abdominal surgery.[7] Therefore, we focused on the surgical incision. For this aim, NOL monitorization is performed before anesthesia induction and surgical incision point. In our case series, effective pain management was obtained with our multimodal analgesic regimen which include ESP block + if needed remifentanil infusion, acetaminophen. Postoperative pain level was the tolerable range (pain scores ≤ 4 (0 to 10) in cases.

Ultrasound usage for regional blocks

Ultrasound guidance for regional anesthesia procedures has become more commonplace and helped to reduce the incidence of certain complications and doses of local anesthetics.[20] We applied ESP block with bupivacaine

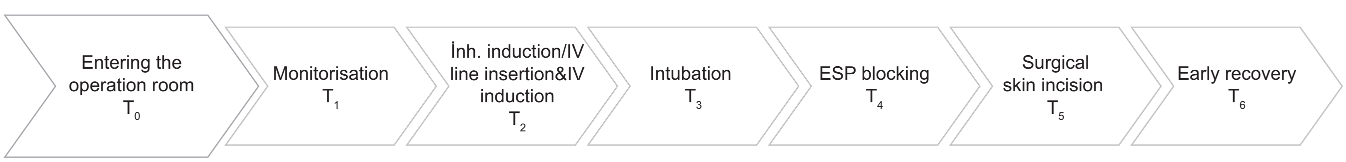

Figure 2: Diagram of each time point for intraoperative HR, BP, and SPO_2 data

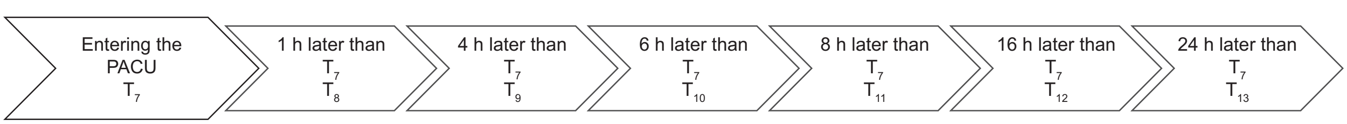

Figure 3: Diagram of each time point for postoperative pain scoring data

Table 3: Included pediatric cases/studies performed ESP block

Literature	Cases	ESP	Local anesthetics	Conclusion
Aksu C. *et al*.[21]	60 patients, 1 to 7 years, ASA I-II, lower abdominal surgery	ESP block preoperative (at L1 level)	0.5 mL/kg 0.25% bupivacaine (max 20 mL) to the patients in ESPB group.	ESP block is effective as QLB
Aksu & Gürkan[22]	Ten patients, 3 to 10 years, bilateral open inguinal hernia repair	ESP block (at L1 level)	0.5–1 ml (0,5 ml/kg 0,25% bupivacaine-maximum dose was limited to 20 ml/per side)	Postoperative pain was evaluated by FLACC ESP block provides an effective postoperative analgesia and reduces opioid requirements
Uysal Aİ *et al*.[23]	5-month-old patient for left diaphragm hernia repair	ESP block (T6 and T10 levels)	0.5 mL/kg 0,25% bupivacaine Paracetamol 10 mg/kg was given as routine analgesic at postoperative 6 h.	The postoperative pain was evaluated by FLACC scale in 15 min, 1.,3.,6.,12 and 24 h. The FLACC scores were, respectively, 3,2,0,0,1,0. No need for rescue analgesic.
Aydın T.[24]	9-month-old patient after a trial of hydrostatic enema reduction had failed	Unilateral caudal to cephalad bi-level ESP block () at T10 and T11 level	3 mL 0.25% bupivacaine	Effective postoperative visceral and somatic pain relief and opioid sparing analgesia The r-FLACC scores were assessed as 0 at 1st, 2nd, 4th, 6th, 12th and 18th postoperative hours (POH). The r-FLACC score was 1 at 24th POH.
El Motlb EAA and El-Emam EM[25]	60 patients, ASA I-II, 6 months to 3 years-elective unilateral inguinal hernia repair	ESP block versus IIN block at L1 level	0.5 mL/kg 0.125 bupivacaine +1 μg/mL fentanyl 15 mg/kg paracetamol suppositories if pain score ≥2–3 every 6 h 10 mg/kg ibuprofen as needed every 8 h	IIN group showed a significantly higher FLACC score at 4 and 6 h, significantly higher number of rescue medication doses and number of patients needed rescue analgesia.
Thomas DT & Tulgar S.[26]	11-year-old, ASA-I, laparoscopic cholecystectomy		15 mL 0.25% bupivacaine	Hourly NRS follow-up revealed NRS <3 during the first 24 h.

ASA, American Society of Anesthesiologist; ESP, Erector spinae plane; IIN, FLACC: The Face, Legs, Activity, Cry, and Consolability

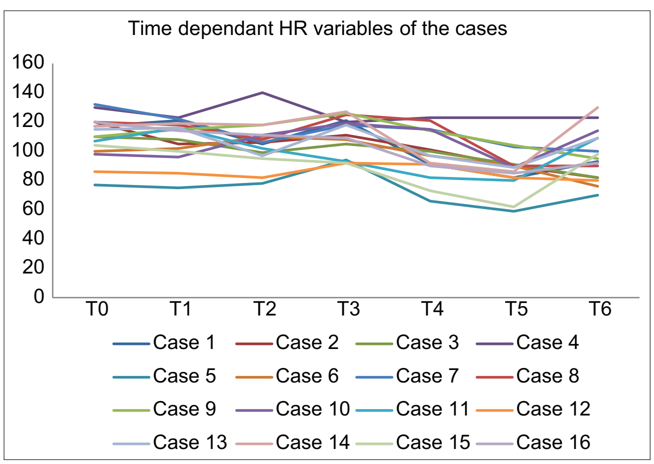

Figure 4: Perioperative HR variables in cases

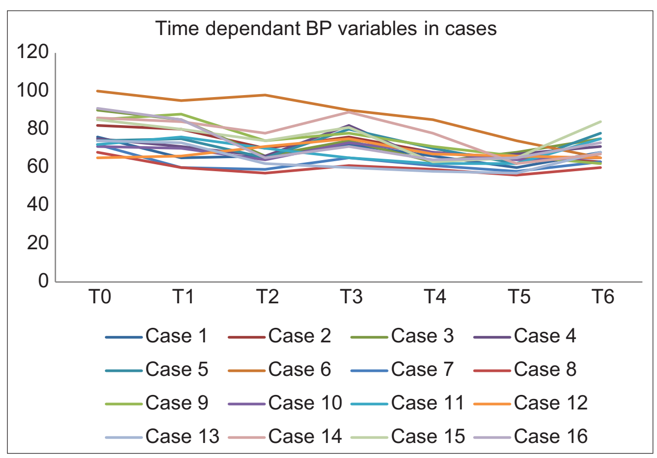

Figure 5: Perioperative BP variables in cases

at doses appropriate to the literature under ultrasound guidance.

Bupivacaine doses for ESP block

There is a lack of consistent and standardized reporting with regard to dosing, analgesia, and motor/sensory changes, which may be attributed to the novelty of ESPB. In pediatric age group, there are different dose regimens for ESP block[21-26] [Table 3]. In the block application, the dose and volume in the literature, which we have achieved successful results in other area blocks, were used.

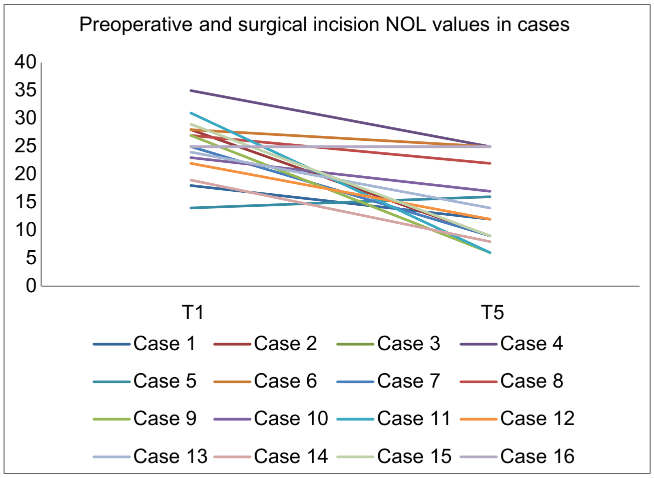

Figure 6: T1 (preoperative) and T5 (surgical incision) time point NOL values in cases

Intraoperative opioid using

Opioid analgesics are used to reduce intraoperative pain in pediatric patients scheduled for abdominal surgery.[27] Clinicians are trying to gradually reduce opioid consumption by using multimodal analgesia, which includes a combination of drugs such as paracetamol or local anesthetics. We used remifentanil infusion together with ESP block as intraoperative analgesic. We started remifentanil at a dose of 0.2 µg/kg/min before induction of anesthesia and then revised the dose according to the change in HR and BP. Intraoperative mean doses of remifentanil were lower than standard maintenance doses in 11 cases. In four cases, the infusion was stopped after the block. Remifentanil infusion at a dose of 0.2 µg/kg/min was required in only one case. This indicates the success of the ESP block in the intraoperative period. This success continued in the postoperative period as well. None of the patients needed additional opioids.

Kim S. H. *et al*. investigated whether intraoperative use of remifentanil resulted in dose-dependent postoperative opioid tolerance in young children. They reported that intraoperative use of 0.3 µg/kg/min remifentanil for approximately 3 h (surgery time: 140–265 min) did not cause acute tolerance, but administration of 0.6 and 0.9 µg/kg/min to young children resulted in dose-dependent acute tolerance 24 h after surgery.[28] The use of regional anesthesia techniques such as ESP block in multimodal analgesia will reduce these concerns. As in our case series, ESP block greatly reduces opioid consumption. Numerous researchers have investigated age-related opioid pharmacokinetics and pharmacodynamics using observational methodologies. However, the appropriate dose for the patient will vary based on many factors, including the underlying disease, medications used, previous exposure to opioids, and the type of surgery. The pharmacokinetics and pharmacodynamics of opioid agents also vary with age.[27] On the other hands, Davis PJ reported that remifentanil has a context-sensitive half-life when given by infusion, and this remains constant even in younger children.[29]

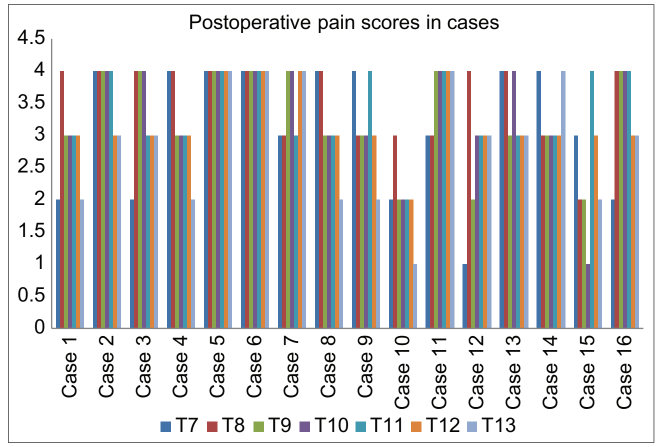

Figure 7: Time-dependent postoperative pain scores in cases

Intraoperative pain follow-up methods

Hemodynamic responses to surgical skin incision are widely used to assess the level of pain. Hemodynamic parameters such as BP and HR increase after nociceptive stimulus. However, these parameters are affected not only by pain but also by many conditions such as changes in intravascular fluid status and depth of anesthesia. Nociception scores are likely affected by the type of general anesthesia, as significant differences in stress response have been reported during volatile and total intravenous anesthesia.[30] Another confounding factor is the patient's age, as autonomic responses vary with age.[31] We added the NOL monitor to the standard monitoring as hemodynamic parameters are affected by many conditions. We found that NOL values were below 25 (range: 0–100) in all cases and were consistent with HR and BP values.

Postoperative analgesia

Aksu *et al*.[32] evaluated the efficacy of ESP block for providing postoperative analgesia in laparoscopic cholecystectomy procedures. Patients were randomized into two groups as ESP and control group. They reported that mean morphine consumptions at postoperative 24th h were 7.5 mg ± 5.8 in the ESP group, while it was 13.2 ± 5.6 mg in the control group ($p < 0.01$). There was also a significant difference between the groups as for NRS scores at 12th and 24th h. Sakae *et al*.[33] compared ESP block and epidural block for postoperative analgesia in open cholecystectomy operations. Pain was more common in the ESPB group at the 2nd and 24th h evaluations. Rescue opioid use within 24 h was tripled in the ESPB group compared with the epidural group. In another study, spinal anesthesia + morphine and spinal anesthesia + ESP block were compared in open unilateral inguinal hernia repair.[34] They concluded that ESP block was an ineffective technique for providing postoperative analgesia and was associated with higher rescue opioid consumption. In the techniques and doses used in our case series, ESP block eliminated the need for postoperative opioids.

Postoperative pain scores

A common approach to quantify postoperative pain is the use of pain scales. Numerous scoring systems validated for measuring pain in children have been developed.[7,8] In this case, series cases of postoperative pain scores were evaluated with different scoring which are suitable for their age (VAS or FRS-R in between 0 and 10 scores). The validity of the FPS-R is supported between the ages of 4 and 12.[14] VAS score can be used for children who are older than 8 years. In our case series, postoperative pain score was measured by VAS or FRC-R at the 24th h.

Limitation

Our case series was a pilot study with a small sample size in the pediatric age group, which limits the generalization of our findings.

Conclusion

As a conclusion, ESP block is significantly a contributing method to the pain control in pediatric cases underwent abdominal surgery. Hemodynamic parameters as a conventional pain monitoring data are compatible to NOL values at surgical incision. Postoperative pain scores were appropriate for pain-free or minimal pain. However, extensive clinical studies are required to reach more conclusive results.

Financial support and sponsorship

This scientific research project was funded by Gazi University. In this study, PMD-200TM monitor was used for intraoperative monitoring of pain.

Conflicts of interest

There are no conflicts of interest.

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