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Ultrasound-guided erector spinae plane block in patients undergoing pediatric abdominal surgery: a randomized study

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Abstract

Background: Erector spinae plane block (ESPB) can provide effective analgesia in pediatric abdominal surgery**.** Additionally, when used as an analgesic method in abdominal surgery, ESPB may increase regional intra-abdominal tissue oxygen saturation (rSO_2) throughout the operation. However, the number of related studies conducted on pediatric patients is insufficient.

Results: Fifty-two patients undergoing lower abdominal surgery were allocated into two groups, the ESPB (E) and the control (C). Group E received general anesthesia plus unilateral ultrasound-guided ESPB, and group C received general anesthesia alone. Intraoperative fentanyl consumption, Face, Legs, Activity, Cry, Consolability (FLACC) score, time to first rescue analgesia and adverse events were recorded over the first 24 h postoperatively. The rSO_2 level was evaluated in both groups throughout the operation. The FLACC score was significantly lower in group E than in group C ($p<0.05$). Four patients in group E required intraoperative fentanyl compared to 12 patients in group C ($p<0.05$). The first rescue analgesic administration time was significantly longer in group E than in group C ($p<0.05$). No significant difference in rSO_2 values was detected between the groups ($p>0.05$). However, in group E, rSO_2 values were significantly increased after the block compared to the postinduction values.

Conclusions: ESPB provides effective perioperative analgesia in children undergoing low abdominal surgery. Although there was no significant difference in rSO_2 values between the groups, ESPB administration consistently increases rSO_2 over time.

Trial registration: The trial was registered at ClinicalTrials.gov before patient enrolment (NCT03808129-13.12.2018).

Keywords: Erector spinae plane block, FLACC scale, Tissue oxygen saturation

Background

Erector spinae plane block (ESPB) is a promising interfacial plane block technique, especially for minor ambulatory surgery patients, providing a simpler and safer alternative to a central block for postoperative analgesia (Petsas et al. 2018). A few randomized controlled trials have demonstrated the efficacy of ESPB for postoperative pain in pediatric patients (El-Emam and El Motlb 2019; Mostafa et al. 2019; Aksu et al. 2019).

The ESPB has been indicated to be efficient when applied to dorsal and ventral rami of the thoracic spinal nerves together with sympathetic nerve fibers (Forero et al. 2016; Yang et al. 2018; Ivanusic et al. 2018; Choi et al. 2019). In addition to the analgesic effect of this technique might be the increase in regional intraabdominal tissue oxygenation (rSO_2). Maintaining regional oxygen saturation (rSO2), especially in pediatric patients, can provide great physiological insight. Adequate tissue oxygenation can both prevent organ dysfunction by

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maintaining splanchnic circulation and decrease perioperative and postoperative morbidity and mortality in the selected patients (Huber et al. 2019).

Near-infrared spectroscopy (NIRS) is a non-invasive technique for evaluating rSO_2 (Jobsis 1977). Two previous studies evaluated changes in rSO_2 following caudal epidural block (CEB) and spinal anesthesia in infants and children (Bettesworth et al. 2012; Froyshteter et al. 2018). However, the depth and intensity of the ESPB effect on rSO2 are unknown, as it has not been investigated before.

In this study, we aimed to determine the effect of ESPB on perioperative analgesia and rSO2 changes in pediatric patients undergoing minor lower abdominal surgery.

Methods

This prospective, randomized clinical trial was approved by the Institutional Clinical Research and Ethics Committee of Bezmialem Vakıf University, Istanbul, Turkey (16.05.2018-16/19). The trial was registered at ClinicalTrials.gov before patient enrolment (NCT03808129-13.12.2018) and was conducted in the Department of Paediatric Surgery at the Bezmialem Vakıf University Medical Faculty Hospital. Fifty-two pediatric patients of both sexes between 6 months to 2 years with American Society of Anaesthesiologists physical status classes I to II and scheduled for elective low abdominal surgery were consecutively enrolled in the study. Infants with coagulation disorders, cardiac or renal disease, hypersensitivity to local anesthetic drugs, developmental or mental retardation, or infection of the block site, those who were undergoing bilateral surgery and those whose parents refused to participate in the study were excluded.

Patients were divided into two groups using random numbers according to a computer-generated sequence (www.randomizer.org). These sequences were generated after obtaining informed consent and were kept in closed and sequentially numbered opaque envelopes. The control group (group C) consisted of 26 individuals who received only general anesthesia, while the ESPB group (group E) consisted of 26 individuals who underwent ESPB with general anesthesia.

The procedure was explained to the families and informed consent was obtained. A dose of 0.5 $mg.kg^{-1}$ of midazolam was given orally to patients 30 min before being taken to the operating room. Three-lead electrocardiography was performed; the heart rate, non-invasive blood pressure, peripheral oxygen saturation, and body temperature were monitored (Datex Ohmeda *Ohmeda*®, Helsinki, Finland). The anesthesia depth was evaluated via bispectral index (BIS) monitoring (Aspect XP Platform).

The rSO_2 measurements were performed with a commercially available device, INVOS 5100B (Somatic Oximeter; Somanetics Corp, Troy, Mich.). To measure rSO_2, the renal oximeter probe was placed at the T10–T12 levels in the region behind the spinal column on the ESPB-treated side. The time points for rSO_2 measurement were as follows: before anesthesia induction, after aanesthesiainduction, at the time of surgical incision and 10, 20, 30, 40, and 50 min before and after the block (10 min) in group E.

After anesthesia induction, peripheral vascular access was achieved with 8% sevoflurane in a medical air/oxygen mixture (50:50) administered by inhalation using a face mask. A laryngeal mask airway was inserted using 1 $\mu g.kg^{-1}$ fentanyl. The sevoflurane concentration (1.5–2%, 4 L O_2/min) was adjusted to maintain the BIS between 40 and 60. During the operation, if a 20% increase occurred in the mean blood pressure or heart rate compared to the baseline values, 0.5 $\mu g.kg^{-1}$ fentanyl was administered to the patient. Intravenous fluid maintenance was achieved via the administration of an isotonic electrolyte solution at a rate of 10 $mL.kg^{-1}/h$.

Group C: The control group did not receive any peripheral nerve block. All patients were monitored before the surgery, and the results were recorded until the end of surgery.

In Group E, ESPB was performed by the same anesthesiologist (S.Y.), who was experienced in fascial blocks. After the patient was placed in the lateral decubitus position and the thoracic area was sterilized with povidone iodide, a 5–14 W linear ultrasound (US) probe covered with sterile gloves was placed in the transverse process of the T8 vertebra. The initial image was optimized with sagittal or transverse scanning. A 22-G 50-mm needle (Stimuplex A, B. Braun, Melsungen, Germany) was placed in-plane with respect to the US probe under the erector spinae muscle fascia until it contacted the end of the T8 transverse process in the cranial/caudal direction. After hydrodissection, the needle tip was confirmed to be between the fascia of the erector spinae muscle group and the transverse process (Fig. 1). The block was performed using 0.5 $ml.kg^{-1}$ of a mixture of 0.25% bupivacaine and 1% lidocaine (1:1), and surgery was allowed to proceed after 15 min. The onset of action of lidocaine is faster than that of bupivacaine. Because we performed ESPB after anesthesia induction, we preferred to use a combination of both drugs to increase the speed of the block effect.

For postoperative analgesia, 15 $mg.kg^{-1}$ paracetamol was administered intravenously in both patient groups 15 min before the end of the procedure, and patients were ventilated with pure oxygen after stopping the anesthetic gases. Then, the laryngeal mask airway was removed after the BIS of the patient increased to greater than 80 and spontaneous respiration reached the adequate tidal

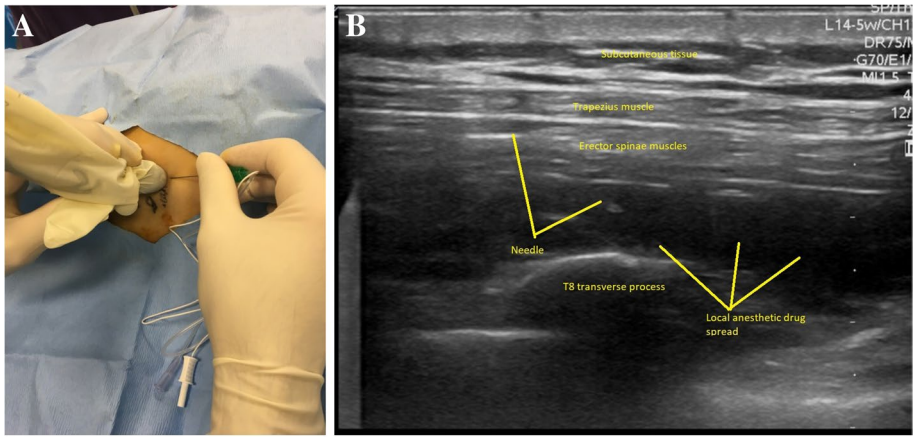

Fig. 1 Ultrasound-guided demonstration of the erector spinae plane block. **A** The patient was placed in the lateral decubitus position after anesthesia induction. The ultrasound lineer probe is placed in a longitudinal parasagittal orientation. **B** The block needle is inserted in plane in a cranial-to-caudal direction to contact the transverse processes. Needle location indicated by arrows with LA deposited deep to the erector spinae muscle

volume. Next, 5 $mg.kg^{-1}$ ibuprofen was administered to the patient if the pain was higher than five according to the FLACC scale (Froyshteter et al. 2018). In cases of insufficient analgesia, an additional dose of paracetamol (10 $mg.kg^{-1}$) was administered 6 h after intravenous paracetamol administration.

The demographic characteristics (sex, age, height, and weight), time until surgery, BIS values, sevoflurane concentration (%) at 10-min intervals during surgery, intraoperative fentanyl requirements, and total duration of the surgery were recorded. Pain assessment was performed using the FLACC scale at the seven time points (on arrival to the post-anesthesia care unit (PACU) and 1, 2, 4, 8, 12, and 24 h postoperatively). FLACC scale evaluations were performed after patient discharge by a video conferencing method. The anesthesiologist who performed the block procedure was blinded to the group allocation because this individual did not participate in postoperative follow-up evaluations. The physician assistant who evaluated the postoperative FLACC scale and the need for analgesia was also blinded to the group allocation because this individual was called to the operating room after the patient was prepared, and the block procedure was completed.

Similarly, groups were compared according to the first time they needed additional analgesics and the number of patients requiring postoperative analgesia during the first 24 h. Patients were compared in terms of possible adverse effects during the study. The occurrence of any adverse effects including emergency delirium, postoperative nausea and vomiting, urinary retention, pruritus, and infection was recorded.

The time required for discharge, as determined by satisfying the patient discharge criteria, was evaluated. Patients' discharge times were recorded, and families' satisfaction levels were recorded as very bad, bad, mediocre, good, or very good. The surgeon's satisfaction was recorded as very bad, bad, mediocre, good, or very good. The primary outcome was measured patient pain scale and rSO_2 levels. The secondary outcome has measured the occurrence of any adverse events and the satisfaction rates of the patients' families and surgeons.

Statistical evaluation

All statistical analyses were performed by using a statistical software program (IBM SPSS Statistics, v22.0; IBM Corp). The normality of distributions was tested by the Shapiro-Wilk test. FLACC and rSO_2 measurements were analyzed using a linear mixed model. Time was included as a repeated effect with first-order autoregressive covariance structure (AR(1)). Treatment group, time, and the interaction treatment group × time were set as fixed effects. The intragroup and intergroup pairwise comparisons were performed using Bonferroni correction. $P < .05$ was considered statistically significant. Categorical data (intraoperative fentanyl requirement, additional analgesics requirement, and adverse event) were analyzed using Fisher's exact test (expected frequency<5) and Likelihood ratio test (expected frequency>5). The mean time to first analgesic administration was analyzed by Kaplan–Meier survival analysis and log-rank statistics.

The calculation of the sample size was based on the FLACC score and rSO_2 values. The G power program revealed that with an effect size (d)=1.039 and SD=1.3 for the rSO_2 values, a minimum of 16 samples was

required for each subgroup with an alpha error of 0.05 and power of 80% (Van de Velde et al. 2016). Based on our unpublished pilot study with 10 patients in both groups, the mean FLACC value at the 8th hour after surgery in the ESPB group was 1.9 ± 1.4 and that in the control group was 3.1±1.9. Accordingly, using a FLACC effect size of 0.920, an SD of 1.4, a power of 0.80 and an α of 0.05, a minimum of 20 samples were required for each subgroup. Considering the possible patient dropout, we increased the sample size to 52 patients, with 26 patients per group.

Results

Fifty-one patients were analyzed in this study (Fig. 2). There was no significant difference between the groups in terms of age, sex, weight, ASA scale, or operation type ($p > 0.05$) (Table 1). Four (15.4%) patients in group E required intraoperative fentanyl compared to 12 (48%) patients in the group C ($P = 0.001$).

After using linear mixed-effect model analysis for rSO_2 values, rSO_2 values never differed between the two groups in Bonferroni-corrected pairwise comparisons ($p>0.05$). However, time-dependent rSO_2 values showed a statistically significant difference ($p=0.018$). When rSO_2 values were compared post-induction with the other times, post-induction rSO_2 values significantly increased after the block only in group E (estimated difference, 2.3 [95% CI, 0.07–4.5] ($p=0.036$) (Fig. 3A).

A linear mixed-effect model analysis of the FLACC scale values showed that the interaction of treatment and time had a significant effect ($p<0.001$). At 1 h postoperatively, the FLACC scale values were significantly lower in group E than in group C (estimated difference, −0.9 [95% CI, −1.6, −0.3]; $p = 0.003$) and remained significantly lower in Bonferroni-corrected pairwise comparisons until 8 h postoperatively; $p= 0.000$ at 2 h, $p=0.000$ at 4

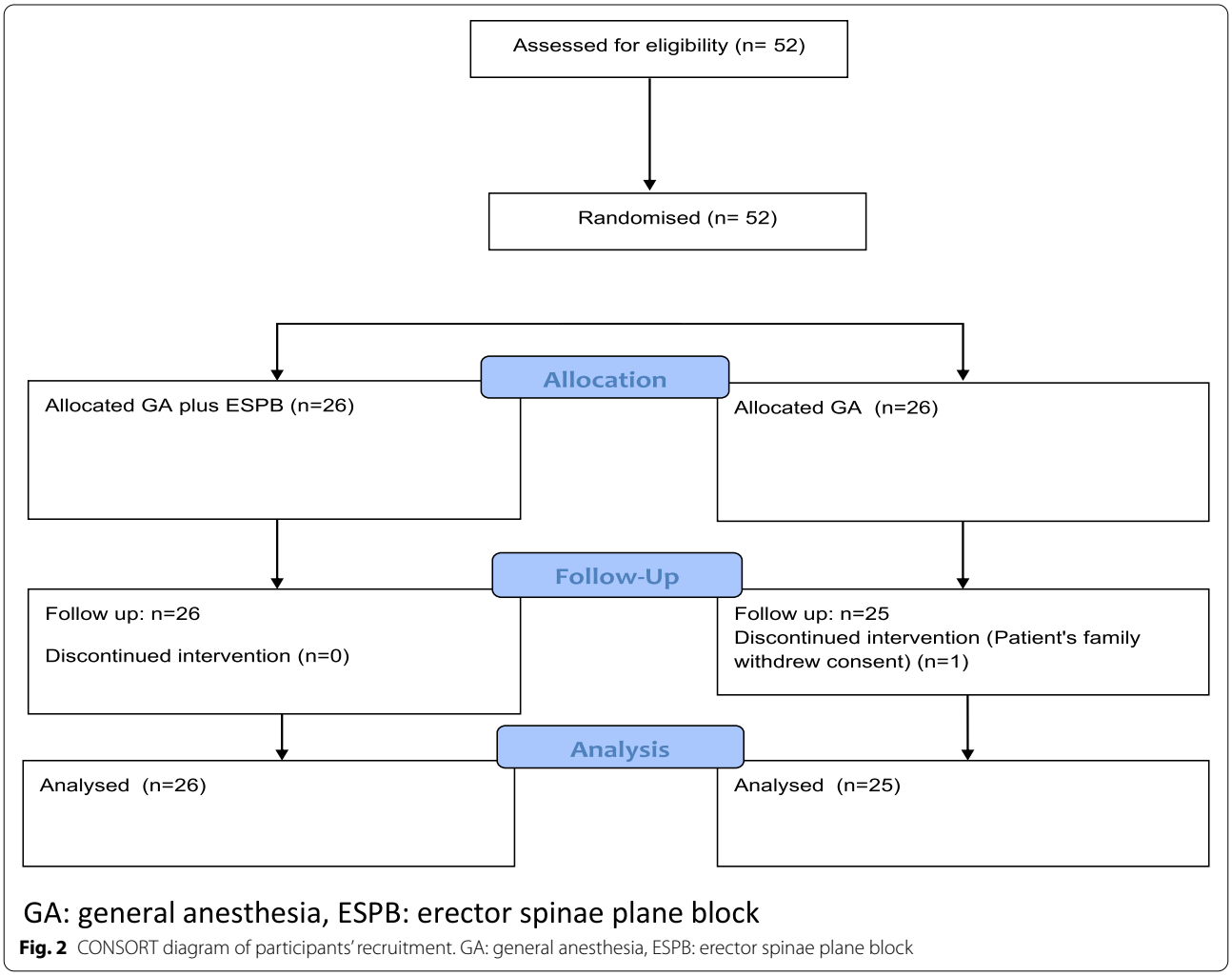

Fig. 2 CONSORT diagram of participants' recruitment. GA: general anesthesia, ESPB: erector spinae plane block

Table 1 Evaluation of the demographic characteristics of the groups

		Group E *n* (%)	Group C *n* (%)
Age (year)	**0–12 month**	16 (61.5%)	12 (48%)
	12–24 month	10 (38.5%)	13 (52%)
Gender	**Male**	23 (88.5%)	20 (80%)
	Female	3 (11.5%)	5 (20%)
ASA	**1**	25 (96.2%)	22 (88%)
	2	1 (3.8%)	3 (12%)
Operation	**Hydrocele**	3 (11.5%)	4 (16%)
	Hydrocele+Inguinal Hernia	0 (0%)	2 (8%)
	Hydrocele+Undescended testis	1 (3.8%)	0 (0%)
	Inguinal Hernia	7 (26.9%)	10 (40%)
	Undescended testis	15 (57.7%)	9 (36%)
Weight (kg) $_{mean\pm SD}$		12±2.22	12.56±2.90

Values are mean (SD) or count (percentage)

ASA American Society of Anesthesiologists physical status

h, and p=0.018 at 8 h (Fig. 3B). Three patients (11.5%) in group E required postoperative rescue analgesia compared to 15 (60%) patients in group C (p=0.000). The time to first rescue analgesic administration was significantly longer in the group E compared to the group C (P =0.001). Figure 4 shows Kaplan–Meier survival analysis and log-rank statistics for the time to first postoperative rescue analgesia administration.

Nausea was observed in two patients in group C and one in group E. There was no significant difference between the groups in terms of the complication rates and the mean discharge time (p>.05).

Although the satisfaction rates of the patients' families and surgeons in group E were good and very good and were higher than those in group C, there were no statistically significant differences between the groups (p>0.05).

Discussion

In the current study, we observed that ESPB resulted in less consumption of analgesics, relatively extended duration of analgesia and greater reduction in pain scores in the first 24 h postoperatively. We also observed that performing ESPB in pediatric patients undergoing low abdominal surgery increased rSO2 values over time, but this did not make a statistically significant difference compared to the control group.

In 2016, Forero et al. (2016) were first to demonstrate in a cadaver model that local anesthetic, injected deep into the erector spinal muscle, penetrates anteriorly through the connective tissues and ligaments that cover adjacent transverse processes, and enters the thoracic paravertebral space. In another study by Yang et al. (2018), the injected dye entered the paravertebral space anteriorly, similar to a previous study. However, in the study of Ivanusic et al. (2018), the injected dye only spread craniocaudally and laterally to the posterior aspect of the costotransverse foramen and did not spread anteriorly to the dorsal and ventral rami. Finally, Choi et al. (2019) showed that paravertebral spread increases in a volume-dependent manner following RSPB.

Real-time monitoring of somatic oximeter using NIRS provides noninvasive continuous access to regional circulations that can facilitate the detection of hypoxia and hypoperfusion and drive perioperative interventions to reduce end-organ ischemic injury. The link between low tissue oxygenation and organ dysfunction has been well established (Bailey and Mally 2016; Joffe et al. 2018; Scott and Hoffman 2014; Hopf et al. 1997).

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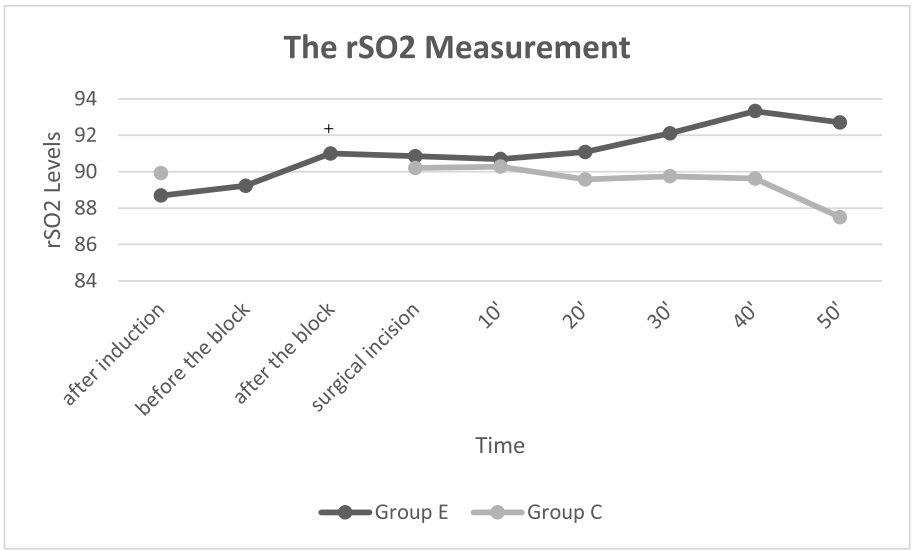
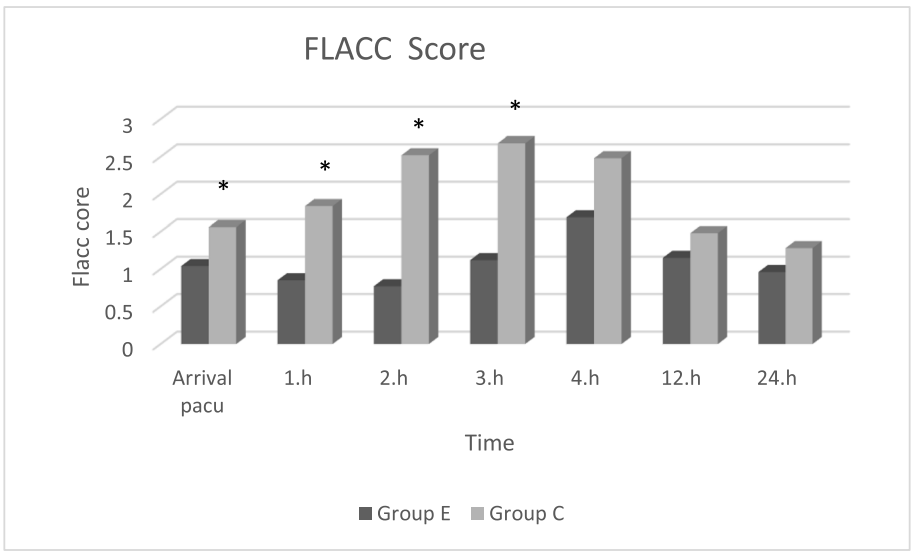
Various factors may be responsible for the decreased tissue oxygenation during the intraoperative period. Beck et al. (2017) performed rSO_2 measurements in the neonatal age group to evaluate renal oxygenation during abdominal surgery and revealed that intraoperative renal rSO_2 values tended to decrease. Sympathetic nervous system activation seems to be the most likely cause of the decreased peripheral perfusion and rSO_2 found in many surgical patients (Hopf et al. 1997). Multiple perioperative factors such as surgical incision, pain, anxiety, and hypovolemia hypothermia can reduce rSO_2 by stimulating sympathetic activation.

Since central or peripheral nerve blocks may increase tissue rSO_2 through a sympathetic block, several studies have focused on the effect of these techniques on rSO2 (Bettesworth et al. 2012; Froyshteter et al. 2018;



A)



B)

Fig. 3 Changes in intraoperative SO_2 and postoperative FLACC in groups. Values of intraoperative rSO_2 levels. *****p: Comparison of intragroup. **B** FLACC in the studied groups. Values are presented as mean± SD. **p*< 0.05. *P* values are corrected using Bonferroni correction (adjusted by multiplication by number of tests)

Beck et al. 2017; Sola et al. 2017). Cerebral and tissue rSO_2 measurements were performed after spinal anesthesia, and the cerebral rSO_2 did not change, but tissue rSO_2 increased (Froyshteter et al. 2018; Sola et al. 2017). Bettesworth et al. (Bettesworth et al. 2012) proposed that caudal epidural block led to an increased tissue rSO_2 rate due to sympathetic blockage. Beck et al. (2017) performed rSO_2 measurements in the neonatal age group to evaluate renal oxygenation during abdominal surgery and revealed that intraoperative renal rSO_2 values tended to decrease.

We conducted measurements before block induction in our patients using the NIRS probe because it did not interfere with the surgical area. We applied ESPB after anesthesia induction and continued recording. When NIRS values were considered, we did not detect any differences between the groups. Measurements of the mean rSO_2 values after induction showed that, among patients

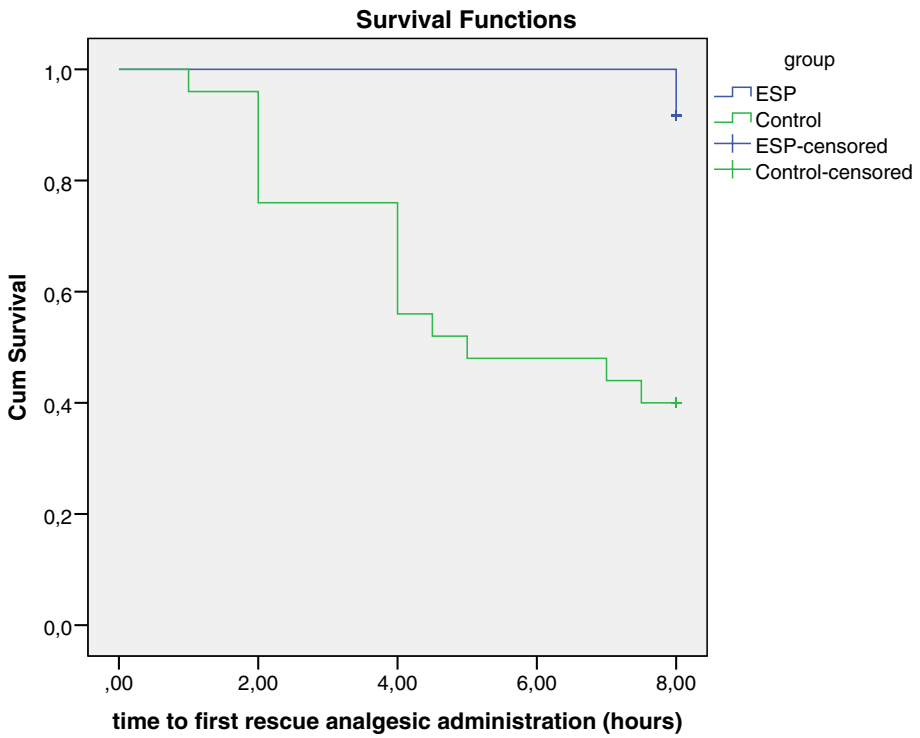


Fig. 4 Kaplan–Meier curve for the time to first rescue analgesic administration

who underwent ESPB, rSO_2 values were significantly increased after the block compared with the postinduction values. Although systolic, diastolic, and mean blood pressure values were similar in both groups and blood pressures were within physiological limits, in group E, the intraoperative rSO_2 levels increased over time.

The reason for the increase in rSO_2 is thought to be that after ESPB, the local anesthetic spreads anteriorly through the connective tissue that spans the transverse processes and then enters the thoracic paravertebral space to anesthetize both the ventral ramus and dorsal ramus of the spinal nerve. Furthermore, the white and gray rami communicate, carrying the preganglionic and postganglionic sympathetic fibers to and from the sympathetic ganglia (Petsas et al. 2018; Huber et al. 2019; Luis-Navarro et al. 2018; Hannig et al. 2018). We found that the rSO_2 differed only within groups, and a difference between groups could not be confirmed. This may have occurred because ESPB was performed unilaterally, and the study was completed in 50 min; no recordings were performed after 50 min. These results suggest that ESPB increases intra-abdominal rSO_2 via sympathetic blockade.

Regional anesthetic blocks are often used in combination with general anesthesia for pediatric surgery and have been shown to reduce the general anesthetic requirements, risk of anesthetic neurotoxicity in young patients, opioid use and postoperative pain, nausea, and vomiting (Frizzell et al. 2017; Willschke et al. 2010; Suresh et al. 2015; Tobias 2009). Although the caudal epidural block is a technique that provides excellent analgesia, the risk of possible neurological complications restricts its use in ambulatory surgery cases (Walker et al. 2018). Therefore, most research is directed towards investigating other regional analgesic methods. US-guided ESPB is a reliable method because the target tissue is easily visualized, and the injection site is far from neural and major vascular structures and the pleura (Muñoz et al. 2017).

Thomas and Tulgar (2018) applied bilateral ESPB to an infant who underwent laparoscopic cholecystectomy and suggested that this block was an effective technique because it blocked both visceral and somatic fibers. They also stated that ESPB provided multi-dermatomal spread from one injection site in contrast to the other regional blocks. In our practice, we observed a spread between the T5 and L1 segments by the US when the injection was performed at the T8 segment. Therefore, we determined that the ESPB application provided sufficient analgesia for lower abdominal surgeries in pediatric patients.

The only complication related to ESPB reported in the literature is pneumothorax, which was observed in an

adult patient (Ueshima 2018). No complications were observed in our study.

There are some limitations of our study. Our study was conducted in a single center and included a relatively small number of patients. ESPB exhibits increased efficacy due to its spread to the paravertebral space, and the short duration of surgery may have affected the rSO_2 levels. We compared the ESPB with conventional intravenous analgesia; therefore, its efficacy needs to be determined with other regional techniques such as transversus abdominis plane block, quadratus lumborum block, and ilioinguinal-iliohypogastric nerve block.

Conclusions

ESPB provided effective perioperative analgesia in pediatric patients undergoing lower abdominal surgery. Although there was no significant difference in rSO_2 values between the groups, ESPB consistently increased rSO_2 over time.

Abbreviations

ESPB: Erector spinae plane block; rSO_2: Regional tissue oxygenation; FLACC: Face, Legs, Activity, Cry, Consolability; CEB: Caudal epidural block; NIRS: Near-infrared spectroscopy; PACU: Post-anesthesia care unit.

Acknowledgements

Not applicable.

Authors' contributions

AT, MT and KK designed the study. AT and SY drafted and modified the manuscript. PP performed the study and collected data. SY performed the ESPB block. The authors read and approved the final manuscript.

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Availability of data and materials

The datasets during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Institutional Clinical Research and Ethics Committee of Bezmialem Vakıf University, Istanbul, Turkey (16.05.2018-16/19). Therefore, the clinical research has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Since children under the age of 16 were enrolled in this study, all the parents of the children provided informed consent on behalf of their child.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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