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Transversus Abdominis Plane Block for Postoperative Analgesia after Laparoscopic Colorectal Surgery

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Abbreviations:
EOM: External Oblique Muscle;
IOM: Internal Oblique Muscle;
LA: Local Anesthetic;
PACU: Post Anesthesia Care Unit;
TAM: Transversus Abdominis Muscle;
TAP: Transversus Abdmominis Plane;
VAS: Visual Analogue Scale;
US: Ultrasound;
EBL: Estimated Blood Loss;
GA: General Anesthesia.

Rezumat

Blocul planului transvers abdominal în controlul durerii postoperatorii după chirurgia laparoscopică colorectală

Introducere: Rezecția laparoscopică reprezintă standardul actual în tratamentul cancerului colorectal, oferind beneficii majore comparativ cu chirurgia deschisă: recuperare accelerată, scoruri mai mici ale durerii postoperatorii, reducerea consumului de opioide şi spitalizare redusă. Implementarea blocului planului transvers abdominal (TAP block) poate amplifica aceste avantaje, optimizând controlul durerii postoperatorii.
Materiale şi Metode: Studiul observațional prospectiv a fost realizat la Institutul Clinic Fundeni, Bucureşti, cu aprobarea Comisiei de Etică. Au fost incluşi pacienți adulți (18-85 ani), ASA I–III, supuşi rezecției colorectale laparoscopice elective. Criteriile de excludere au inclus contraindicațiile pentru TAP block, necesitatea unor tehnici analgezice suplimentare şi anumite comorbidități. Blocul TAP a fost efectuat bilateral sub ghidaj ecografic, utilizând ropivacaină 0,25%. Durerea a fost evaluată prin Scala Vizual-Analogă (VAS) la 1, 2, 4, 8, 12 şi 48 de ore, iar consumul de analgezice (opioide, paracetamol, tramadol, Neodolpasse) a fost monitorizat riguros.
Rezultate: Grupul TAP a prezentat o reducere semnificativă a consumului de paracetamol ($p = 0,011$), confirmând necesarul analgezic mai redus comparativ cu grupul control. Timpul median până la prima solicitare de analgezic a fost semnificativ prelungit la pacienții cu bloc TAP (8 ore, IQR: 0,00) față de control (5 ore, IQR: 1,00), $p < 0,001$.
Concluzii: Blocul TAP s-a dovedit eficient ca parte a analgeziei multimodale, reducând consumul de opioide şi non-opioide şi crescând confortul şi satisfacția pacienților. Integrarea tehnicilor de anestezie regională în practica chirurgicală standard este esențială pentru optimizarea rezultatelor postoperatorii. Sunt necesare studii randomizate suplimentare pentru validarea acestor observații şi clarificarea mecanismelor implicate.

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Cuvinte cheie: blocul planului transvers abdominal (TAP block), consum de opioide, interval până la prima administrare de analgezic, chirurgie laparoscopică colorectală

Abstract

Introduction: Laparoscopic resection has become the standard surgical technique in treating colorectal cancer. This approach has many advantages over open surgery such as: faster recovery, lower postoperative pain with reduced postoperative pain scores and opioid requirements and shorter hospital-stay. Improving postoperative pain management by performing transversus abdominis plane block enhances some of the benefits of laparoscopic colorecat surgery. The aim of our study was to emphasize the role and the benefits of transversus abdominis plane block after laparoscopic colorectal resection.

Material and Methods: This prospective observational cohort study was conducted at the Fundeni Clinical Institute in Bucharest, Romania, and received ethical approval from the institutional Ethics Committee. We included adult patients aged 18 to 85 years, classified as ASA physical status I-III, undergoing elective laparoscopic colorectal surgery. Exclusion criteria comprised contraindications to TAP block, the necessity for additional analgesic interventions, and specific medical conditions. The TAP block was performed under ultrasound guidance, utilizing 0.25% ropivacaine administered bilaterally. Postoperative pain was evaluated through the Visual Analog Scale (VAS) at intervals of 1, 2, 4, 8, 12, and 48 hours. Analgesic consumption was meticulously recorded, focusing on opioids, paracetamol, tramadol, and Neodolpasse.

Results: The findings indicated a significant reduction in paracetamol consumption within the TAP block group, evidenced by a p-value of 0.011, which suggests lower analgesic requirements compared to the control group. Furthermore, the median time to the first analgesic request was significantly prolonged in the TAP block group, recorded at 8 hours (IQR: 0.00) versus 5 hours (IQR: 1.00) in the control group, with a p-value of <0.001. These results imply that the TAP block not only enhances analgesia but also extends the interval before additional analgesics are necessary.

Conclusions: The TAP block demonstrates substantial efficacy in multimodal analgesia, significantly reducing both opioid and non-opioid analgesic consumption while improving patient comfort and satisfaction. These findings emphasize the TAP block's effectiveness in addressing somatic pain in the abdominal region. Integrating regional anesthesia techniques into standard surgical protocols is essential for optimizing patient outcomes. Future randomized controlled trials are warranted to further validate these findings and elucidate the underlying mechanisms involved.

Keywords: TAP block, opioid consumption, time to first analgesic, laparoscopic colorectal surgery

Introduction

The Transversus Abdominis Plane (TAP) block has emerged as a valuable technique in regional anesthesia, particularly in abdominal surgery. The anterior abdominal wall is composed of the external oblique, internal oblique, and transversus abdominis muscles, with innervation arising from the anterior rami of T6–T12 (1,3). Posteriorly, the abdominal wall is reinforced by the quadratus lumborum, psoas major, and erector spinae muscles, enveloped by the thoracolumbar fascia (1, 4-6). Targeting the fascial plane between the internal oblique and transversus abdominis muscles, the TAP block effectively provides analgesia by interrupting sensory input from T7 to L1 (7–9).

Initially described by Rafi (2001) and McDonnell (2007), this approach has demonstrated efficacy in procedures such as cesarean section, hernia repair, and colorectal surgery (10–12). Beyond analgesia, regional techniques preserve immune function, attenuate surgical stress, and may contribute to improved oncological outcomes by reducing inflammation and limiting opioid exposure (13). However, these effects remain subject to confirmation, as large-scale retrospective analyses have reported inconsistent findings (14,15). The pharmacokinetics of ropivacaine and bupivacaine further influence TAP block utility, with perineural administration yielding prolonged analgesia compared to intrathecal routes (16,17).

The primary aim of this prospective, observational study is to evaluate the analgesic efficacy of the Transversus Abdominis Plane (TAP) block in patients undergoing elective laparoscopic colorectal surgery, compared to a control group receiving standard analgesic care without regional block intervention.

The primary objective was to assess the impact of TAP block administration on postoperative analgesic requirements, specifically the total consumption of opioids, paracetamol, tramadol, and Neodolpasse. Additionally, the secondary outcomes include time to first analgesic request, length of hospital stay, and patient satisfaction with postoperative pain management.

Materials and Methods

This investigation employed a monocentric prospective observational cohort, design aimed at assessing the analgesic efficacy and safety profile of the Transversus Abdominis Plane (TAP) block in patients undergoing elective colorectal surgery, represented by The Oncological and Hepatobiliopancreatic Surgery Department from Fundeni Clinical Institute, Bucharest, Romania. The study received ethical approval from the Fundeni Clinical Institute Ethics Committee (Study No. 1891/2025). Patient data were extracted exclusively from clinical records, ensuring the confidentiality and integrity of sensitive information. Data collection was performed by the anesthetic team.

Patient Population

The study sample consisted of adult patients selected based on specific inclusion criteria: patients aged between 18 and 85 years, who underwent laparoscopic colorectal surgery, and patients with physical status I-III, according to the American Society of Anesthesiologists (ASA). Written informed consent was duly obtained from all participants after comprehensive discussions surrounding the procedural implications and potential risks.

Patients were excluded from the study if they had ASA physical status IV-V, abdominal wall abnormality, local anesthetic allergy, morbid obesity (BMI > 40 kg/m2), opioid, alcohol, and substance abuse, psychiatric disease, need for an interpreter, coagulopathy, or cirrhosis Child-Pugh C. Further exclusions included patients requiring unanticipated thoracic epidural analgesia (TEA) or intraoperative conversion from laparoscopic to open surgery. All procedures performed in this study, involving human participants, were conducted under the Declaration of Helsinki (revised in 2013).

The study population comprised adult patients who underwent elective laparoscopic oncological colorectal procedures under general anesthesia between December 2021 and December 2024. Eligible patients received either a transversus abdominis plane (TAP) block or Paracetamol, Neodolpasse, Tramadol and Morphine for postoperative analgesia.

Statistical Analysis

All statistical analyses were performed using R software, version 4.4.2 (R Core Team, 2024; R Foundation for Statistical Computing, Vienna, Austria; https://www.R-project.org).

This prospective, non-randomized experimental study was conducted on a cohort of 119 patients who were allocated into two groups: Group A (n=54), which received a Transversus Abdominis Plane (TAP) block, and Group B (n=65), which did not receive any form of regional anesthesia.

Anesthetic Agents and Equipment

The TAP block was performed utilizing a Stimuplex® Ultra 360® needle (B.Braun, Germany), characterized by a 20-gauge diameter and an overall length of 100 mm. The local anesthetic agent administered for the procedure was 0.25% ropivacaine, with a volume of 20 ml being injected bilaterally.

Ultrasound Guidance Protocol

The implementation of ultrasonographic guidance was critical for enhancing the accuracy of needle placement during the TAP block. The linear probe was meticulously positioned in the transverse plane, targeting the midaxillary line situated between the lower costal margin and the iliac crest. This anatomical landmark facilitated optimal visualization of the external oblique, internal oblique, and transversus abdominis muscles, thereby aiding in landmark identification (*Fig. 1*).

Postoperative Pain Evaluation

Postoperative analgesia was methodically evaluated using the Visual Analog Scale (VAS) at

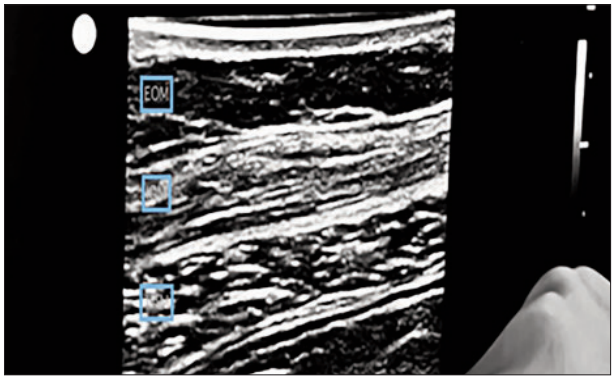

Figure 1. Needle Insertion Technique: An in-plane approach was rigorously employed for the insertion of the needle. The advancement of the needle was executed in an anteromedial direction towards the TAP, defined as the fascial plane interposed between the internal oblique and transversus abdominis muscles. Achieving accurate placement of the needle tip was confirmed via real-time ultrasound imaging, ensuring that the injectate could be effectively delivered into the targeted area. Upon confirmation of the correct positioning, the designated volume of ropivacaine was injected, with the successful block defined by the visualization of the spread of the anesthetic agent within the fascial plane.
(Fundeni Clinical Institute Archive)

specified intervals, including 1, 2, 4-, 8-, 12-, and 48-hours post-TAP block.

Analgesia Duration Assessment

The duration of analgesia was comprehensively defined as the time interval from the administration of ropivacaine until the patient's first request for additional analgesic intervention. In accordance with a structured rescue analgesia protocol, intravenous paracetamol was administered when patient-reported VAS scores reached ≥ 3. Should analgesia be insufficient two hours after initial treatment, intravenous diclofenac (1.5 mg/kg, with a maximum dosage of 150 mg) was provided. If pain persisted, tramadol (1 mg/kg IV, not exceeding 200 mg) was administered within a 24-hour window, alongside the availability of intravenous morphine (0.1 mg/kg) for additional pain management as deemed necessary.

Monitoring of Adverse Events

Throughout the procedure and subsequent postoperative period, vigilant monitoring for adverse events was performed. Particular attention was directed towards hemodynamic stability, with specific thresholds established for bradycardia (heart rate < 60 bpm or a reduction of 20% from baseline) and hypotension (a 20% decrease in systolic blood pressure). The occurrence and nature of any adverse events were meticulously documented to facilitate a thorough assessment of the safety and tolerability of the TAP block procedure.

The primary objective was to investigate the effect of the TAP block on postoperative analgesic requirements, including opioid, paracetamol, tramadol, and Neodolpasse consumption, as well as the time to first analgesic request, regardless of the analgesic agent used.

Continuous variables were analyzed using Welch's two-sample t-test when the data approximated a Gaussian distribution. In cases where normality could not be assumed, the Brunner-Munzel test, a generalization of the Wilcoxon rank-sum test, was applied. For categorical variables, Pearson's Chi-squared test was employed when the binomial distribution could reasonably be approximated by the normal distribution; otherwise, Fisher's exact test was used.

Results are presented as mean ± standard deviation (SD) for normally distributed continuous variables and as median with interquartile range (IQR) for non-normally distributed data. Categorical variables are reported as absolute frequencies and percentages. A p-value of less than 0.05 was considered statistically significant.

Results

In this prospective, non-randomized study of 119 patients (Group A: TAP block, n = 54; Group B: no block, n = 65), baseline demographics and clinical variables - including sex, age, BMI, and ASA classification - were comparable (all $p > 0.05$), confirming the homogeneity of the cohorts (*Table 1*).

This demographic parity enhances the internal validity of subsequent comparative analyses, suggesting that any postoperative differences observed are more likely attributable to the intervention - rather than confounding demographic imbalances.

The distribution of gender between the two groups revealed no statistically significant difference ($p = 0.59$). Group A included 35% females and 65% males, while Group B reported 40% females and 60% males.

Mean patient age did not differ significantly (Group A: 68 ± 9 years vs. Group B: 67 ± 7 years; $p=0.32$). This is noteworthy, as advanced age may influence pain sensitivity and opioid metabolism,

Table 1. Baseline demographic characteristics of the study population

Variable	Group A (TAP Block) N = 54	Group B (No Block) N = 65	p-value[1]
Sex, n (%)			0.59
- Female	19 (35%)	26 (40%)	
- Male	35 (65%)	39 (60%)	
Age (Mean ± SD)	68±9 years	67±7 years	0.32
Body Mass Index (BMI) (Mean ± SD)	29.31 ± 2.48	28.75±2.48	0.22
ASA Physical Status Classification, n (%)			0.39
- ASA II	25 (46%)	25 (38%)	
- ASA III	29 (54%)	40 (62%)	

[1]Brunner-Munzel test; Fisher's exact test; Pearson's Chi-squared test.

yet the matched means mitigate concerns over age-driven outcome disparities.

The American Society of Anesthesiologists (ASA) physical status classification, an important indicator of preoperative health, was balanced across both groups (p=0.39). ASA II patients constituted 46% of Group A and 38% of Group B, while ASA III patients were 54% and 62%, respectively.

BMI values were similarly distributed across the two groups (Group A: 29.31 ± 2.48 vs. Group B: 28.75 ± 2.48; p = 0.22). The absence of significant difference here indicates that body composition, a variable known to affect both surgical complexity and analgesic pharmacokinetics, was not a confounding factor.

The analysis of surgical characteristics indicates a marked distinction in the distribution of surgery types between the two study groups, with a statistically significant difference noted (p=0.002) (*Table 2*).

A significant difference was observed in the distribution of surgery types (p=0.002). While Group A had a higher proportion of Type 1 surgeries (53% vs. 37%), Group B showed a markedly higher representation of Type 2 procedures (26% vs. 4%).

The average duration of surgery was almost identical between the two groups (Group A: 244 ± 58 minutes vs. Group B: 247 ± 49 minutes; p= 0.83). This indicates uniform surgical exposure and physical trauma, minimizing the likelihood that intraoperative duration influenced post-operative analgesia needs.

Conversely, the estimated intraoperative blood loss and surgical duration appear statistically indistinguishable between Group A and Group B (p=0.41 and p=0.83, respectively). These results suggest that technical demands and hemodynamic burden were consistent across cohorts, indicating comparable operative complexity, except for the difference in surgical type previously mentioned.

In this study, patients who received a transversus abdominis plane (TAP) block demonstrated a reduced requirement for supplemental analgesics and exhibited a significantly prolonged interval before the first analgesic request when compared to the control cohort. These findings support the incorporation of the TAP block as an integral element of multimodal analgesia in laparoscopic colorectal surgery, particularly in mitigating non-opioid analgesic consumption and enhancing early postoperative patient comfort (*Table 3*).

Total opioid consumption, the primary end-

Table 2. Surgical Characteristics of the Study Population

Variable	Group A (TAP Block) N = 54	Group B (No Block) N = 65	p-value[1]
Estimated Blood Loss (Mean ± SD)	273 ± 297 mL	238 ± 79 mL	0.41
Type of Surgery, n (%)			0.00
- Type 1 Low anterior resection	29 (53%)	24 (37%)	
- Type 2 Right side colonic resction	2 (4%)	17 (26%)	
- Type 3 Left side colonic resection	16 (30%)	9 (14%)	
- Type 4 Subtotal colectomy	4 (8%)	8 (12%)	
- Type 5 Creation of stoma	3 (5%)	7 (11%)	
Surgery Duration (Mean ± SD)	244 ± 58 min	247 ± 49 min	0.83

[1]Brunner-Munzel test; Fisher's exact test; Pearson's Chi-squared test.

Table 3. Postoperative analgesic consumption and time to first analgesic request

Variable	Group A (TAP Block) N = 54	Group B (No Block) N = 65	p-value[1]
Opioid Dose (Median, IQR)	18 (8.00)	18 (2.00)	0.128
Time to First Analgesic (Median, IQR)	8 (0.00)	5 (1.00)	<0.001
Paracetamol Dose (Median, IQR)	4 (2.00)	4 (0.00)	0.011
Tramadol, n (%)			0.003
- 50 mg	0 (0%)	14 (22%)	
- 100 mg	15 (28%)	12 (18%)	
- 150 mg	5 (9%)	8 (12%)	
- 200 mg	34 (63%)	31 (48%)	
Neodolpasse, n (%)			0.021
- 250 mg	3 (6%)	13 (20%)	
- 500 mg	31 (57%)	39 (60%)	
- 750 mg	20 (37%)	13 (20%)	

[1]Brunner-Munzel test; Fisher's exact test; Pearson's Chi-squared test.

point, did not significantly differ between the TAP block and control groups (p=0.128). This result indicates that the TAP block, when used in the context of multimodal analgesia, does not independently reduce opioid requirements. This may reflect the effectiveness of the opioid-sparing strategies already in place for both groups, which were comprehensive and included systemic analgesics (*Fig. 2*).

Paracetamol consumption was significantly lower in the TAP block group (p=0.011). This reduction in non-opioid analgesic use underscores the potential of TAP block to reduce the need for additional analgesics, further supporting its role in multimodal pain management. The result high lights the TAP block's efficacy in targeting somatic pain in the abdominal region, thereby reducing the reliance on medications such as paracetamol (*Fig. 3*).

There was a significant difference in tramadol consumption between the groups (p=0.003). Fewer patients in the TAP block group required

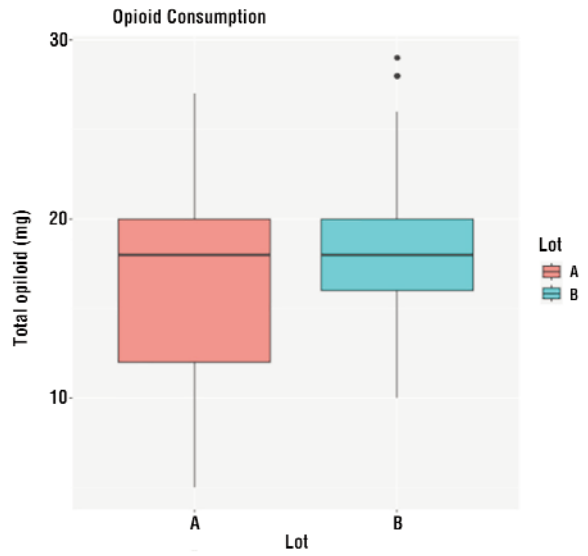

Figure 2. A comparative analysis of opioid dosing between two groups: the TAP block group and the control group. Both groups have a median opioid dose of 18, indicating that they required similar amounts of opioids for pain smanagement.

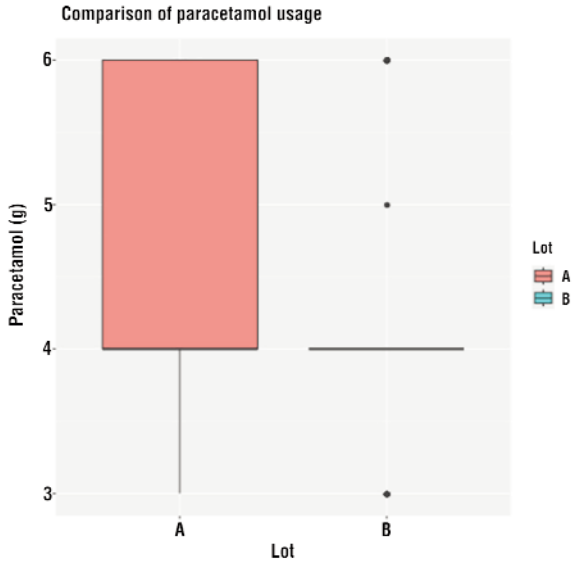

Figure 3. The significant reduction in paracetamol consumption observed in the TAP block group, with a p-value of 0.011 indicating statistical significance.

the lowest 50 mg dose of tramadol, suggesting that TAP block provided better control over postoperative pain. Additionally, a larger proportion of patients in the TAP block group required the higher 200 mg dose of tramadol, which may reflect reduced cumulative need for analgesic intervention over time.

Neodolpasse use was significantly reduced in the TAP block group (p=0.021), with a lower requirement for smaller doses in this group. This reinforces the idea that TAP block provides superior analgesia, particularly for somatic pain, which is often treated with non-opioid analgesics like Neodolpasse. The significant reduction in use of smaller doses also suggests improved overall pain control.

Patients who received a TAP block demonstrated a significantly longer time to first analgesic request and lower consumption of adjunctive analgesics (paracetamol, tramadol, and Neodolpasse), although total opioid use did not differ significantly between groups.

In the second outcome we evaluated the time to first analgesic requirement between the TAP block group and the control group. The results indicated that the median time to first analgesic administration was significantly longer in the TAP block group, at 8 hours (interquartile range: 0.00), compared to 5 hours (interquartile range: 1.00) in the control group. The statistical analysis yielded a p-value of <0.001, confirming a significant difference between the two groups (*Fig. 4*).

These findings suggest that the TAP block effectively prolongs the time before patients necessitate additional analgesics, thereby indicating its potential role in enhancing pain management strategies. The results underscore the TAP block's efficacy in providing sustained analgesia, contributing to improved postoperative care and patient comfort.

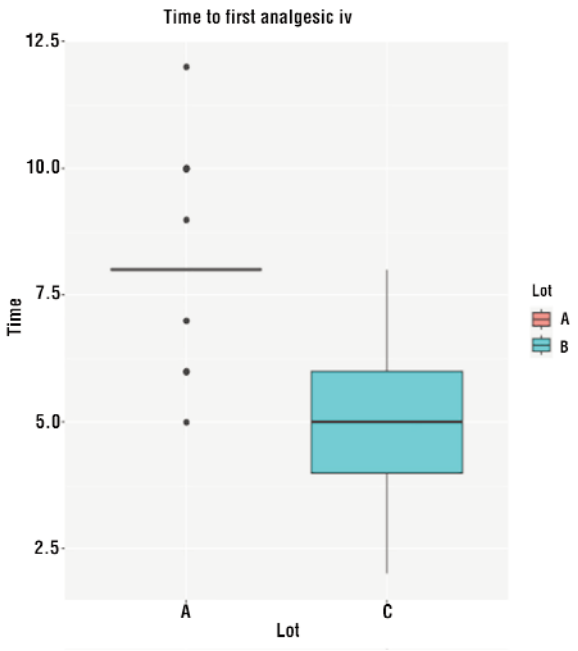

Figure 4. The comparison of time to first analgesic requirement, showing that patients in the TAP block group experienced a longer duration before needing additional analgesics compared to those in the control group, emphasizing the TAP block's effectiveness in enhancing pain management.

Discussion

Despite the lack of a significant difference in total opioid consumption, the findings support the conclusion that TAP block is effective at sparing the use of non-opioid analgesics. The reduced need for nonopioid medication indicates that TAP block contributes to a more balanced pain management approach by enhancing early postoperative analgesia (18).

The observed effects of the TAP block on delaying analgesic request and reducing non-opioid analgesic use suggest that its primary benefit lies in its ability to provide early and sustained pain relief, rather than in reducing opioid consumption alone. This emphasizes the TAP block's role as a complementary component of a multimodal pain management strategy (19,20).

The significant delay in the need for rescue analgesia in the TAP block group suggests that patients experienced better early postoperative comfort, which could facilitate a smoother emergence from anesthesia and quicker recovery. The TAP block may contribute to improved patient satisfaction by reducing the need for frequent analgesic administration (21,22).

These results further underscore the importance of TAP block in the context of multimodal analgesia. Although the TAP block did not reduce opioid consumption significantly, it played a crucial role in reducing reliance on adjunct analgesics, enhancing the overall efficacy of the pain management strategy (23).

The significant prolongation of time to first analgesic request, combined with reduced consumption of non-opioid analgesics, suggests that TAP block is particularly beneficial in the early postoperative phase, where pain control is

critical for recovery (24).

The role of TAP block in reducing postoperative analgesic consumption aligns with principles of Enhanced Recovery After Surgery (ERAS) protocols, which emphasize minimizing the use of opioids and promoting faster recovery. The findings support the incorporation of TAP block as TAP block offers an effective solution for postoperative pain control in laparoscopic colorectal surgery. By delaying the need for rescue analgesia and reducing the consumption of adjunct pain relief, TAP block improves the overall postoperative experience. The volume of intraoperative blood loss, a parameter known to impact perioperative hemodynamic stability and recovery, did not differ significantly between the two groups (Group A: 273 ± 297 mL vs. Group B: 238 ± 79 mL; $p = 0.41$)(25,26).

Despite the positive outcomes observed with the TAP block in terms of non-opioid analgesic sparing, it did not significantly reduce opioid consumption. This indicates that while TAP block is an effective adjunct, it may not be sufficient as a sole analgesic approach for managing postoperative pain in all patients (27).

The results reaffirm the value of TAP block within a broader multimodal pain management framework. By reducing the need for adjunct analgesics, the TAP block helps to optimize pain management without significantly altering opioid consumption patterns (28).

While the lack of a significant reduction in opioid consumption may seem disappointing, the significant prolongation of time to first analgesic request and reduced need for non-opioid analgesics represent clinically meaningful improvements in postoperative pain management (29).

Although patient satisfaction was not directly measured, the prolonged time to first analgesic request and reduced use of additional analgesics suggest that the TAP block contributes to a more comfortable and quicker recovery process, potentially enhancing patient outcomes and satisfaction (30).

The findings support the integration of TAP block as a routine part of the multimodal analgesia protocol in laparoscopic colorectal surgery, particularly for its role in delaying the need for rescue analgesia and minimizing the use of adjunct non-opioid analgesics (31,32).

The study demonstrates that the TAP block can effectively complement opioid-based pain management strategies by reducing the need for adjunct analgesics, supporting its role in multimodal pain management (33).

This study provides evidence for incorporating TAP block into postoperative pain management protocols, particularly for its ability to delay the need for further analgesia and reduce reliance on non-opioid medications (34).

Future Research Directions

Further research is warranted to explore whether combining TAP block with other regional analgesia techniques could further reduce opioid consumption and enhance postoperative recovery outcomes. Given its efficacy in reducing non-opioid analgesic use and improving pain control, TAP block may become a key component of Enhanced Recovery After Surgery (ERAS) pathways for laparoscopic colorectal surgery.

Limitation

The limitations of this study include issues related to the subjective nature of pain assessment, the lack of randomization, and insufficient long-term follow-up data on the efficacy of TAP block in postoperative pain management, thereby underscoring the necessity for further research to validate and expand upon the findings presented.

Conclusions

While the TAP block did not significantly reduce opioid consumption, its impact on reducing non-opioid analgesic use and prolonging the time to first analgesic request suggests it is a valuable adjunct in multimodal pain management strategies for laparoscopic colorectal surgery.

In summary, the results support the TAP block as an effective strategy for enhancing postoperative analgesia, particularly in the early recovery phase. Its ability to reduce reliance on non-opioid analgesics and delay the need for additional pain relief highlights its potential to improve patient comfort and recovery outcomes.

Author's Contributions

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data.

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Conflicts of Interest

The authors declare no conflicts of interest.

Funding

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Ethical Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Fundeni Clinical Institute Ethics Committee (Study No. 1891/2025).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement

The raw data supporting the conclusions of this article will be made available by the authors on request.

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