







## ORIGINAL RESEARCH



# Modified thoracoabdominal nerve block through perichondrial approach for laparoscopic appendectomy in children: a randomized trial

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**Abstract**

The modified thoracoabdominal nerve block through perichondrial approach (M-TAPA), an interfascial plane block, effectively induces analgesia in the anterior and lateral thoracoabdominal walls and has demonstrated efficacy in adult patients. However, its application in the pediatric population remains unexplored. This investigation aims to assess the efficacy of M-TAPA in children undergoing laparoscopic appendectomy. Sixty pediatric patients undergoing laparoscopic appendectomy under general anesthesia were enrolled in this single-center study. Preoperatively, the participants were randomly assigned to receive either port-site local anesthetic infiltration or M-TAPA. The primary outcome measure was the numeric rating scale (NRS) pain score assessed 6 hours postoperatively. Secondary outcomes included NRS pain scores at various time intervals, requirement for rescue analgesia, time to first request for rescue analgesics, and incidences of postoperative complications such as nausea, vomiting and shoulder tip pain. The results revealed significantly lower NRS scores in the M-TAPA group compared to the local anesthetic infiltration group, except at the 24-hour mark post-laparoscopic appendectomy ( $p < 0.05$ ). Additionally, the local anesthetic infiltration group exhibited a higher rate of rescue analgesic usage (53.3%,  $n = 16$ ) compared to the M-TAPA group (13.3%,  $n = 4$ ) ( $p = 0.001$ ). Although the incidences of nausea, vomiting and shoulder pain were elevated in the local anesthetic infiltration group relative to the M-TAPA group, these differences did not reach statistical significance ( $p > 0.05$ ). In conclusion, M-TAPA demonstrates superior efficacy in postoperative analgesia compared to port-site local anesthetic injection in pediatric laparoscopic appendectomies.

**Keywords**

Pediatrics; Appendectomy; Ultrasonography; Nerve block; Local anesthetics; Postoperative pain

## 1. Introduction

Appendectomy is a common emergency surgical procedure in the pediatric population [1, 2], often performed laparoscopically due to its postoperative advantages. However, despite its minimally invasive nature, postoperative pain remains a significant challenge [3].

In laparoscopic appendectomy, pain may arise from two main sources: somatic pain due to the surgical incision and visceral pain caused by inflammation from peritoneal stretching [3, 4]. In addition to conventional pain management methods involving non-opioid analgesics (*i.e.*, paracetamol and nonsteroidal anti-inflammatory drugs) and opioids, regional analgesia techniques such as port-site local anesthetic infiltration (LAI), rectus sheath block, and transversus abdominis plane block are being increasingly utilized [1, 5].

Tulgar *et al.* [6] reported a modified thoracoabdominal nerve block through a perichondrial approach (M-TAPA), which has been recently applied in abdominal surgeries for adults. This technique within an interfascial plane has shown effectiveness in delivering analgesia to the anterior and lateral thoracoabdominal walls [7]. In M-TAPA, local anesthetic (LA) is administered just below the costal cartilage, deep to the origin of the transversus abdominis muscle, targeting the anterior and lateral cutaneous branches of the T5–T12/L1 thoracoabdominal nerves [6–8].

To date, there has been a lack of research on the application of M-TAPA in the pediatric population despite its demonstrated efficacy in providing postoperative analgesia in adult laparoscopic surgeries. Herein, this study aims to assess the effectiveness of M-TAPA in children undergoing laparoscopic appendectomy by comparing port-site LAI and M-TAPA with

the primary objective to evaluate postoperative pain scores, and secondary objectives including a comparison of rescue analgesic requirements, family satisfaction levels, and incidences of postoperative complications.

## 2. Methods

### 2.1 Research methodology

This single-center, prospective, randomized clinical study was conducted at a university-affiliated educational hospital in Ankara Health Sciences University.

The inclusion criteria comprised patients aged 8–17 years, classified as American Society of Anesthesiologists (ASA) physical status I–II E, scheduled for laparoscopic appendectomy following a diagnosis of acute appendicitis, and possessing the ability to self-report pain levels using the numeric rating scale (NRS). Exclusion criteria included ASA III–IV status, parental refusal, known allergy to any study medications, presence of perforated appendicitis, inability to cooperate or communicate effectively, mental disability, bleeding disorders, and evidence of infection at the injection site or underlying conditions contraindicating regional anesthesia or port-site LAI.

Patients undergoing laparoscopic appendectomy in the pediatric surgery operating room were randomly assigned to one of the following two groups using a computer-assisted method (JMP, version 12.0.1, SAS Institute Inc., Cary, NC, USA): a port-site LAI group and an ultrasound-guided M-TAPA group.

### 2.2 Anesthesia management

Intravenous injections were administered in the operating room. Premedication consisted of midazolam at a dosage of 0.05 mg/kg, with a maximum dose of 2 mg. Endotracheal intubation was facilitated by administering fentanyl at a dosage of 1 µg/kg (maximum 50 µg), lidocaine at 1 mg/kg, propofol at 3–4 mg/kg, and rocuronium at 0.6 mg/kg. Anesthesia maintenance comprised a mixture of 50%–50% O<sub>2</sub>-Air, sevoflurane at 0.8–1 minimum alveolar concentration, and remifentanyl at 0.05–0.2 mcg/kg/min. The dosages of sevoflurane and remifentanyl were adjusted based on the patient's hemodynamic status.

Appendectomies were performed laparoscopically by two surgeons utilizing three ports. After anesthesia induction, an 11-mm camera port was inserted at the umbilicus using an open technique. Pneumoperitoneum was achieved via carbon dioxide insufflation. Two additional 5-mm ports were placed, one in the suprapubic region and the other in the lower left quadrant. Intra-abdominal pressure was maintained at 10–12 mmHg post-port insertion.

For postoperative analgesia, morphine was administered at a dosage of 0.05 mg/kg. To prevent nausea and vomiting, all patients received intravenous ondansetron at a dosage of 0.1 mg/kg (up to 4 mg) at the conclusion of surgery. Reversal of neuromuscular blockade was accomplished with sugammadex at a dosage of 2 mg/kg, followed by extubation once airway protective reflexes, spontaneous breathing, and an adequate level of consciousness were regained.

### 2.3 Protocol for port site local anesthetic infiltration

At the end of the surgery, before extubation, the surgeon administered 0.17 mL/kg of 0.25% bupivacaine (with a maximum dose of 2 mg/kg) through infiltration into the skin, subcutaneous tissue, and muscle fascia at each of the three laparoscopic ports.

### 2.4 M-TAPA protocol

The same anesthesiologist (author EE, possessing over 10 years of experience in regional anesthesia) utilized ultrasound guidance (Sonosite, Inc., Bothell, WA, USA) to perform bilateral M-TAPA at the end of the surgery before extubation. Using a high-frequency linear probe (6–13 MHz), designated as HFL38, the external oblique muscle (EOM), internal oblique muscle (IOM) and transversus abdominis muscle (TAM) were visualized along the costochondral angle in the sagittal plane at the 10th costal margin (Fig. 1). At two sites bilaterally, situated in the midclavicular line at the level of the 10th rib (arcus costarum), 0.25 mL/kg of 0.25% bupivacaine (with a maximum dose of 2 mg/kg) was administered between the upper fascia of the transversus abdominis muscle and the lower fascia of the costochondral tissue (Fig. 2).

### 2.5 Pain assessment using NRS

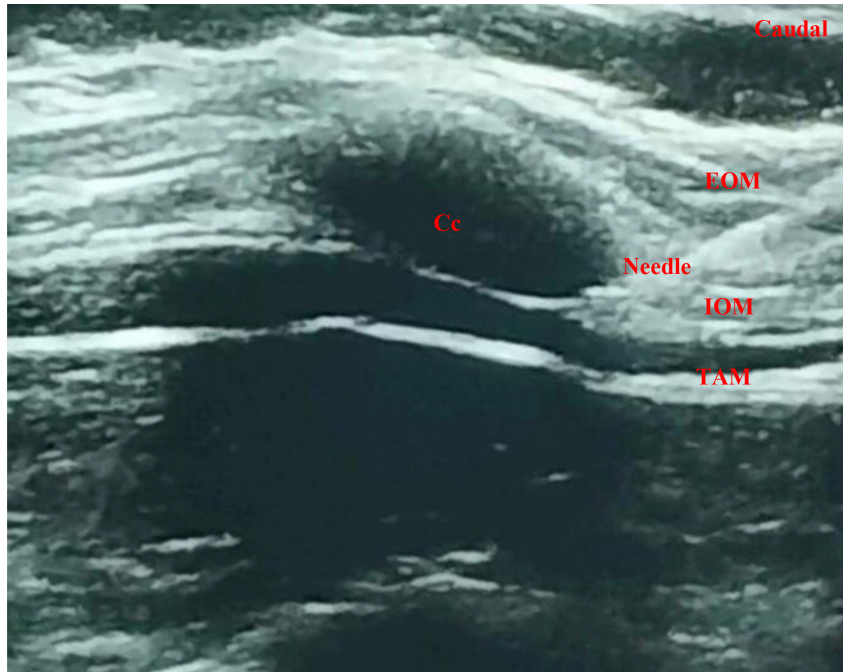
Pain assessment utilized NRS, which ranges from 0 (indicating no pain) to 10 (representing the worst imaginable pain), as all our patients were 8 years old and fully cooperative [9].

### 2.6 Parent satisfaction assessment (5-point Likert scale)

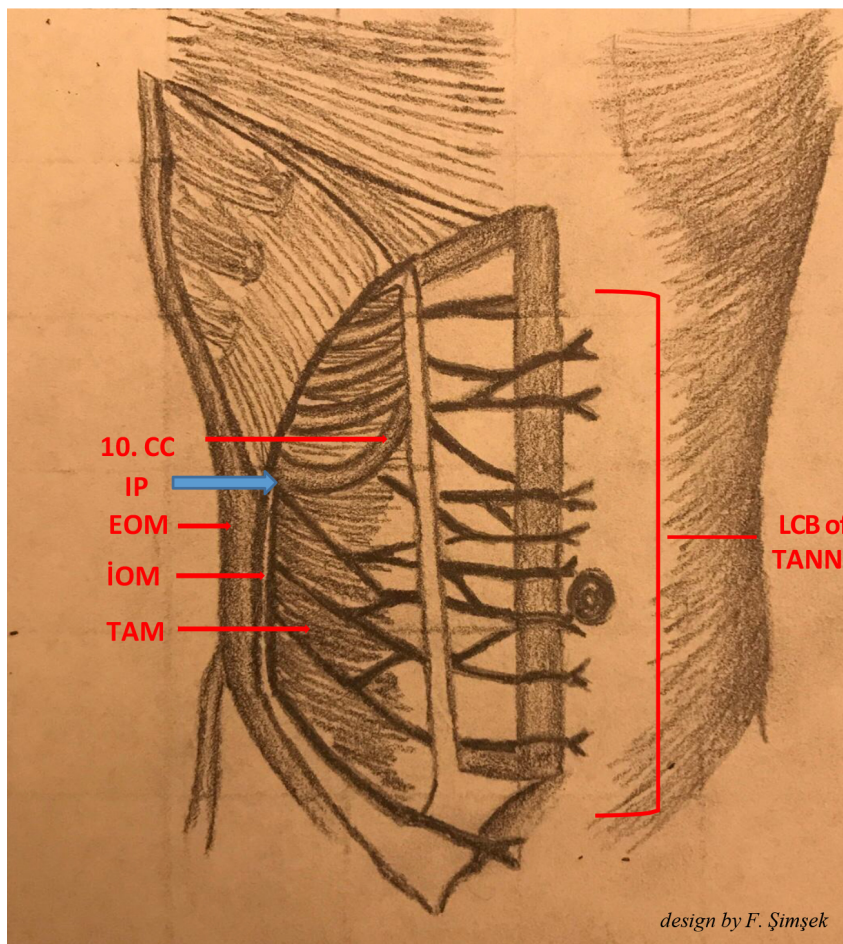
A 5-point Likert scale was used to evaluate family satisfaction, where a score of 5 denoted “very satisfied” and a score of 1 indicated “very dissatisfied” [10], which was obtained by self-assessment at the clinic 12 hours after the surgery.

### 2.7 Study outcomes

The primary outcome measure was the NRS pain score assessed at 6 hours postoperatively. Secondary outcomes included NRS pain scores at additional time intervals, the requirement for rescue analgesia (yes/no), the time elapsed until the initial request for rescue analgesia (hours), incidence of postoperative complications such as nausea, vomiting, and shoulder tip pain, as well as measurements of parent satisfaction utilizing a 5-item Likert satisfaction scale during the postoperative period. All assessments were conducted within a 24-hour window following surgery. Outcome evaluations were performed upon admission to the post-anesthesia care unit (PACU) and subsequently at 1, 4, 6, 12 and 24 hours postoperatively by an investigator blinded to group allocation. Patients with an NRS score equal to or greater than 4 were administered intravenous (IV) paracetamol at a dosage of 15 mg/kg. In instances of nausea and vomiting, IV ondansetron was administered as a rescue antiemetic at a dosage of 0.1 mg/kg.



**FIGURE 1. M-TAPA block; Reverse ultrasound anatomy.** Cc: Costal Cartilage; EOM: External Oblique Muscle; IOM: Internal Oblique Muscle; TAM: Transversus Abdominis Muscle.



**FIGURE 2. Anterior abdominal wall anatomy and innervation.** IP: injection point; LCB of TANN: lateral cutaneous branches of thoracoabdominal nerves; CC: Costal Cartilage; EOM: External Oblique Muscle; IOM: Internal Oblique Muscle; TAM: Transversus Abdominis Muscle.

## 2.8 Statistical analysis

Sample size calculation was performed using G\*Power (version 3.1.9.6, HHU, Düsseldorf, Germany) [11]. A preliminary study comprising 10 patients at our clinic was used for the power analysis, focusing on the NRS at 6 hours postoperatively, which is the primary outcome of this study. A reduction of two points in the mean NRS pain score was considered clinically significant. The preliminary investigation revealed a mean of 3.4 points and a standard deviation (SD) of 2.5. To achieve statistical significance at an  $\alpha$  error of 0.05 (two-tailed) with a power of 0.85, each group was required to include a minimum of 30 patients. Thus, 32 patients were included in each group to accommodate potential patient dropouts.

The normal distribution of continuous measurements in the study was assessed using the Shapiro-Wilk test (for  $n < 50$ ) and skewness-kurtosis tests. Descriptive statistics were presented as frequencies (%) for categorical data and as mean  $\pm$  SD or median (Q1–Q3) for normally or non-normally distributed continuous data, as appropriate. Differences between groups for normally or non-normally distributed continuous data were determined using the “Independent *t*-test” or “Mann Whitney U test”, respectively. The frequency distribution of categorical variables between groups was analyzed using the chi-square test. Statistical significance was set at  $p < 0.05$ , and analysis was performed using the SPSS statistical package program (ver. 26; IBM Corp., Armonk, NY, USA).

## 3. Results

Seventy-three patients were screened for eligibility between June 2023 and December 2023. Three patients did not meet the inclusion criteria, and 6 declined to participate in the study. After obtaining informed consent, 64 patients were randomized. However, the surgical approach was changed from laparoscopic to open appendectomy for 2 patients, and perforated appendicitis was detected intraoperatively in another 2 patients. Consequently, the final study cohort comprised 60 patients who did not experience any adverse events or complications. The study flow diagram is shown in Fig. 3.

Among these 60 participants, 65% ( $n = 39$ ) were males, 35% ( $n = 21$ ) were females, and 5% ( $n = 3$ ) of the entire cohort had systemic diseases. The mean age, weight, and height were  $12.96 \pm 3.04$  years,  $49.38 \pm 15.24$  kg, and  $155.67 \pm 12.85$  cm, respectively. The average duration of anesthesia and surgery were  $64.98 \pm 13.15$  and  $54.02 \pm 13.31$  minutes, respectively. Baseline characteristics did not significantly differ between the groups (Table 1).

Table 2 presents a comparison of the NRS scores between the groups. Except for 24 hours post laparoscopic appendectomy, the NRS scores were significantly lower in the M-TAPA group compared to the LAI group (Fig. 4). Specifically, the NRS scores at the 6th postoperative hour was  $2.30 \pm 1.49$  in the LAI group and  $1.10 \pm 1.35$  in the M-TAPA group ( $p = 0.002$ ).

Furthermore, 33.3% ( $n = 20$ ) of all patients required rescue analgesics, with a higher percentage observed in the LA infiltration group compared to the M-TAPA group (53.3%,  $n = 16$  vs. 13.3%,  $n = 4$ ) ( $p = 0.001$ ) (Table 3). The time to the first

request for rescue analgesics was similar between the groups. No complications were associated with the block procedure, including IV injection, bleeding, or local anesthetic toxicity. Postoperative complications, including nausea, vomiting and shoulder pain, were more frequent in the LAI group compared to the M-TAPA group (53.3%,  $n = 16$  vs. 33.3%,  $n = 10$ ); however, no statistically significant difference was observed between the groups ( $p = 0.118$ ).

A statistically significant difference was observed between the groups in favor of the M-TAPA group in regard to postoperative parental satisfaction levels, as evaluated using a 5-point Likert satisfaction scale ( $p = 0.040$ ). The combined rate of “very satisfied” and “satisfied” parents was 38.3% ( $n = 23$ ) for all patients, 56.7% ( $n = 17$ ) for the M-TAPA group, and 20% ( $n = 6$ ) for the LAI group. Conversely, the combined rate of “dissatisfied” and “very dissatisfied” was 40% ( $n = 24$ ) for all patients (Table 4).

## 4. Discussion

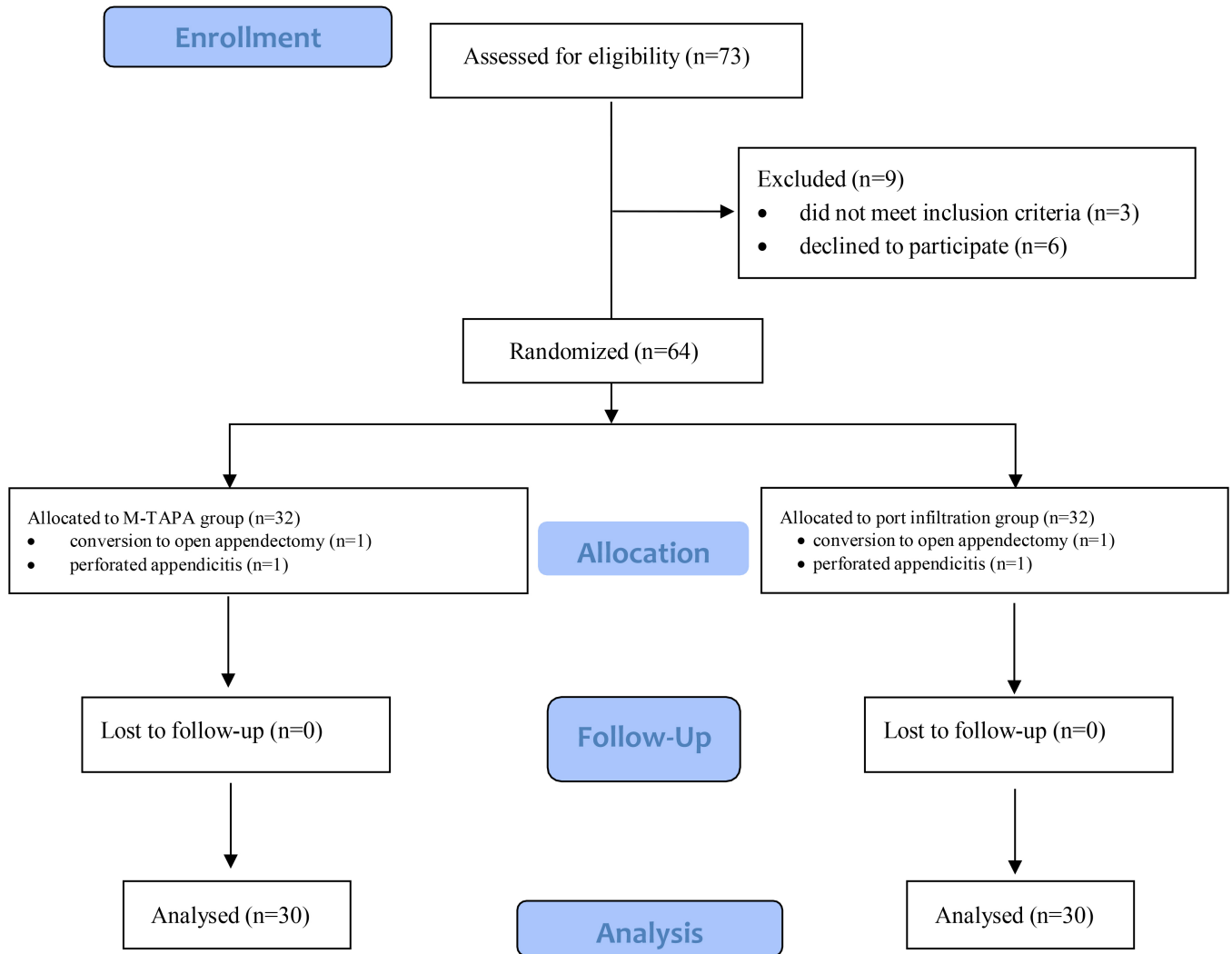
In this study, we conducted a comparative study between ultrasound-guided bilateral M-TAPA and LAI at port entry sites for postoperative analgesia in pediatric laparoscopic appendectomies, and the findings indicated that M-TAPA was more effective in providing postoperative analgesia than LAI and positively influenced family satisfaction.

Despite being minimally invasive, laparoscopic appendectomy often leads to significant postoperative pain. This pain results from surgical manipulation and intraperitoneal carbon dioxide insufflation, which causes diaphragmatic irritation, peritoneal stretching, and shoulder pain due to retained insufflation gas in the abdominal cavity after surgery [5]. Effective analgesia is essential for enhancing patient comfort and family satisfaction [5, 12].

Apart from systemic administration of intravenous paracetamol, nonsteroidal anti-inflammatory drugs, and opioids, local anesthetic infiltration into port entry sites and regional analgesia techniques such as transversus abdominis plane block and rectus sheath block have become increasingly utilized in recent years [3–5]. Despite the well-known side effects of opioids, including respiratory depression, nausea, vomiting and prolonged hospital stay, they continue to be widely used for pain management [12, 13]. Incorporating regional analgesic techniques into a multimodal approach helps to reduce opioid consumption in minimally invasive surgeries.

Interfacial plane blocks such as rectus sheath block and transversus abdominis plane block have started to be performed in pediatric patients [1, 3, 5]. Hamill *et al.* [14] demonstrated that rectus sheath block provided superior analgesia compared to LAI in laparoscopic appendectomies in children, particularly within the first 3 hours postoperatively. Similarly, Nagappa *et al.* [3] found that the postoperative analgesic efficacy of transversus abdominis plane block surpassed that of caudal block for laparoscopic appendectomies in children.

Recent studies have shown that M-TAPA is effective for postoperative analgesia in adults undergoing laparoscopic cholecystectomy [6, 7]. Anatomically, the anterolateral abdominal wall is innervated by the anterior branches of the T7–L1 nerves [15, 16]. M-TAPA has been demonstrated



**FIGURE 3. Flow chart of patients selection.** M-TAPA: modified thoracoabdominal nerve block through perichondrial approach.

**TABLE 1. Comparison of baseline characteristics between the groups.**

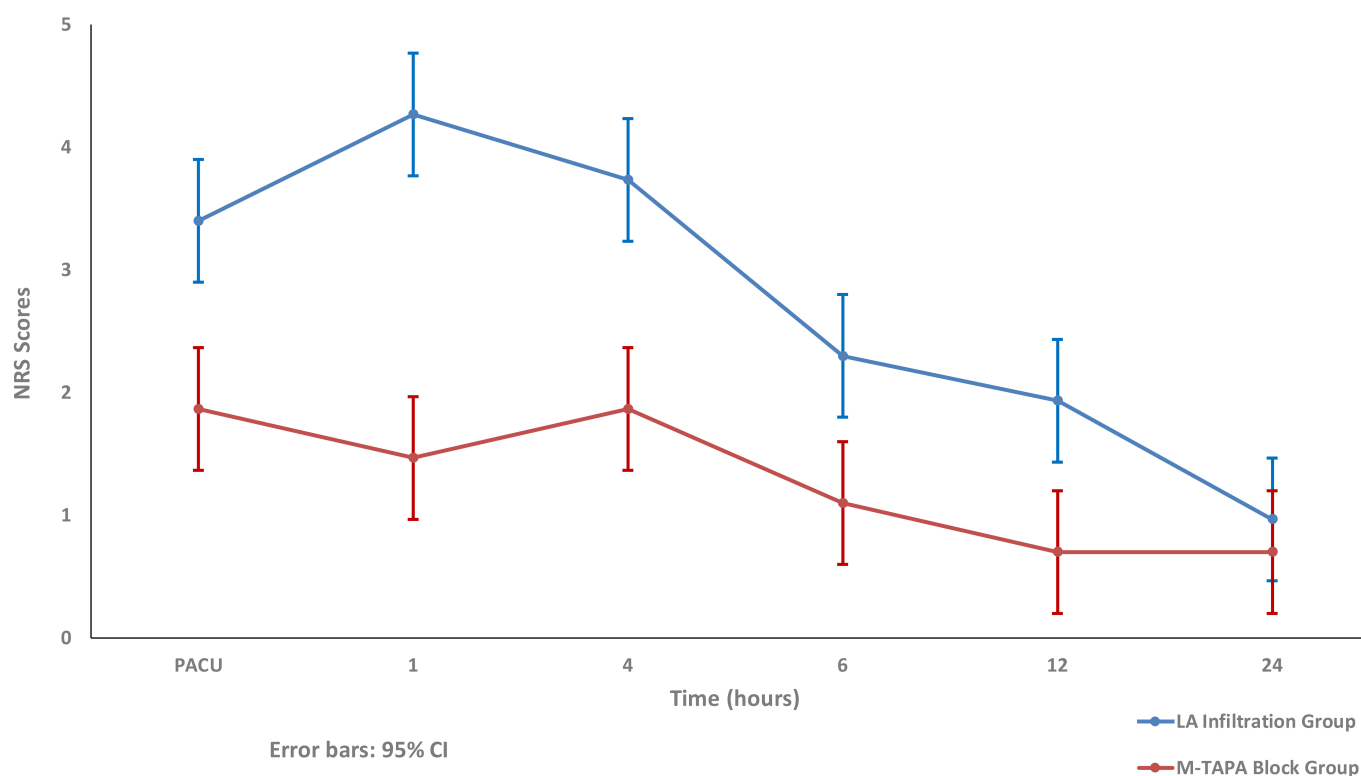
Variable	LA Infiltration Group (n = 30)	M-TAPA Group (n = 30)	p-Value
Age, yr	12.70 ± 2.97	13.23 ± 3.14	0.502*
Weight, kg	46.10 ± 13.54	52.67 ± 16.35	0.096*
Height, cm	153.23 ± 11.29	158.10 ± 14.01	0.144*
BMI, kg/m <sup>2</sup>	19.25 ± 3.91	20.68 ± 4.31	0.184*
Duration of anesthesia, min	63.63 ± 14.54	66.33 ± 11.69	0.431*
Duration of surgery, min	55.10 ± 14.54	52.93 ± 12.10	0.533*
ASA class, N (%)			
I	28 (49.1)	29 (50.9)	0.554 <sup>†</sup>
II	2 (66.7)	1 (33.3)	
Gender, N (%)			
Male	19 (48.7)	20 (51.3)	0.787 <sup>†</sup>
Female	11 (52.4)	10 (47.6)	

Data are presented as mean ± SD and frequency (%). \*Independent two sample t-test, <sup>†</sup>Chi-squared test. Abbreviations: LA: local anesthetic; M-TAPA: modified thoracoabdominal nerves block through perichondrial approach; BMI: body mass index; ASA: American Society of Anesthesiologists.

**TABLE 2. Comparison of pain (NRS) scores between the groups.**

Variable	LA Infiltration Group (n = 30)	M-TAPA Group (n = 30)	p-Value*
PACU NRS	3.40 ± 2.36	1.87 ± 1.68	0.010
1st hour NRS	4.27 ± 2.29	1.47 ± 1.41	<0.001
4th hour NRS	3.73 ± 1.95	1.87 ± 2.08	0.001
6th hour NRS	2.30 ± 1.49	1.10 ± 1.35	0.002
12th hour NRS	1.93 ± 1.39	0.70 ± 0.65	<0.001
24th hour NRS	0.97 ± 0.96	0.70 ± 0.99	0.202

Data are presented as mean ± SD. \*Independent two sample t-test. Abbreviations: LA: local anesthetic; M-TAPA: modified thoracoabdominal nerves block through perichondrial approach; PACU: postanesthesia care unit; NRS: Numeric rating scale.



**FIGURE 4. Error bars for NRS score.** NRS: Numeric rating scale; LA: local anesthetic; M-TAPA: modified thoracoabdominal nerve block through perichondrial approach; CI: Confidence Intervals.

to block the anterior and lateral cutaneous branches of the T6–T12/L1 thoracoabdominal nerves, providing effective analgesia [15, 17]. The intercostal nerves traverse beneath the costal cartilage and connect to the origin of the transversus abdominis muscle, and LA is injected just below the costal cartilage, deep into the origin of the transversus abdominis muscle for M-TAPA [17, 18].

Considering the anatomical aspects of trocar insertions in pediatric laparoscopic appendectomy, M-TAPA may offer comparable postoperative analgesia. Despite our literature search yielding no controlled studies on M-TAPA in pediatric patients, case reports have shown promising outcomes. For instance, Ozen *et al.* [19] successfully applied M-TAPA to an 8-year-old undergoing laparoscopic cholecystectomy, resulting in effective analgesia as assessed by the Face, Legs, Activity, Cry, Consolability (FLACC) scale 24 hours

postoperatively, without the need for additional analgesics. Similarly, Kumar *et al.* [20] employed M-TAPA via a subcostal incision in a 10-year-old undergoing splenectomy, with the highest visual analog scale score being three at 24 hours postoperatively. Our study further supports these findings by demonstrating that M-TAPA provided effective analgesia and reduced the requirement for postoperative rescue analgesics, consistent with the observations in case reports.

Potential complications of M-TAPA include vascular injury, abdominal wall hematoma, LA toxicity, and lung injury [7, 19]. However, performing M-TAPA under ultrasound guidance by experienced practitioners minimizes these risks, and no complications related to M-TAPA were encountered in our study.

**TABLE 3. Postoperative analgesic and complication outcomes between the groups.**

Variable	LA Infiltration Group (n = 30)	M-TAPA Group (n = 30)	p-Value
Rescue analgesia requirement, N (%)			
Yes	16 (53.3)	4 (13.3)	0.001 <sup>†</sup>
No	14 (46.7)	26 (86.7)	
Time to first request for rescue analgesic (h), median (Q1–Q3)	1.00 (1.00–2.50)	1.00 (1.00–2.50)	0.289 <sup>††</sup>
Postoperative Complications, N (%)			
Nausea/vomiting, N (%)			
Yes	11 (36.7)	5 (16.7)	0.080 <sup>†</sup>
No	19 (63.3)	25 (83.3)	
Shoulder tip pain, N (%)			
Yes	9 (30.0)	5 (16.7)	0.222 <sup>†</sup>
No	21 (70.0)	25 (83.3)	

Data are presented as frequency (%) and median (Q1–Q3). <sup>†</sup>Chi-squared test; <sup>††</sup>Mann Whitney U-test. Abbreviations: LA: local anesthetic; M-TAPA: modified thoracoabdominal nerves block through perichondrial approach.

**TABLE 4. Postoperative parental satisfaction levels between the groups.**

Variable	LA Infiltration Group (n = 30)	M-TAPA Group (n = 30)	p-Value <sup>†</sup>
5-point Likert satisfaction scale, N (%)			
Very satisfied	1 (3.3)	6 (20.0)	0.040 <sup>†</sup>
Satisfied	5 (16.7)	11 (36.7)	
Neutral	9 (30.0)	4 (13.3)	
Dissatisfied	11 (36.7)	5 (16.7)	
Very dissatisfied	4 (13.3)	4 (13.3)	

Data are presented as frequency (%). <sup>†</sup>Chi-squared test. Abbreviations: LA: local anesthetic; M-TAPA: modified thoracoabdominal nerves block through perichondrial approach.

### 5. Limitations

Our study encountered several limitations. Firstly, achieving objectively similar rates of blockage in all patients using current methods was challenging due to variations in practitioner skill and patient diversity. Secondly, the total volume of local anesthetic was restricted to 30 mL for both sides, suggesting the need for further investigation into different volumes and doses. Additionally, more studies are warranted to assess the effectiveness of M-TAPA in various anterior abdominal wall surgeries in pediatric patients. Lastly, our study did not evaluate the duration of hospital stay.

### 6. Conclusions

This study compared port-site LAI with ultrasound-guided M-TAPA in pediatric laparoscopic appendectomy, revealing a significant decrease in postoperative pain scores and rescue analgesic demands, which was associated with a high level of patient and family satisfaction. Notably, this present study is the only randomized controlled trial conducted on M-TAPA in pediatric patients. Moving forward, it is essential to investigate the application of M-TAPA in other pediatric abdominal surgeries. Additionally, further research is warranted to determine

its effectiveness in open pediatric surgical procedures.

### AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

### AUTHOR CONTRIBUTIONS

EE—created the methodology, conceptualized, and supervised the study. GBB and UK—provided resources and visualization. FS—took part in investigation. HEA and SFK—provided data curation. EE and YO—administered the project. GBB and FS—wrote the original draft. EE, UK and FS—reviewed and edited the original draft.

### ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The ethical approval of this study was authorized by the Gulhane Training and Research Hospital, University of Health Sciences Medical Research Assessment Committee with

the decision number 2023/75 on 12 April 2023. The study was registered at Clinical Trials (Trial registration number NCT06039150). Written informed consent was obtained from all patients before study inclusion.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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