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Effectiveness of Transversus Abdominis Plane Block in Post-Cesarean Section Pain Management: randomized controlled trial

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ABSTRACT

Background: Among the regional anesthetic methods applied in lower abdominal surgeries, including cesarean section, is the transversus abdominis plane (TAP) block. Postoperative pain control after cesarean section is significant to avert complications such as venous thromboembolism, improve early recovery, and improve the mother-child relationship. Between June 2020 and October 2021, we conducted a study at Beni Suef University Hospital to evaluate the use of TAP block in patients undergoing cesarean sections.

Methods: One hundred ladies under spinal anesthesia who were having cesarean sections participated in a prospective, randomized, controlled study (approval no. FMBSUREC/08032020/ El Mekkawy. Our research Participants were divided into one of the two groups at random. Bupivacaine was used in an ultrasound-guided TAP-block for Group I (n = 50), whereas saline solution was used as a placebo for Group II (n = 50). The Visual Analog Scale (VAS) and Verbal Descriptor Scale (VDS), opioid consumption, and ambulation time

Results: Groups were similar regarding age, BMI, and parity ($p>0.05$). However, TAP block was shown to reduce 24-hour cumulative morphine consumption (8.44±0.99 mg vs 11.00±0.86 mg, $p<0.001$), time to first analgesic request (219.26±56.06 vs 168.83±41.45 min, $p=0.001$), and to significantly lower 12, 24, and 48-hour postoperative pain scores ($p<0.001$). Additionally, the TAP group had a decreased incidence of nausea and sleepiness ($p<0.05$) and ambulated quicker (148.52 min vs. 207.92 min, $p<0.001$).

Conclusion: In addition to lowering opioid use, and improving maternal recovery block, when used in conjunction with multimodal analgesia, dramatically improves post-caesarean pain management.

Trial Registration: FMBSUREC/08032020/ El Mekkawy.

KEYWORDS: Analgesia, Bupivacaine, Cesarean Section, Pain, Transverse Abdominis Plane Block.

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INTRODUCTION

A cesarean section is a common surgery characterized by incisions to the abdomen and uterus, with over 1 million performed in the United States of America per year, making it the most common surgical procedure [1]. Factors such as advancing maternal age, pregnancies with higher complexity, and changing obstetric practices have all contributed to an overall rising U.S. cesarean rate — from 5% in 1970 to, most recently, 32.2% in 2022 [2]. Although efforts to appropriately reduce cesarean delivery when not medically necessary are yielding some results, cesarean delivery rates remain unacceptably high worldwide, and experts

expect to see only moderate changes to their use because cesarean deliveries are requisite for many high-risk pregnancies [3]. Successful management of intra- and postoperative pain for cesarean deliveries is essential for maternal comfort but also to enable early mobility, promote mother-infant bonding, and help prevent the transition from acute to chronic pain states [4], [5]. Notably, despite advances in pain management, pain after cesarean delivery is still a considerable hallmark of postoperative discomfort owing to the invasiveness of the procedure, including skin incision, open uterine incision and postoperative uterine contractions.

Cesarean deliveries are most commonly performed under regional anaesthesia, although general anaesthesia is necessary in some circumstances. Thus, all equipment to secure and maintain the patient's airway must be available [6], [7]. At present, multimodal analgesia, defined as the use of multiple medications with different mechanisms of action (acetaminophen, opiates, and nonsteroidal anti-inflammatory medications) to maximize analgesic efficacy while minimizing opioid consumption, has become standard care [6], [8]. However, the ideal postoperative pain management regimen remains to be definitively established, and the over-reliance on opioids is concerning because of potential side effects such as nausea, pruritus, sedation and, in severe cases, respiratory depression [9]. Cesarean delivery pain management consists of a combination of preoperative anaesthesia and the application of an enhanced recovery after surgery (ERAS) protocol that covers preoperative, perioperative, and postoperative periods [10]. Anaesthesia of nerve branches extending from T6 to L1 is achieved through the TAP block and appears to be a valuable adjunct to postoperative analgesia following lower abdominal surgery. The technique offers an alternative to potential replacement for spinal opioids to reduce the use of opioids and their side effects if either of them are administered from surface landmarks [11], [12], [13], [14] or under ultrasound [11], [12], [13], [14]. Complications have been rare since the widespread acceptance of the US-guided technique for the TAP block [15], [16], [17]. It has been shown to have a significant decrease in postoperative opioid consumption in patients having cesarean delivery when used as part of a multimodal analgesic regimen without long-acting intrathecal opioids [18], [19]

The purpose of this study is to compare the effectiveness of the TAP block using bupivacaine versus placebo in postoperative pain management in women undergoing cesarean sections. Using a more specific quantification of the analgesic effects of TAP blocks on opioid consumption and patient-reported pain, we aim to generate further evidence for when and how TAP blocks should be used in the post-cesarean analgesic regimen.

METHODS

Study design & patients' enrollment

This study, a prospective randomized controlled trial, was conducted on 100 pregnant women who were admitted to the outpatient clinic of the Obstetrics & Gynecology Department at Beni Suef University Hospital between June 2020 and October 2021 and who were undergoing cesarean sections (approval no. FMBSUREC/08032020/ El Mekkawy). The study was designed to answer the research question: Does the use of ultrasound-guided transversus abdominis plane (TAP) block with bupivacaine reduce postoperative pain and opioid consumption compared to placebo in cesarean section patients under spinal anesthesia?

Patients' criteria

Women included in this study were divided into two groups by random allocation table as follows: Group I included 50 patients who received ultrasound-guided TAP block using bupivacaine, and Group II included 50 patients who received an ultrasound-guided TAP block using normal saline (placebo).

A total of 100 pregnant women scheduled for elective cesarean sections were recruited consecutively from the outpatient clinic of the Obstetrics & Gynecology Department at Beni Suef University Hospital. Recruitment took place between June 2020 and October 2021, during patients' routine preoperative clinic visits. Trained research staff and attending physicians approached eligible patients, explained the study objectives and procedures in detail, and assessed eligibility based on predefined inclusion and exclusion criteria. Those who met the criteria and agreed to participate provided written informed consent prior to enrollment. All participants were educated on how to use the Visual Analog Scale (VAS) for postoperative pain assessment. This process ensured appropriate selection, ethical recruitment, and consistency in baseline understanding across all enrolled patients.

Inclusion criteria:

Women between the ages of 25 and 35 who are under spinal anesthesia for a new cesarean section not a previous one.

Exclusion Criteria:

The study excluded patients who weighed less than 50 kg or more than 100 kg, as well as those who were medically contraindicated for spinal anesthesia. Those with significant systemic disorders including diabetes mellitus or hypertension, as well as those on patient-controlled analgesia (PCA), were excluded. Patients having a history of substance misuse (alcohol or drug dependency), endometriosis, or known allergies to any study-related drugs were also not included. Participants were also excluded if they had a history of prior cesarean deliveries, had bleeding disorders, or needed an emergency cesarean surgery because of complications such fetal distress or unintentional bleeding.

History taking

Every patient had a thorough medical history, with a focus on surgical and medical history. Name, age, height, weight, BMI, particular medically significant habits, obstetric history, and family history are all examples of personal history. Current history: including gestational age, mode of delivery, gravity, and parity.

Ethical consideration

Every procedure was completed in compliance with the institutional committee's ethical guidelines. The Beni Suef University Hospital's Hospital Local Medical Ethics Committee approved the study. The study's purpose and procedures were described to the participants, and all gave their signed informed consent after being briefed on the study's nature and scope and given instructions on how to use the visual analogue scale (VAS) to quantify postoperative pain.

Technique of the USG-TAP block

An ultrasound-guided transversus abdominis plane (TAP) block was performed following the cesarean section, which provides analgesia to the nerves supplying the lower abdominal wall. The patient's skin was scrubbed with 2% chlorhexidine solution before the procedure to avoid infection and maintain sterility. A high-frequency (12 MHz) ultrasound linear probe (MySono U6, SAMSUNG MEDISON CO., LTD.) was used for accurate anatomical visualization and injection guidance. Syringes of 40 ml of 0.25% bupivacaine (intervention group) or normal saline (placebo group) were prepared under rigid aseptic settings. The study was double-blinded, so neither the investigators administering the injection nor the patients themselves knew the solution injected, removing any bias from potential pain relief assessment. An ultrasound probe was placed along the mid-axillary line, approximately midway between the costal margin and iliac crest, to establish a well-defined view of the subcutaneous fat, but also the external and internal oblique muscles, transversus abdominis muscle, peritoneum, and intraperitoneal cavity. Under an in-plane approach, A Stimuplex AB/BRAUN Melsungen AG, Germany, 100 mm, 20G short bevel needle was administered, followed by popper determination of the muscle layers as it was advanced to ensure the needle tip was accurately placed between the internal oblique and transversus abdominis muscles. The solution (20 ml) was injected on each side (left and right), and the successful injection was confirmed by the appearance of an echolucent lens-shaped spread between the two muscle layers. Following the administration of the TAP block, Patients were closely monitored for potential complications, including bradycardia (low heart rate), arrhythmias (irregular heartbeat), and hypotension (low blood pressure). No such events were observed in any of the patients. For the first 24 hours postoperatively, continuous recordings of vital signs were conducted in the operating room and the post-anesthesia care unit for patient safety.

Control Group and Protocol for Conventional Analgesia

Patients in the control group were subjected to a placebo TAP block, in which 20 ml of normal saline was bilaterally injected into the transversus abdominis plane using a similar ultrasound-guided method. To guarantee adequate pain management was achieved, both groups received standardized multimodal analgesia postoperatively (Everyone had the same standard). Analgesia was provided in the form of intravenous paracetamol (1000 mg every 8 hours) as a first-line therapy. If the patient needed then further analgesia was given, intravenous pethidine (0.5 mg/kg) was administered as an opioid analgesia.

Outcome Assessment and Postoperative Monitoring

Postoperative patients were assessed for pain level at various times using validated scoring tools (Visual Analog Scale, VAS). Postoperative nausea and vomiting (PONV), time to first ambulation, and total opioid consumption were additional outcome measures. Toxicity monitoring was required, including ongoing assessment for adverse effects of the injection or systemic analgesics. Due to the heterogeneity of reported outcomes when evaluating TAP block in midline surgical procedures, this study was designed to standardize a procedure, pain management protocol, and postoperative monitoring methods to objectively examine the effectiveness of the TAP block in reducing postoperative pain, opioid use, and promoting early recovery after cesarean section.

Pain scoring

With 15 years of clinical expertise, the researcher helped patients communicate what they needed to say so the assessors could determine the different levels of pain based on the visual analogue score. Three, six, nine, twelve, and twenty-four hours following the conclusion of the TAP block, the visual analogue scale (VAS) pain ratings will be measured both at rest and during movement. On a visual analogue scale (VAS), with 0 cm representing no pain and 10 cm representing the greatest pain (20), the patients will be asked to rate their level of discomfort. These sentences refer to the ladder using Pain Creators to create a new chart known as the VDS. Patients choose the statement that best describes their current pain. However, it is most appropriate to use with higher-functioning patients who can understand and respond to the scale verbally. For older adults, including those with mild to moderate cognitive impairment, the VDS is the preferred tool for measuring pain intensity. Verbal Descriptor Scale (VDS) has six categories There are several types of pain: none, mild, moderate, severe, very severe, and worst possible [20].

Sedation scoring

Minimal sedation, moderate sedation, profound sedation, and general anaesthesia are defined by distinct clinical status (1-6 levels) under sedation. Level 1 is a fully awake and anxious patient. At level 2, the patient appears calm and cooperates adequately. Patients at Level 3 are arousable in response to verbal commands. Level 4s will respond to light stimulation and will respond vigorously to painful stimuli. Level 5: sluggish or absent response to painful physical stimulation; Level 6: no response to painful stimulation. Importantly, sedation levels 5 and 6 are deemed acceptable for adequate sedation. During these periods, drug consumption as well as adverse symptoms such nausea, vomiting, and pruritus, as well as how they were treated, were assessed.

Primary outcome

Evaluating the postoperative pain score following the USG-TAP block.

Secondary outcomes:

Nausea and vomiting after surgery.

Early walking.
Opioid analgesic dosage requirements and side effects.
Issues.

Data Collection
It is simply a process of processing the data, which is computerized, as the data or results are collected suitably after arrangement.

Statistical analysis
MedCalc version 19.6 and SPSS version 25.0 (IBM Corp.) were used to assemble and analyze the data. There were two phases of the analysis. First, qualitative data were displayed as frequencies and percentages, while quantitative data were summarized using descriptive statistics as mean, standard deviation, median, and range. Second, to investigate correlations and discrepancies among variables, inferential statistics were utilized. When anticipated frequencies were low, the Fisher's Exact Test was employed, and the Chi-square test evaluated relationships between categorical variables. When comparing the means of two groups, the Mann-Whitney U test was employed for non-normal distributions and the Student's t-test for normally distributed data. ANOVA examined variations between three or more groups. Pearson's coefficient for normally distributed data and Spearman's rank for non-normal data were used to assess correlations. The threshold for statistical significance was chosen at $p < 0.05$, with $p < 0.01$ and $p < 0.001$ indicating greater importance.

Sample Size
Sample size was calculated using G*Power 3.1 software. Using a two-tailed independent t-test to detect a moderate effect size (Cohen's $d = 0.6$), with 80% power and a significance level of 0.05, the minimum required sample was 45 participants per group. To account for potential attrition or protocol deviations, we enrolled 50 participants per group, for a total of 100. This decision was also supported by previous findings from McDonnell et al. (2008), who demonstrated significant postoperative analgesic benefits of TAP block in cesarean section patients using a similarly sized randomized controlled trial. [21]

RESULTS
Figure 1 is a CONSORT flow diagram of participant flow through the study. From 256 patients screened for inclusion, 156 were excluded for a range of reasons. The remaining 100 were randomized and equally allocated between TAP block (n=50) and placebo (n=50) groups, receiving all their assigned interventions. There were no losses to follow-up or discontinuations.

Demographic information of the study population of 100 patients, equally divided between the TAP and control arms, are outlined in Table 1. There were no statistically significant differences between the two groups' age, height, weight, and BMI. The mean ages of the control and the TAP group were around 29.34 and 30.16 years, respectively (p=0.184). With control and TAP group measurements of 25.72 and 25.84, respectively, the BMI measurements were also equivalent between groups, as well as heights and weights (p=0.754).

Parity between the study groups is compared in Table 2, where no obvious differences are seen. Both the control and TAP groups had the same parity distribution (negative, one time, two times) of 36% none, 50% one, and 14% two (p>0.999).

The average blood loss throughout the procedure did not differ significantly between the groups, as shown in Table 3, with the TAP group losing an average of 787.56 ml and the control group losing 770.22 ml (p=0.419). But there was a much other time to ambulation after surgery, with the TAP group ambulating sooner (148.52 minutes) than the control group (207.92 minutes), which suggests that the TAP group had a faster recovery (p<0.001). **(Figure 2)**

The differences in VAS-measured pain intensities at various postoperative time intervals are represented in Table 4. At surgery + 2, + 4, and + 6 hours, the VAS ratings of the groups did not have any significant differences. **(Figure 3)**

The TAP group was significantly lower than control in pain intensity. at 12 and 24 hours (median VAS of 3 vs. 4 in controls, p=0.040 and p<0.001, respectively). **(Figure 3)**

The control group reported slightly lower VAS scores at 48 hours compared to the TAP group, (p<0.001), There were significant differences over time when the control and TAP groups' visual analog scale (VAS) changes at various times were compared (p<0.001 for both groups). Pain scores in both groups were low and did not significantly change at 2, 4, and 6 hours after surgery (p>0.999). Pain scores did increase significantly by 12 hours, peaked at 24 hours, and then decreased modestly. After the onset at a median of 0.0 at initial time points, the VAS scores of the control group peaked at 4 (IQR: 2-5) at 12 hours and subsequently decreased slightly to 3 (IQR: 2-4) at 24 hours. The TAP group also showed the same trend, with VAS scores rising to a median of 3 (IQR: 2-4) at 12 and 24 hours, showing marginally better pain control than the control group at these time points. Pairwise comparisons showed that VAS at 24 hours were higher than at earlier times but not significantly different from VAS at 12 hours, implying reaching a plateau of pain levels after the initial postoperative hours. Friedman's test also revealed a statistically significant difference in VAS scores over time across groups (p<0.001). **(Table 5)**

There were significant differences at certain points of time while evaluating pain of cough. At 6 hours, the VAS on cough for the TAP group was appreciably lesser (1.88±0.72) compared to that of the control group (4.90±1.33, p=0.001), reflecting the TAP block to be more effective in the control of pain during early postoperative hours. Following assessments indicated the opposite trend; at 12, 24, and 48 hours, VAS on cough scores of the TAP group were significantly greater at 4.96±0.81 at all three time

points, whereas scores of the control group were lesser (p=0.001 at all three time points).

There were not discernable between-groups differences at 2 or 4 hours (p>0.05), so the levels of coughing pain were equal early after surgery.

The total dose of morphine in the TAP group (8.44±0.99 mg) was lower compared to the control group (11.00±0.86 mg) at 24 hours post-surgery. The difference was significant at a very high level (p<0.001), and the confidence interval signified clinical significance (-2.39 to -2.19). The doses between groups did not vary, however, significantly at 48 hours post-surgery (p=0.098). **(Table 6)**

Effective pain management was established by the TAP group's much longer duration (219.26±56.062 minutes) compared to the control group (168.83±41.45 minutes) up to the first analgesic administration (p=0.001). There is an extremely large and large confidence interval (-140.25 to -61.47) for this conclusion. **(Table 7)**

Multinomial logistic regression was applied to test the effectiveness of the TAP block for post-cesarean analgesia. 'Time to ambulation' and 'time of first analgesic' correlated significantly with improved outcomes in the TAP group with p-values for both being 0.000. The odds ratio for time to ambulation was especially high at (24.777), suggesting a high level of association of the time to ambulation with the effectiveness of the TAP block. No significant correlations existed between analgesia effect and age, weight, BMI, or blood loss (p>0.05). **(Table 8)**

There were wide differences in trouble frequency among groups. Increased morphine use will probably be of negative consequence, according to the increased rate of nausea and vomiting (16% vs. 0%, p=0.013) and drowsiness (40% vs. 20%, p=0.02) in the control group. Except for no report of intestinal damage or subcutaneous hematoma post-op, there were no appreciable differences in respiratory depression or pruritus between groups. **(Table 9)**

DISCUSSION

Yan et al. found TAP blocks enhanced post-cesarean pain on rest, in accordance with our observations of improved recovery. In addition to these findings, our study also observed decreased opioid requirements, demonstrating heterogeneity in the effects of TAP blocks based on various patient states [22]. Alemnew and Lemma found TAP blocks were more effective than wound infiltration in cesarean pain management post-delivery, reducing tramadol and diclofenac consumption and delaying analgesia need ($p < 0.05$). This is corroborated by our study, which also indicated TAP blocks' enhanced analgesic efficacy and reduced opioid consumption [23]. Tao et al. explored the impact of transversus abdominis plane (TAP) blocks on postoperative recovery after cesarean deliveries under general anesthesia. They reported significant improvements in Quality of Recovery (QoR-15) scores, comfort, and early ambulation capabilities ($p < 0.001$), with faster times to first ambulation and flatus. These findings confirm our evidence, demonstrating the efficacy of TAP blocks to enhance postoperative recovery parameters [24]. Hozien et al. (2024) contrasted adjuvants with bupivacaine in TAP blocks after cesarean sections. Dexamethasone added considerably increased prolongation of analgesia and reduced opioid use compared with controls (p=0.041, p=0.006). These enhancements align with our findings on TAP blocks' effectiveness in postoperative pain management [25]. Abdallah, Halpern, and Margarido's systematic review and meta-analysis assessed the efficacy of the transversus abdominis plane (TAP) block in reducing postoperative morphine use and pain after cesarean delivery under spinal anesthesia.In five trials with 312 patients, they stated that TAP blocks decreased morphine consumption by 24 mg and pain scores by 0.8 cm without the presence of spinal morphine, proving to be beneficial in multimodal analgesic regimens where spinal morphine is not used. These results support our study's conclusions about the benefits of TAP blocks in postoperative pain management [26]. In a randomized double-blind trial, 62 parturients received a TAP block, significantly reducing tramadol use by 50% and lowering pain scores for 24 hours post-cesarean section ($p < 0.001$). This aligns with our findings, highlighting TAP blocks' efficacy in enhancing postoperative recovery and reducing opioid dependency [27]. The efficacy of the TAP block in reducing the reliance on opioids post-cesarean section aligns with existing research advocating for regional anesthesia techniques to mitigate postoperative pain [28].

A number of previous investigations have indicated no differences in demographic factors of age, weight, height, body mass index (BMI), and parity among study groups that have received TAP blocks and control interventions. Srivastava et al. [29], Borys et al. [30], Buluc et al. [31], and Abed-Alnabi et al. [32] all indicated that patient characteristics were similar in their respective trials of TAP blocks ($p > 0.05$). Likewise, Alhosainy et al. [33] and Marzouk et al. [34]. Could not identify any demographic differences with statistical significance between the TAP block and the control groups. In our study, these were similarly matched baseline characteristics of age, weight, BMI, and parity, such that the observed postoperative pain and opioid consumption differences must have been due to the intervention, rather than due to patient variation.

Numerous studies confirm our result that TAP blocks intensively decrease postoperative pain and opioid use. Belavy et al. [35] had proven that morphine use decreased when ultrasound-guided TAP blocks were added to a multimodal analgesia regimen following spinal anesthesia. Likewise, Abdallah et al. [36] had proven that TAP blocks decreased postoperative opioid use when spinal morphine was avoided. Carney et al. [21] and Mishriky et al. [37] also substantiated that TAP blocks reduced pain severity scores, opioid consumption, and complications while extending the time to the first request for analgesia. These results are in agreement with our study, where total opioid intake was significantly decreased in the TAP group, further establishing its effectiveness in multimodal pain management protocols.

The findings of our study on the increased time to first analgesic request are corroborated by Tarekegn et al. [38], where the TAP

block group took significantly longer before needing further analgesia ($p = 0.000$). Their findings showed that the initial analgesic request was 286.00 ± 166.31 minutes for the TAP group versus 76.25 ± 22.05 minutes for the control group. McDonnell et al. also stated that TAP block was associated with better analgesia for 48 hours, which is in agreement with our study, where extended analgesic effects were noted) [20], [21], [39].

Tarekegn et al. [38] and Alhosainy et al. [33] established that 24 hours post-surgery, the tarrying VAS reduction was elicited with lesser VAS values at movement. McDonnell et al. [40] and Fusco et al. [41] documented that TAP block increased postoperative analgesia, prolonged duration of pain relief, and prolonged time to request first analgesia. These results are in accordance with our study, in which the TAP group showed a significantly lower score on VAS and improved dynamics of recovery after cesarean section.

Although supported by strong evidence, there are studies that contradict our results. Borys et al. [30] did not find any differences in pain severity or overall analgesic consumption between the TAP block and control groups, which is contrary to our findings of decreased opioid consumption and better pain control. Buluc et al. [31] did not also find any difference in the operation time or in the pain scores, which implies that there might be variability in the effectiveness of TAP block depending on surgical or patient factors.

Our study found no significant differences in the postoperative side effects such as nausea, vomiting, and sedation. These findings were consistent with those of Abed-Alnabi et al. [32] and Marzouk et al. [34], who reported that, despite a decrease in opioid intake, opioid-related side effects were somewhat reduced in the TAP block group; however, statistical differences were not noted ($p > 0.05$). Patient satisfaction with analgesia was, however, significantly greater in recipients of TAP block reported by Belavy et al. [35] and Tan et al. [42], who noted greater patient satisfaction and better mobility in patients receiving TAP block. Fusco et al. [41] conducted a systematic review of eleven randomized controlled trials, confirming higher patient satisfaction, reduced postoperative nausea and vomiting, and prolonged time to first analgesia request with TAP blocks compared to placebo.

Proper management of pain following a cesarean section is essential. Insufficient pain control can lead to a higher need for opioids, extended hospital stays, and delayed mobility, which may increase the risk of thromboembolism [43], [44], [45]. The transversus abdominis plane block (TAPB) is a straightforward regional anesthesia technique that provides effective pain relief and is associated with minimal complications [40], [46], [47]. This study specifically addresses the described deficit with regard to the need for effective pain control interventions with minimal opioid consumption following cesarean section. By demonstrating the utility of the TAP block in not only reducing pain but also enhancing recovery dynamics (earlier ambulation and later need for analgesics), it contributes significantly to the subject matter of multimodal pain control interventions in obstetric surgery.

These results have a number of important implications. Practically, the addition of TAP blocks to standard postcesarean section care can significantly improve patient outcomes by reducing pain and opioid-related side effects. Theoretically, this confirms the principle of multimodal pain management in obstetrics [48], [49], [50], in which regional anesthesia techniques can be cornerstone components of effective post-surgical pain management regimens.

The strengths of the study are that it has an RCT with double-blinding, which minimizes bias and maximizes validity. It used a standardized ultrasound-guided TAP block for precision and multi-point pain assessment with VAS and VDS. The clinically significant outcomes of opioid consumption, time to first analgesia, early ambulation, and PONV were measured, which provides a comprehensive overview of recovery. Rigorous statistical analysis fortified data reliability, and rigorous inclusion/exclusion fortified high internal validity. Ethical approval, informed consent, and adverse event monitoring also safeguarded patient safety. However, there are limitations in the study. Single-site study design may limit external validity, and sample size (100 participants), although sufficient to detect large differences, is quite small. In addition, follow-up was only 24 hours, which did not allow for long-term determination of pain relief. Larger multi-center populations and longer follow-up would strengthen future studies to enhance generalizability.

Examining the long-term impact of decreased opioid utilization after cesarean on mother and infant may also give additional insight into the usefulness of TAP blocks in obsthetic surgery. Although the results are encouraging, care should be taken not to overgeneralize the advantages of TAP blocks. The implications of the study are generalizable to the population and the conditions under which the study was carried out. It would be premature to extrapolate these results to other groups or types of surgery without additional evidence.

CONCLUSION

The transversus abdominis plane (TAP) block significantly improved postoperative analgesia in cesarean section patients, as demonstrated by reduced opioid consumption, lower pain scores at key time points, faster ambulation, and fewer opioid-related side effects. These findings support the TAP block's use as a safe and effective adjunct to multimodal analgesia protocols. Ultrasound-guided TAP block should be considered safe as a routine adjunct in multimodal analgesia protocols for cesarean delivery to improve pain control, reduce opioid-related side effects, and enhance maternal recovery. However, given the single-center design, modest sample size, and short follow-up, broader studies are needed to confirm its generalizability and to explore optimal combinations with other analgesics.

Limitations

This study has several important limitations that should be acknowledged. First, the follow-up period was limited to 48 hours, which precluded evaluation of long-term outcomes such as chronic pain or sustained recovery satisfaction. Second, the single-center design may limit the generalizability of findings beyond similar tertiary hospital settings. Although strict inclusion criteria enhanced internal validity, the exclusion of patients with comorbidities or prior cesarean sections introduces selection bias and may reduce the applicability of results to broader obstetric populations. Additionally, postoperative pain was assessed using subjective tools such as the Visual Analog Scale (VAS) and Verbal Descriptor Scale (VDS), which are prone to individual interpretation and variability influenced by factors like anxiety, prior pain experiences, and perception thresholds. Procedural variability, while minimized through ultrasound-guided TAP block administration, remains a possible source of outcome differences due to the operator-dependent nature of regional anesthesia techniques. These factors collectively highlight the need for larger, multicenter trials with longer follow-up and broader patient populations to validate and extend our findings.

Declarations

Consent for Publication

All authors read and approved the final manuscript.

Availability of data and materials

Data supporting the results of this study are included within the manuscript.

A. Ethical Approval

This study was approved by the Local Medical Ethics Committee of Beni Suef University Hospital. All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee approval no. FMBSUREC/08032020/ El Mekkawy

B. Human/Animal Guidelines

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments.

C. Consent for Publication

Written informed consent was obtained from all individual participants included in the study for publication of the data.

Availability of Data and Materials

Data are available from the corresponding author on reasonable request.

Competing Interests

The authors declare no competing interests.

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Authors' Contributions

The outlined conceptualization: SAN, AEAME, AAE.
Investigation: SAN, SA, FK, SW.
Methodology: HAE, AAE, AEAME.
Resources: SAN, AEAME, SA, HAE.
Supervision: SAN, AEAME.
Visualization: AEAME, AAE, HAE, SA, FK, SW.

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List of Abbreviations

Abbreviation	Full Term
TAP	Transversus Abdominis Plane
VAS	Visual Analog Scale
VDS	Verbal Descriptor Scale
PONV	Postoperative Nausea and Vomiting
RCT	Randomized Controlled Trial
BMI	Body Mass Index
USG	Ultrasound-Guided
PCA	Patient-Controlled Analgesia
ERAS	Enhanced Recovery After Surgery
SD	Standard Deviation
IQR	Interquartile Range
CI	Confidence Interval

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Table (1): Demographic data among the studied patients (N=100).

Variables	Studied Groups		t	P value	% CI	
					Lower	Upper
	Control N=50	TAP group N=50				
Age (years) Mean± SD	29.34±2.99	30.16±3.14	1.337	0.184	-2.04	0.40
Wight (kg) Mean± SD	68.68±7.90	69.40±7.56	0.466	0.643	-3.79	2.35
High(m) Mean± SD	1.64±0.12	1.64±0.09	0.029	0.977	-0.04	0.04
BMI (kg/m^2) Mean± SD	25.72±2.01	25.84±1.80	0.314	0.754	-0.88	0.64

t: independent t test X^2: chi-square test CI: confidence intervals

Table (2): Parity and among the studied groups.

Parity	All studied patients				X^2	P value
	Control group N=50		TAP group N=50			
	No.	%	No.	%		
Negative	18	36.00	18	36.00	0.000	>0.999
One time	25	50.00	25	50.00		
Two time	7	14.00	7	14.00		

X^2: chi-square test

Table (3): Blood loss and time to ambulation among the studied groups.

Variables	Studied Groups		t	P value	%CI	
	Control N=50	TAP group N=50			Lower	Upper
Blood Loss (ml) Mean± SD	770.22±39.65	787.56±31.06	0.811	0.419	-8.35	19.91
Time to ambulation (min) Mean± SD	207.92 ±28.42	148.52 ±28.55	9.921	**<0.001***	-17.82	-11.88

t: independent t test CI: confidence intervals *significant

Table (4): Visual analog scale (VAS) variation after different times among the groups.

Variables	Studied Groups		U	P value	%CI	
	Control N=50	TAP group N=50			Lower	Upper
VAS Variation after 2h Median (IQR)	0.0±0.0	0.0±0.0	NA	----	----	----
VAS Variation after 4h Median (IQR)	0.0±0.0	0.0±0.0	NA	----	----	----
VAS Variation after 6h Median (IQR)	0.0±0.0	0.0±0.0	NA	----	----	----
VAS Variation after 12h Median (IQR)	4 (2-5)	3 (2-4)	2.086	**0.040***	0.03	1.09
VAS Variation after 24h Median (IQR)	3 (2-4)	3 (2-4)	6.651	**<0.001***	0.79	1.45
VAS Variation after 48h Median (IQR)	2 (1-3)	3 (2-4)	4.869	**<0.001***	-1.46	-0.62

IQR: Interquartile range (25th percentile -75th percentile) VAS: Visual analog scale U: Mann-Whiteny test *significant CI:

confidence interval

Table (5): Comparison of visual analog scale (VAS) variation at different times for the studied groups.

Control group			VAS Variation after 2h	VAS Variation after 4h	VAS Variation after 6h	VAS Variation after 12h	VAS Variation after 24h	P-value*
	Median (IQR)		0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	4 (2-5)	3 (2-4)	**<0.001**
	VAS Variation after 2h	0.0 (0.0-0.0)						
	VAS Variation after 4h	0.0 (0.0-0.0)	>0.999					
	VAS Variation after 6h	0.0 (0.0-0.0)	>0.999	>0.999				
	VAS Variation after 12h	4 (2-5)	**<0.001**	**<0.001**	**<0.001**			
	VAS Variation after 24h	3 (2-4)	**<0.001**	**<0.001**	**<0.001**	>0.999		
TAP group			VAS Variation after 2h	VAS Variation after 4h	VAS Variation after 6h	VAS Variation after 12h	VAS Variation after 24h	P-value*
	Median (IQR)		0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	3 (2-4)	3 (2-4)	**<0.001**
	VAS Variation after 2h	0.0 (0.0-0.0)						
	VAS Variation after 4h	0.0 (0.0-0.0)	>0.999					
	VAS Variation after 6h	0.0 (0.0-0.0)	>0.999	>0.999				
	VAS Variation after 12h	3 (2-4)	**<0.001**	**<0.001**	**<0.001**			
	VAS Variation after 24h	3 (2-4)	**<0.001**	**<0.001**	**<0.001**	>0.999		

* P-value for Friedman's test. Other p-values reported in the matrix are for the pairwise comparisons with Bonferroni adjustment for multiple tests

Table (6): Visual analog scale variation on cough after different times among the studied groups.

Variables	**Studied Groups**		**U**	**P value**	**%CI**	
					Lower	**Upper**
	Control N=50	**TAP group N=50**				
VAS on cough after 2h Mean± SD	1.00±0.81	0.98±0.77	0.127	0.899	-0.29	0.33
VAS on cough after 4h Mean± SD	3.34±1.14	3.10±1.49	0.907	0.367	-0.29	0.77
VAS on cough after 6h Mean± SD	4.90±1.33	1.88±0.72	14.139	**0.001***	2.60	3.44
VAS on cough after 12h Mean± SD	4.02±1.45	4.96±0.81	-4.006	**0.001***	-1.41	-0.47
VAS on cough after 24h Mean± SD	2.98±0.84	4.96±0.81	-11.982	**0.001***	-2.31	-1.65
VAS on cough after 48h Mean± SD	2.92±0.85	4.96±1.24	-9.558	**0.001***	-2.46	-1.62

VAS: Visual analog scale U: Mann-Whiteny test *significant CI: confidence interval

Table (7): Morphine cumulative doses and time of first analgesic among the studied groups.

Variables	Studied Groups		t	P value	%CI	
					Lower	Upper
	Control N=50	TAP group N=50				
Cumulative dose of morphine after 24h Mean ±SD	11.00±0.86	8.44±0.99	13.80	**<0.001***	-2.39	-2.19
Cumulative dose of morphine after 48h Mean ±SD	23.98±7.15	22.20±2.36	1.67	0.098	-0.33	3.89
Time of first analgesic (min) Mean ±SD	168.83±41.45	219.26±56062	5.08	**0.001***	-140.25	-61.47

t: independent t test *significant CI: Confidence intervals

Table (8): Multinomial logistic regression analysis using TAP block as the Dependent Variable.

Variable	β	Std. Error	p-value	Odds (OR)	95% Confidence	
					Lower	Upper
Age	0.086	0.067	0.198	1.659	0.956	1.243
Wight	0.010	0.027	0.715	0.134	0.958	1.064
BMI	0.013	0.109	0.908	0.013	0.818	1.253
Blood Loss	-0.010	0.008	0.237	1.398	0.974	1.006
Time to ambulation	0.242	0.049	**0.000***	24.777	1.158	1.402
Time of first analgesic	0.010	0.002	**0.000***	17.095	1.005	1.015

Table (9): Incidence of complications among the two studied groups

Variables	Studied Groups				FET or X^2	P value
	Control N=50		TAP group N=50			
	No.	%	No.	%		
Drowsiness	20	40	10	20	4.76	**0.02***
Respiratory depression	3	6	1	2	0.61	0.30
Nausea and vomiting	8	16	0	0	8.70	**0.013***
Pruritus	4	8	1	2	0.36	0.16
Surgical complications						
Subcutaneous hematoma	0	0	0	0		
Intestinal injury	0	0	0	0		

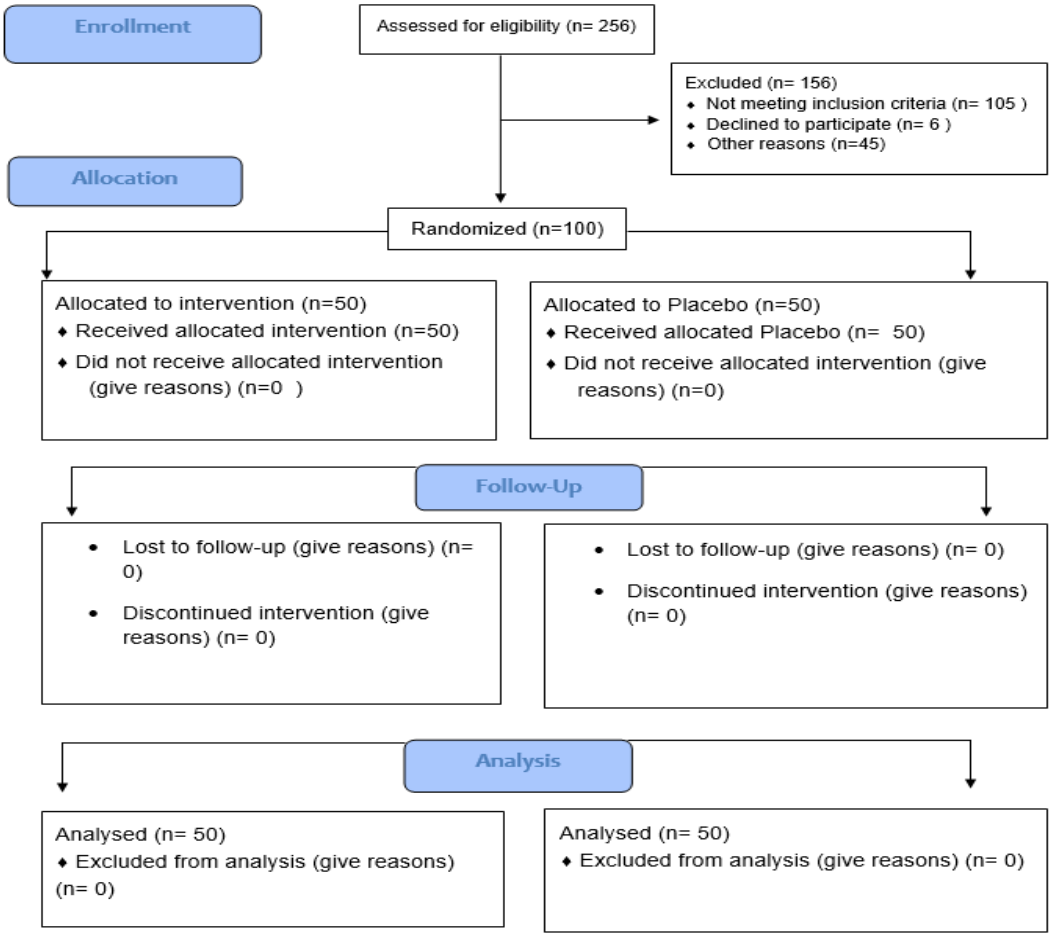

Figure. 1 Consort flow chart

CONSORT diagram illustrating participant flow through the randomized controlled trial.

A total of 256 patients were screened for eligibility; 156 were excluded. The remaining 100 were randomized equally into the TAP group (n = 50) and control group (n = 50). All participants received their allocated intervention and were analyzed. No losses to follow-up were reported.

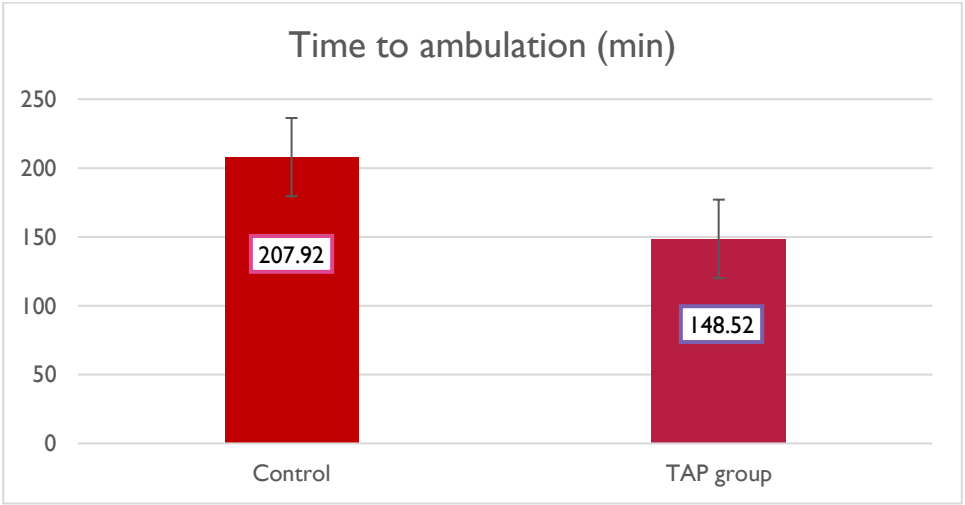

Figure (2): time to ambulation among the studied patients

Comparison of time to ambulation (in minutes) between the TAP block group and the control group. The x-axis represents the two study groups. The y-axis shows mean ambulation time in minutes. The TAP group demonstrated significantly faster ambulation (148.52 ± 28.55 min) compared to the control group (207.92 ± 28.42 min), $p < 0.001$.

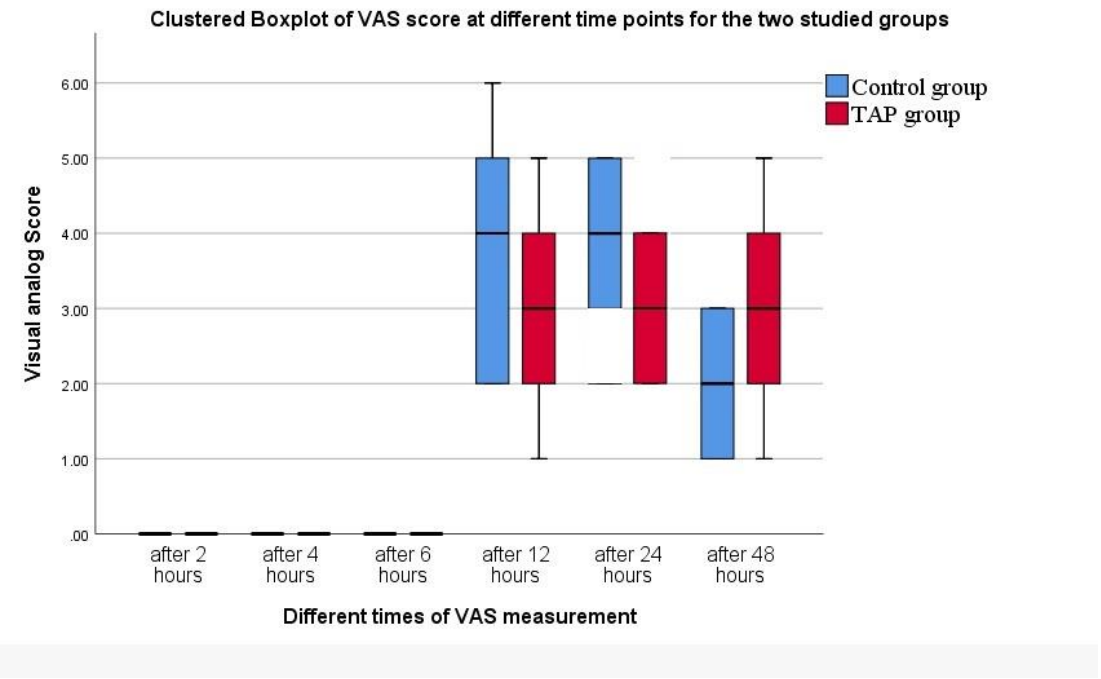

Figure (3): Visual Analog Scale Variation among the studied patients

Median Visual Analog Scale (VAS) pain scores at rest across postoperative time points: 2, 4, 6, 12, 24, and 48 hours. The x-axis shows time since surgery (in hours), and the y-axis represents VAS pain scores (0 = no pain; 10 = worst pain). Pain scores were similar in both groups during the first 6 hours, but significantly lower in the TAP group at 12 and 24 hours ($p < 0.05$).

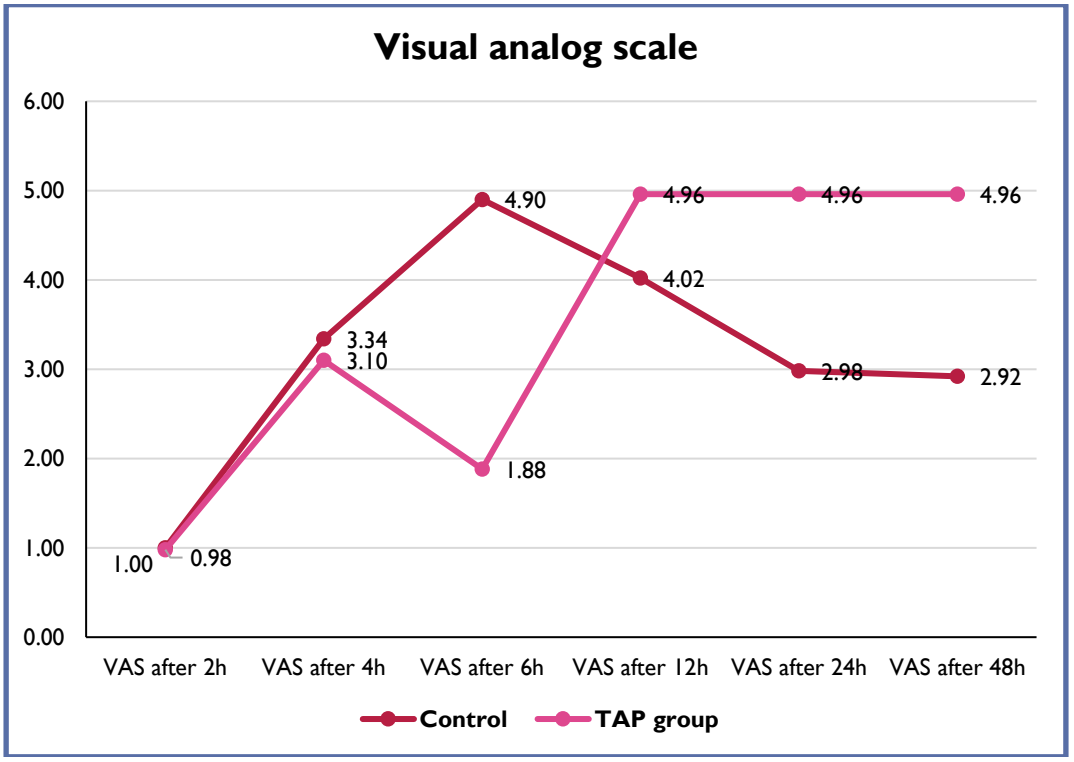

Figure (4): Visual analog scale (VAS) variation on cough among the studied patients.

Mean VAS pain scores during coughing at 2, 4, 6, 12, 24, and 48 hours postoperatively. The x-axis indicates time after surgery (in hours), and the y-axis shows pain score. At 6 hours, the TAP group showed significantly lower cough-related pain ($p = 0.001$), but paradoxically, higher scores were observed at 12, 24, and 48 hours. Further clarification is required in the discussion to explain this trend.

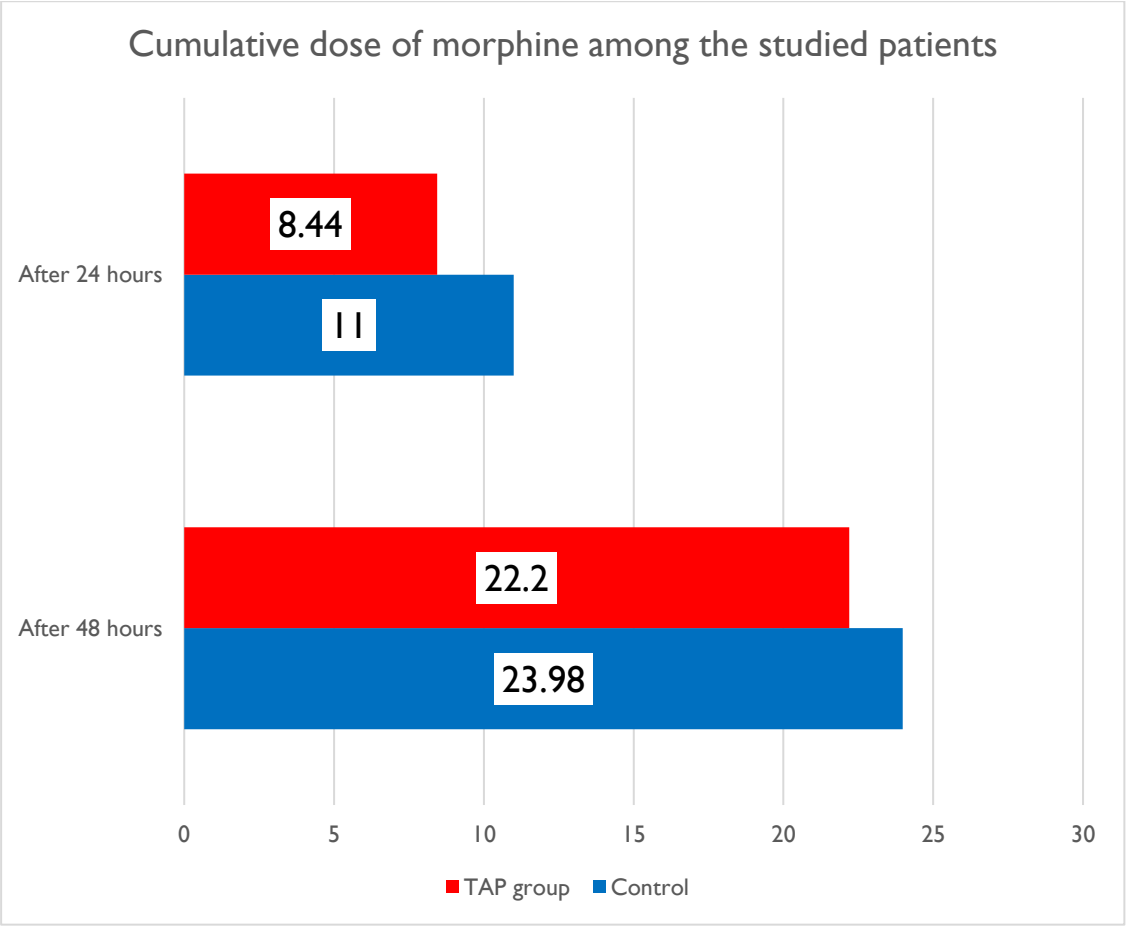

Figure (5): Cumulative dose of morphine among the studied patients.

Comparison of cumulative morphine use (mg) over the first 24 postoperative hours. The x-axis shows the treatment groups (TAP vs. control), and the y-axis indicates total morphine dose in milligrams. The TAP group required significantly less morphine (8.44 ± 0.99 mg) than the control group (11.00 ± 0.86 mg), $p < 0.001$.