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Research Article

The effectiveness of M-TAPA on pain management and quality of recovery after cesarean section: A prospective randomized controlled study

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ABSTRACT

Objective: Moderate-to-severe pain is a common complaint after cesarean section (C/S) and may adversely affect the recovery and well-being of both the mother and the newborn. This prospective randomized controlled trial aimed to determine whether ultrasound-guided modified thoracoabdominal nerve block via the perichondral approach (M-TAPA) improves postoperative analgesia and quality of recovery after cesarean section.

Methods: This single-center study included pregnant women scheduled for elective cesarean section, beyond the 37th week of gestation, with American Society of Anesthesiologists (ASA) physical status II. Participants were randomly allocated to the M-TAPA group or the control group. Postoperative pain was assessed using the numeric rating scale (NRS), and quality of recovery was assessed using the 15-item Quality of Recovery Scale (QoR-15). Primary and secondary outcomes were statistically compared between groups.

Results: Patients who received M-TAPA showed significantly lower pain scores than the control group at rest and with movement at postoperative hours 2, 4, 8, and 16 ($p < 0.05$); however, NRS values at postoperative hour 24 were similar between groups. Opioid consumption was similarly reduced, and QoR-15 scores were higher in the M-TAPA arm compared with the control group ($p = 0.001$).

Conclusion: M-TAPA provides effective analgesic management after cesarean section. M-TAPA is important for supporting recovery and reducing opioid requirements, thereby improving outcomes in women undergoing cesarean section.

Trial Registration: The study was registered at ClinicalTrials.gov (ID: NCT06078475).

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1. Introduction

Cesarean section (C/S) is one of the most common delivery methods worldwide. Approximately one fifth of all births worldwide are performed in this way [1]. A substantial proportion of women experience moderate-to-severe pain after the procedure. This pain prolongs the recovery process and delays the mother's return to daily activities. It may also weaken mother-infant bonding,

complicate breastfeeding, and adversely affect the mother's psychological state [2,3].

Acute pain after surgery develops in response to operative tissue damage and the accompanying inflammatory process, gradually diminishing as tissues heal. When this pain is inadequately treated, the likelihood of hyperalgesia and persistent pain increases [4]. Effective perioperative care therefore relies on a patient-specific multimodal plan [5]. Such regimens typically combine

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opioids with nonsteroidal anti-inflammatory drugs. However, opioids whether administered systemically or neuraxially can cause undesirable effects even at standard doses, including respiratory depression, nausea, vomiting, sedation, pruritus, and opioid-induced hyperalgesia. Various alternative approaches, including interfascial plane blocks, have been adopted to reduce these opioid-related complications.

The perichondral approach to thoracoabdominal nerve block (TAPA), a relatively new interfascial plane technique, produces analgesic coverage over the anterolateral thoracoabdominal wall corresponding to the T5–T12 dermatomal distribution [6]. It was later adapted into a single-injection form and termed M-TAPA; this method has been found effective in numerous minor and major surgeries [7–11]. However, to date no randomized trial has evaluated the efficacy of M-TAPA in postoperative pain control after cesarean section.

Strategies aimed at improving postoperative recovery generally focus on alleviating pain, encouraging early oral intake and mobilization, minimizing complications, and shortening hospital stay. Their effectiveness has traditionally been assessed using concrete clinical outcomes, particularly complication rates and length of hospital stay. However, these metrics do not reflect how patients personally perceive their recovery or experience changes in their well-being. As a result, valid, reliable, patient-centered tools for assessing recovery have become necessary. The Quality of Recovery-15 (QoR-15) questionnaire offers a concise and practical way of capturing recovery from the patient's own perspective. With robust psychometric properties such as strong internal consistency, split-half reliability, and test-retest reproducibility, it serves as a dependable tool that allows clinicians to identify clinically relevant changes in recovery status. These properties have made QoR-15 a sensitive and evaluative endpoint applicable in both routine practice and research studies. Because it takes only about four minutes to complete, this tool encourages patient cooperation and consistently achieves high response and completion rates. Its widespread adoption among patients and practitioners across various healthcare settings further reinforces its real-world usefulness. Scores are consistently lower in patients who develop complications, show an inverse relationship with operative time and length of hospital stay, and have been documented to correlate positively with the patient's own global VAS rating of recovery [12].

The aim of this study was to examine the analgesic performance of ultrasound-guided M-TAPA after cesarean section. Compared with standard care, we hypothesized that ultrasound-guided M-TAPA would reduce postoperative pain scores and opioid consumption and improve quality of recovery after cesarean section. The primary endpoint was the comparison of QoR-15 scores between the M-TAPA and control groups at postoperative hour 24, which served as the time point underlying the sample size calculation. Secondary endpoints were postoperative pain scores at rest and with movement, postoperative opioid consumption, and opioid-related side effects.

2. Materials and Methods

2.1. Study design, ethical approval and setting

The present prospective randomized controlled trial was carried out at a single institution following the ethical standards outlined in the Declaration of Helsinki. Prior to enrollment, each participant received a detailed explanation of the study protocol and provided written informed consent. The trial received ethical clearance from the Ethics Committee of the University of Health Sciences Bursa City Hospital (approval no. 2022-10/13) as well as from the Turkish Medicines and Medical Devices Agency (23-AKD-154). The trial was registered on the ClinicalTrials.gov platform (identifier: NCT06078475; first posted: October 11, 2023).

Eligible participants were ASA II pregnant women scheduled for elective cesarean section beyond the 37th week of gestation. Women who were using anticoagulants, had a bleeding diathesis, had allergy or hypersensitivity to local anesthetics or opioids, had infection at the injection site, reported alcohol or substance dependence, required general anesthesia, or declined to participate were excluded. The remaining patients were assigned to one of two groups: the M-TAPA Group (receiving M-TAPA) or the Control Group, using a computer program.

Before being taken to the operating room, venous access was established with an 18 G cannula. Electrocardiography, non-invasive arterial blood pressure, and peripheral oxygen saturation were monitored throughout surgery. For the spinal block, each woman was placed in a sitting position; after appropriate aseptic and antiseptic preparation, a 26-gauge pencil-point spinal needle (B. Braun, Melsungen, Germany) was advanced into the subarachnoid space via a midline approach at the L3-4 or L4-5 interspace. After free, clear cerebrospinal fluid was observed, 12.5 mg hyperbaric bupivacaine was administered. The block level was confirmed with the pinprick test, and surgery began once an adequate block was achieved.

Once surgery had ended, women allocated to the M-TAPA group were positioned supine for block application. Following skin preparation with an aseptic technique, ultrasound visualization was performed with a high-frequency linear transducer (GE ML6-15-D Matrix Linear, Boston, USA), and an 80 mm block needle (Stimuplex Ultra®, Braun, Melsungen, Germany) was used for injection. The transducer was oriented in the sagittal plane at the intersection of the midclavicular line with the costal cartilage. The lower costochondral angle was then identified sonographically, and under in-plane needle guidance the needle trajectory was directed from caudal to cranial (Fig. 1). Correct needle-tip location was verified by observing appropriate saline hydrodissection, after which 20 mL of 0.25% bupivacaine was deposited on each side, yielding a cumulative volume of 40 mL.

For safety, the needle tip and local anesthetic spread were continuously monitored in real time under ultrasound guidance; negative aspiration was confirmed before each injection to avoid intravascular administration, and the drug was injected incrementally in 5 mL aliquots. The total bupivacaine dose (100 mg, approxi-

mately 1.3-1.5 mg/kg) remained below the maximum safe single-dose threshold widely accepted in the obstet-

ric population; no evidence of local anesthetic systemic toxicity was observed in any patient.

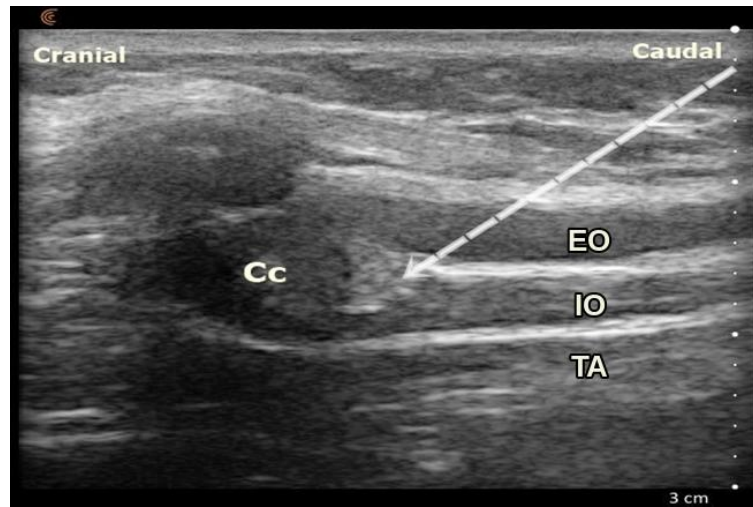


Fig. 1. Sonographic anatomy of the M-TAPA block. Arrows indicate the needle direction. Cc: costal cartilage; EO: external oblique; IO: internal oblique; TA: transversus abdominis.

2.2. Perioperative analgesia management, postoperative analgesia protocol, and pain measurement

After surgery, all participants in both the M-TAPA and Control groups routinely received 1000 mg paracetamol three times daily. Local wound infiltration was not performed by the surgical team in either group. Postoperative assessment was performed by an anesthesiologist who was not involved in the study intervention and was blinded to group allocation; however, because no sham block was performed in the control group, patients and the bedside clinical care team were not blinded to group allocation; this should be considered when interpreting subjective endpoints such as pain scores and QoR-15 results.

Postoperative pain was assessed using a 10 cm numeric rating scale (NRS) ranging from 0 (no pain) to 10 (worst pain imaginable). Both resting (passive) and movement-related (active) scores were recorded at hours 0, 2, 4, 8, 16, and 24. Active NRS assessment was performed during the patient's in-bed movement (coughing or changing position) at hours 0, 2, and 4, and during mobilization at the other time points. When a patient's NRS value was ≥ 4 , intravenous meperidine 0.5 mg/kg was administered as rescue analgesia. Analgesic agents used during the postoperative period, total opioid requirement, and side effects such as nausea, vomiting, and pruritus were recorded.

2.3. Assessment of quality of recovery

Relying exclusively on pain intensity and opioid requirements yields only a partial view of how a patient truly progresses after surgery. To overcome this shortcoming, the QoR-15, a 15-item instrument evaluating five distinct domains, namely pain, physical comfort, physical independence, psychological support, and emotional state, was developed as a concise, dependable, and clinically feasible measure of postoperative recovery [13,14]. For the purposes of the current study, recovery

quality was quantified using the linguistically validated Turkish adaptation of this scale [15].

2.4. Sample size and statistical analyses

The required sample size was derived from a pilot study of 12 individuals. In this pilot study, the mean 24-hour QoR-15 score was 125.67 ± 22.35 in the M-TAPA group and 110.83 ± 13.35 in the control group. Based on these data, 52 patients were required to achieve two-sided $\alpha = 0.05$, a large effect size (0.8), and 80% power. To account for a possible 15% dropout rate, enrollment of 60 patients was planned. The 24-hour QoR-15 score was chosen as both the primary endpoint and the basis for the power calculation, because it is a composite endpoint reflecting the overall analgesic and functional benefit of the block; the 24-hour NRS score was used as a secondary endpoint for between-group comparison of pain intensity.

All statistical analyses were performed using SPSS Statistics for Windows (Version 29.0, IBM Corp., Armonk, NY, USA, 2022). Normality of distribution was examined using the Kolmogorov-Smirnov test. Depending on whether the data followed a normal distribution, continuous variables were compared using Student's t-test or the Mann-Whitney U test, and categorical variables were compared using Pearson's chi-square test or Fisher's exact test, as appropriate. Results are presented as median and 25th-75th percentile, mean and standard deviation (SD), or number and percentage, with $p < 0.05$ considered statistically significant.

3. Results

Patient enrollment and group allocation are summarized in the CONSORT flow diagram (Fig. 2). Sixty patients were enrolled and equally assigned to the M-TAPA group ($n = 30$) and the control group ($n = 30$); all randomized patients completed the study per protocol and were included in the analysis.

CONSORT Flow Diagram

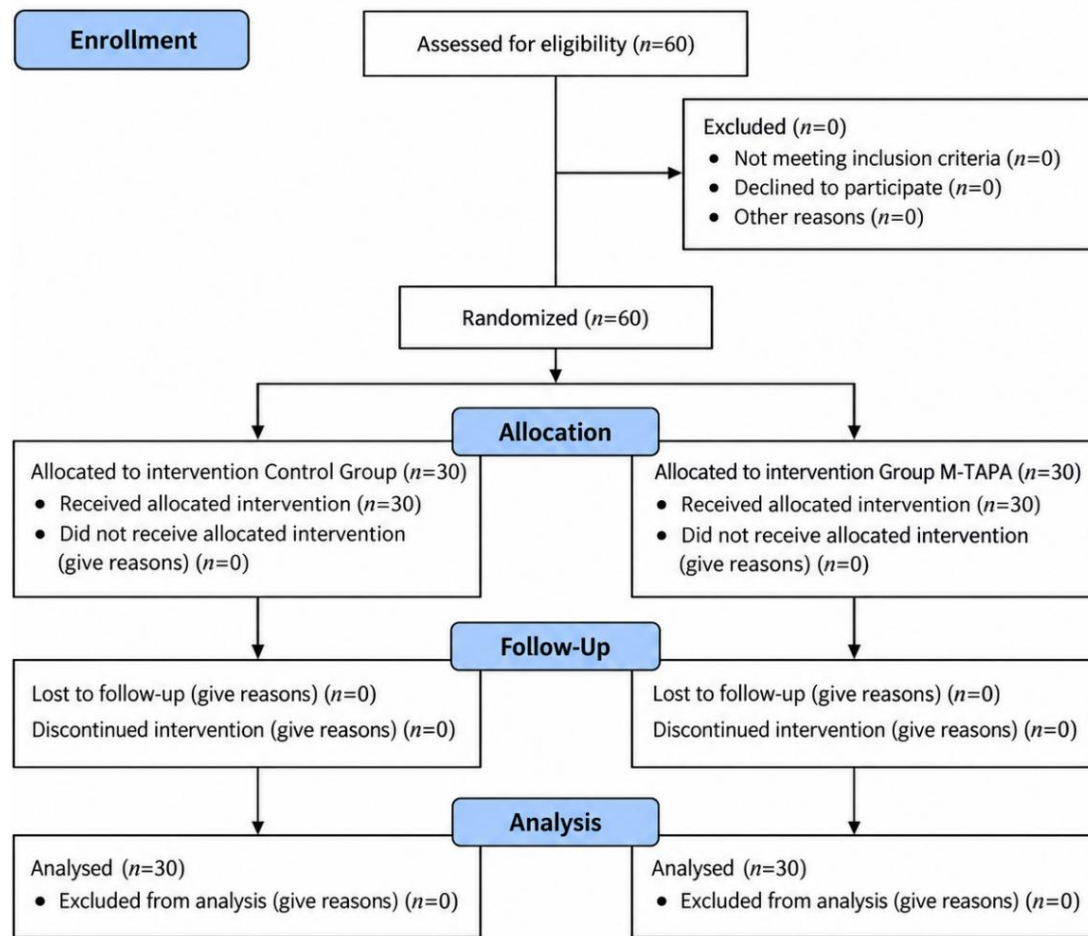


Fig. 2. Study flow diagram.

No statistically significant difference was found between the two groups in age ($p = 0.521$), height ($p = 0.167$), weight ($p = 0.098$), duration of surgery ($p = 0.052$), or duration of anesthesia ($p = 0.075$) (Table 1).

QoR-15 scores measured at postoperative hour 24 were significantly higher in the M-TAPA group than in the control group [128.5 [113.0-136.3] vs. 109.5 [98.0-127.0], $p = 0.001$). When the five subdomains of the QoR-15 scale (pain, physical comfort, physical independence, psychological support, and emotional state) were evaluated together, patients in the M-TAPA group showed a markedly more positive overall perception of recovery compared with the control group. This difference was consistent not only with the reduction in pain scores but also with the overall improvement in patients' physical

and emotional well-being (Table 2).

The need for rescue analgesia ($p = 0.020$) and total meperidine dose ($p = 0.001$) were significantly lower in the M-TAPA group than in the control group (Table 2).

In the M-TAPA group, pain scores measured both at rest and with movement were significantly lower than in the control group at hours 2, 4, 8, and 16 (at rest, respectively $p = 0.002$; $p = 0.003$; $p = 0.003$; $p = 0.024$; with movement, respectively $p = 0.001$; $p < 0.001$; $p < 0.001$; $p = 0.008$). No significant difference between groups was found at hours 0 and 24 (at rest, $p = 0.682$ and $p = 0.349$; with movement, $p = 0.096$ and $p = 0.258$) (Table 3).

The frequency of nausea ($p = 0.766$) and vomiting ($p = 0.612$) were similar between groups, and no patient experienced pruritus (Table 4).

Table 1. Comparison of demographic data and surgical procedures between groups.

	M-TAPA (n = 30)	Control (n = 30)	p value
Age	30.0±5.4	29.1±5.4	0.521
Height (cm)	166.0±5.2	164.0±5.9	0.167
Weight (kg)	78.4±8.5	82.5±10.2	0.098
Duration of surgery (min)	52.4±12.3	59.3±14.5	0.052
Duration of anesthesia (min)	63.6±13.3	70.3±15.3	0.075

Values are expressed as mean ± standard deviation or number. kg: kilogram, cm: centimeter, ASA: American Society of Anesthesiologists, mcg: microgram, min: minute.

Table 2. Comparison of QoR-15 and rescue analgesia between groups.

	M-TAPA (n = 30)	Control (n = 30)	p value
Need for rescue analgesia (+); n (%)	21 (70.0)	28 (93.3)	0.020
Rescue analgesic dose (mg); med (25-75P)	40.0 (0.0 - 60.0)	90.0 (50.0 - 100.0)	0.001
QoR-15; med (25-75P)	128.5 (113.0 - 136.3)	109.5 (98.0 - 127.0)	0.001

Values are expressed as median (interquartile range).

Table 3. Comparison of active and passive NRS assessments between groups.

At rest				With movement			
Hour	M-TAPA (n = 30)	Control (n = 30)	p value	Hour	M-TAPA (n = 30)	Control (n = 30)	p value
0	0.0 (0.0 - 1.0)	0.0 (0.0 - 1.3)	0.682	0	0.0 (0.0 - 0.0)	0.0 (0.0 - 1.0)	0.096
2	3.0 (2.0 - 4.0)	4.5 (3.8 - 7.0)	0.002	2	4.0 (3.0 - 5.0)	6.0 (5.0 - 7.3)	0.001
4	3.0 (2.3 - 4.0)	4.0 (3.0 - 5.0)	0.003	4	4.0 (3.8 - 5.0)	6.0 (5.0 - 7.3)	<0.001
8	3.0 (2.0 - 3.0)	4.0 (3.0 - 5.0)	0.003	8	4.0 (4.0 - 4.3)	5.0 (5.0 - 6.3)	<0.001
16	3.0 (1.0 - 3.0)	3.5 (2.0 - 4.0)	0.024	16	4.0 (3.0 - 4.0)	4.0 (3.0 - 5.0)	0.008
24	2.0 (1.0 - 3.0)	2.0 (1.0 - 3.0)	0.349	24	3.0 (2.0 - 3.3)	3.0 (2.0 - 4.0)	0.258

Data are expressed as median (25th-75th percentile). The symbol p is italicized. Note: NRS values recorded at postoperative hours 0 and 2 may have been affected by residual sensory-motor block from spinal anesthesia; these early time points should be interpreted with caution.

Table 4. Comparison of side-effect frequency between groups.

	M-TAPA (n = 30)	Control (n = 30)	p value
Nausea (+); n (%)	8 (26.7)	7 (23.3)	0.766
Vomiting (+); n (%)	1 (3.3)	3 (10.0)	0.612
Pruritus (+); n (%)	0 (0.0)	0 (0.0)	-

Values are expressed as number.

4. Discussion

According to our results, M-TAPA provided effective pain control after cesarean section: compared with the control group, women who received the M-TAPA block had lower pain scores, lower opioid requirements, and better quality of recovery.

Cesarean section is among the most commonly performed surgeries worldwide; in 2018, approximately 20% of deliveries worldwide were performed this way [1]. Data from our country for 2022 show that 60.1% of deliveries were performed by cesarean section [16]. Because women who undergo this procedure generally experience moderate-to-severe pain afterward, adequate analgesia is of great importance for both mother and infant in such a frequently performed surgery. When intrathecal opioids are not used, the Procedure-Specific Postoperative Pain Management (PROSPECT) group recommends the transversus abdominis plane (TAP) block; the literature also describes the effective use of quadratus lumborum (QL) and erector spinae plane (ESP) blocks for analgesia after cesarean section [17].

Each of these techniques has its own advantages and limitations. The classic TAP block is technically simple and widely known, but it primarily covers the T10-T12 dermatomes and may not reliably block the upper abdominal wall. The QL block can provide broader and more visceral coverage owing to posterior spread, but it

is technically more demanding and requires a needle trajectory close to the paraspinous space. The ESP block is easy to perform and has a favorable safety profile because of its distance from major vessels and the peritoneal cavity, but its analgesic mechanism and reliability of abdominal wall coverage remain debated. In contrast, M-TAPA is performed from a single, easily identifiable landmark, is technically reproducible, and, based on cadaveric spread data, may cover a broader craniocaudal dermatomal area (T4-T12) compared with a single-injection TAP block, which may reduce the number of injections needed for bilateral multidermatomal coverage. Considered together with the favorable analgesic and opioid-sparing results observed in the present study, these theoretical advantages suggest that M-TAPA may be a reasonable alternative within multimodal analgesia algorithms for cesarean section; however, direct comparative trials with TAP, QL, and ESP blocks are still needed to establish its comparative position.

M-TAPA, a newer interfascial plane technique described by Tulgar et al., has been reported to provide analgesia across the anterior and lateral abdominal wall along the T7-T11 dermatomes [6]. Cadaveric studies have shown dye spread between T4-T12 with both TAPA and M-TAPA [18]; broader staining over the transversus abdominis has been reported with the M-TAPA approach [19]. Another cadaveric study reported that M-TAPA injections adequately stained the T9-T11 segmental nerves [20].

The M-TAPA block is an interfascial plane block that targets the terminal branches of the thoracoabdominal intercostal nerves extending into the abdominal wall, achieved by applying local anesthetic adjacent to the inferior perichondrial surface of the costal cartilage. In this approach, local anesthetic spread is thought to progress craniocaudally along the costal margin, potentially affecting the anterior cutaneous branches and, more variably, the lateral cutaneous branches. Data in the literature on the dermatomal spread of the M-TAPA block are heterogeneous; cadaveric dye studies have reported that nerve branches can be stained over a wide craniocaudal area between T4-T12 after a single injection [18–20]. However, some publications suggest that the M-TAPA block may anatomically target the T4/T5-T12/L1 thoracoabdominal nerves, and thus that spread may extend to the L1 level [21]. Given these differences, the analgesic effect observed in the present study is difficult to explain by a single dermatomal mechanism alone. The analgesic benefit may plausibly arise from blockade of nerve branches at the T12 level contributing to the incision line, reduced somatic afferent transmission of adjacent thoracoabdominal nerves, and/or indirect modulation of visceral afferent input. However, since L1-derived innervation cannot be said to be consistently and predictably covered by the M-TAPA block, the analgesic contribution at this level should be considered variable.

Recent anatomical investigations attempt to offer a plausible explanation for the considerable inter-study variability in the reported dermatomal distribution of M-TAPA. Ohgoshi et al. delineated a previously undescribed fascial compartment situated adjacent to, yet anatomically discrete from, the M-TAPA plane, namely, the space bounded by the endothoracic fascia, diaphragm, and costodiaphragmatic recess (SEDIC), demonstrating through cadaveric dissection that costal cartilage or tendinous structures consistently separate this compartment from the M-TAPA plane. In their volunteer investigation, conventional M-TAPA injection yielded reliable anesthesia of the lateral cutaneous branches (LCBs) in only 3 of 10 participants, and even in these cases the block level extended only as far as T12; by contrast, direct deposition of local anesthetic within the SEDIC, a technique the authors designated re-modified TAPA (RM-TAPA), extended LCB coverage to T8–T12 in the majority of participants [22]. This anatomical demarcation provides a coherent explanation for the inconsistent lateral blockade reported in earlier M-TAPA literature, suggesting that dependable coverage of the LCBs requires the injectate to traverse this fascial or tendinous barrier and gain access to the SEDIC, a passage that does not occur reliably following conventional M-TAPA administration. On this basis, Murata has proposed that, in view of its distinct anatomical substrate, the SEDIC-targeted injection warrants recognition as a discrete, precisely designated technique, the "SEDIC block", rather than being subsumed under successive modifications of the TAPA nomenclature [23].

Clinical evidence on M-TAPA remains limited and is largely restricted to case reports. When the block was applied to 10 women undergoing gynecological surgery, anesthesia in the anterior cutaneous branch region lasted up to a median of 6.5 dermatomes at postopera-

tive hour 24 [24]. In a separate study, M-TAPA was found to reduce postoperative pain scores and significantly lower opioid use compared with the control group in patients undergoing laparoscopic cholecystectomy [25]. Opioid requirement after laparoscopic cholecystectomy has also been shown to be lower with M-TAPA compared with the oblique subcostal transversus abdominis plane block [26]. In a case report, a pediatric patient undergoing laparoscopic cholecystectomy required no postoperative analgesia after M-TAPA [27]. When applied to a patient undergoing sleeve gastrectomy, sensory block lasted up to 56 hours [8]. In another case series, unilateral volumes of 15 and 20 mL produced sensory block between T6–T12 [19].

In the present study, the M-TAPA block reduced both resting and movement-related pain scores in cesarean patients and reduced postoperative opioid requirement. The pain relief effect after cesarean section surgery lasted up to 16 hours. An improvement in the patients' quality of recovery was also observed.

Beyond statistical significance, these findings may carry clinically meaningful implications. Lower movement-related pain scores in the M-TAPA group are particularly important, because the primary barrier to early mobilization after cesarean section is not resting pain but movement-related pain. Better control of dynamic pain may facilitate earlier ambulation, more comfortable holding of the infant, positioning for breastfeeding, and closer mother-infant interaction in the early postpartum period, while the accompanying reduction in opioid consumption may also lower the risk of maternal sedation. Considered together with the improvement in QoR-15 scores, these results suggest that the benefit of M-TAPA extends beyond pain scores alone to functionally meaningful aspects of early postoperative recovery.

Some limitations should be noted. First, the study was conducted at a single center. Second, the sample size was not large enough to detect a difference in opioid-related side effects between the M-TAPA and control groups. Third, although the outcome assessor was blinded, because no sham block was performed in the control group, patients and the bedside clinical care team were not blinded to group allocation; this may have influenced subjective endpoints such as pain scores and QoR-15 results. Fourth, quality of recovery was not assessed preoperatively as a baseline value; this limits our ability to measure the change attributable to surgery and to the block itself, and should be incorporated into future protocols. Finally, this study did not assess long-term outcomes such as chronic postsurgical pain. Nevertheless, this is the first study to test the efficacy of M-TAPA in women undergoing cesarean section, and the findings need to be confirmed by larger, multicenter studies.

5. Conclusions

In conclusion, this prospective randomized controlled trial demonstrates that bilateral M-TAPA provides effective analgesia in women undergoing cesarean section. Compared with standard care, M-TAPA significantly reduced both resting and movement-related pain scores throughout the early postoperative period, lowered the

need for rescue analgesia and total opioid consumption, and was associated with markedly higher QoR-15 scores across the domains of pain, physical comfort, physical independence, psychological support, and emotional state. This reflects a more favorable overall recovery experience. Because the primary barrier to early mobilization after cesarean section is not pain at rest but pain with movement, the block's pronounced effect on dynamic pain may facilitate earlier ambulation, easier handling and positioning of the infant for breastfeeding, and closer mother-infant contact in the early postpartum period, while its opioid-sparing effect may further reduce the risk of maternal sedation. Taken together with the technique's reliance on a single, easily identifiable landmark and its technical reproducibility, these benefits support considering M-TAPA as a practical addition to multimodal analgesia protocols after cesarean section. Solely because of the limitations discussed above, the present findings should be regarded as an initial step rather than a definitive conclusion. Larger, multicenter randomized trials, preferably incorporating baseline recovery assessment and longer follow-up, are therefore needed to confirm these results and to clarify M-TAPA's position relative to established techniques such as the transversus abdominis plane, quadratus lumborum, and erector spinae plane blocks.

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Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

AI Assistance

During the preparation of this manuscript, ChatGPT was used exclusively for language editing and stylistic refinement. The authors take full responsibility for the content, interpretation, and conclusions of the published article.

Ethics Approval and Consent to Participate

This study was approved by Bursa City Hospital Ethics Committee (Approval Number: 2022-10/13; Date: 16.09.2022). Written informed consent was obtained from all participants. All procedures were conducted in accordance with relevant guidelines and regulations.

Author Contributions

Ahmet Kacıroglu: conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, validation, visualization, writing – original draft, writing – review and editing.

Mursel Ekinci: conceptualization, data curation, formal analysis, investigation, methodology, writing – original draft, writing – review and editing.

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