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ORIGINAL RESEARCH

External oblique intercostal plane block versus subcostal transversus abdominis plane block for pain control in supraumbilical surgeries: a randomised controlled clinical trial

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Background: The external oblique intercostal block (EOIB) was designed to provide upper median and lateral abdominal wall analgesia. Its efficacy was mainly explored in case reports and retrospective studies. Our study aimed to prospectively assess EOIB efficacy in open supraumbilical procedures compared to subcostal transversus abdominis plane (TAP) blockade for pain control in the first 24 postoperative hours.

Methods: A total of 63 adult patients scheduled for variable upper abdominal procedures involving supraumbilical incision were allocated randomly to three groups (21 each). After induction of general anaesthesia, patients received either EOIB (group E), subcostal TAP block (group T), or no block (group C). The primary study outcome was morphine consumption in the first 24 postoperative hours. Secondary outcomes included intraoperative fentanyl supplements, haemodynamic variables, time to first rescue analgesia, postoperative Visual Analogue Scale (VAS) scores, the occurrence of complications, and patient satisfaction.

Results: The 24-hour postoperative morphine consumption and time to first rescue analgesia were significantly lower and longer, respectively, in the EOIB and subcostal TAP groups compared to the control group ($p < 0.001$) without significant differences between the intervention groups. VAS scores at rest and during cough were significantly higher in the control group than in the intervention groups. However, EOIB achieved less intraoperative fentanyl requirements than subcostal TAP ($p = 0.04$), with better haemodynamic stability and longer control of pain than the control group.

Conclusion: The EOIB is as effective as subcostal TAP in delivering optimal analgesia and reducing perioperative opioid requirements. Considering the intraoperative advantages of EOIB in terms of lower fentanyl needs and better haemodynamic control, the EOIB is an attractive substitute for postoperative pain reduction following open upper abdominal surgeries.

Keywords: abdominal incisions, external oblique, TAP block, postoperative, analgesia, nerve blocks

Introduction

Supraumbilical surgical incisions, such as subcostal laparotomy, can cause severe postoperative pain, significant respiration impairment, and prolonged recovery. Integrating these open procedures into the Enhanced Recovery After Surgery (ERAS) programme requires identifying suitable analgesic alternatives to provide optimal pain control and avoid delayed functional recovery.[1]

Regional anaesthetic techniques have been developed to produce adequate analgesia while minimising the use of opioids that have multiple negative effects. For many years, the gold standard for major abdominal surgeries has been epidural analgesia, which carries serious complications. However, it could not always provide clinically significant differences in pain management compared to ultrasound-guided fascial plane blocks that have evolved as a fast-growing substitute for neuraxial methods.[2]

Somatic sensation in the upper abdominal wall originates mainly from the lateral and anterior cutaneous branches of lower intercostal (T6–T10) nerves; thus, targeting these nerves can block the surgical incisional pain in this region.[3] One of the traditional field blocks frequently employed during laparotomies is the TAP block, with three main approaches based on the site of anaesthetic infiltration: subcostal, lateral, or posterior. The analgesic action of the subcostal TAP block extends to cover upper abdominal dermatomes (T6–T9). However, this approach mainly anaesthetises the median abdominal region while leaving the lateral regions unblocked. Therefore, it cannot adequately cover all surgical sites above the umbilicus.[4]

A novel modification of the fascial plane blocks that may effectively cover the upper lateral abdomen is the EOIB, introduced by Hamilton et al.[5] in 2018. They suggested that if local anaesthetic (LA) is injected into a thoracic fascial plane, it can extend to block the lateral cutaneous intercostal branches and provide adequate analgesia for upper median and subcostal abdominal incisions.[5]

In addition to the potential analgesic efficacy of EOIB, the distant access point from vascular structures offers a substantially lower risk when used in anticoagulated patients.[6] Moreover, the superficial approach of the block is favourable in obese patients compared to traditional regional procedures. The possibility of placing a catheter away from the surgical site with no need for special patient positioning is also beneficial for patients in acute pain.[7]

Despite the promising results that EOIB has shown in various situations, its analgesic effectiveness has not yet been adequately tested in randomised clinical trials or compared to the widely performed subcostal TAP block.[7] In this study, we hypothesised that ultrasound-guided EOIB would provide effective analgesia for supraumbilical surgical incisions and might be a better alternative to subcostal TAP block due to its lateral spread in the abdominal wall.

Methods

After approval of the institutional ethics committee board (reference number RC.1-5-2022) and obtaining written informed consent from the participants, this prospectively randomised controlled double-blinded trial was performed on patients undergoing supraumbilical surgeries at Benha University Hospital from June 2022 to August 2023. The study was registered prospectively in clinicaltrials.gov (NCT05432557) and was conducted in compliance with the 2013 Helsinki Declaration.

A total of 63 patients of both genders, aged 20–60 years, with a body mass index (BMI) ≤ 30 kg/m^2, American Society of Anesthesiologists (ASA) class I or II, and scheduled for elective supraumbilical surgeries with midline or lateral incisions (epigastric hernia repair, gastrectomy, open cholecystectomy, splenectomy) under general anaesthesia were included in the trial. Patients with a history of allergy to the used LA drugs, cutaneous lesions at the needle entry point, coagulation disorders, sepsis, hepatic dysfunction, psychiatric diseases, or a history of prolonged opioid use were excluded from the trial.

The participants enrolled in the trial were randomly allocated to three groups (21 each) using a random table list generated by computer at a 1 : 1 : 1 ratio. An independent anaesthesia coordinator opened the opaque, sealed envelopes (used to hide the group assignments) and prepared the LA mixture in 20 ml volume (10 ml bupivacaine 0.5%, 5 ml lidocaine 2% and 5 ml isotonic saline). The coordinator reported the type of assigned block to the anaesthetist performing the block following anaesthesia induction. Patients in group E received ultrasound-guided EOIB with 20 ml LA mixture, group T received ultrasound-guided subcostal TAP block with 20 ml LA mixture, while group C (control group) did not receive any injections. The patients were blinded to random group assignment as they received the block after general anaesthesia induction. Additionally, the investigator was not involved in patient enrolment and anaesthesia management and could not communicate any data about study groupings to the study coordinator, anaesthesiologist, or surgeon.

Standard monitoring equipment (electrocardiogram, pulse oximetry, and non-invasive blood pressure monitoring) was applied in the operating theatre. Each patient was premedicated with 2 mg of midazolam and 4 mg of ondansetron through a secured intravenous (IV) line. To induce general anaesthesia, IV propofol (1.5 mg/kg), fentanyl (1–2 µg/kg), and rocuronium (0.6 mg/kg) were administered. A single senior anaesthesiologist with four years' experience in pain management performed the two blocks using a General Electric ultrasound machine (LOGIQ e, GE HealthCare, United Kingdom) and a high-frequency linear probe (6–13 MHz) to perform the blocks after anaesthesia induction and before the surgical incision.

Patients in group E (EOIB) were positioned supine, and the ultrasound probe was placed on the anterior thoracic wall medial to the anterior axillary line by 1–2 cm, at the sixth level intercostal space, with a paramedian sagittal oblique view produced by slight angulation of the cranial end medially. The following structures were visualised from superficial to deep: subcutaneous tissues, external oblique muscle, intercostal muscles, pleura, and the lung (Figure 1). The needle was introduced using the in-plane approach in a craniocaudal direction to place the needle endpoint at the tissue plane between the external oblique muscle and intercostal muscles. A testing dose of saline was injected for hydrodissection to allow needle advancement towards the ribs. Then, LA was injected until a good elevation of the muscle occurred. The block technique was performed bilaterally if needed.

Patients in group T (subcostal TAP block) were positioned supine, and the ultrasound probe was located obliquely along the subcostal border close to the xiphisternum. The transversus abdominis muscle beneath the rectus abdominis was identified (Figure 1). Using the in-plane approach, the block needle was advanced through the rectus muscle from cephalad to caudal direction towards the transversus abdominis muscle. Then, the LA mixture was injected into the tissue plane between the two muscles. The block technique was performed bilaterally if needed.

Inadequate pain control intraoperatively was managed by fentanyl bolus (1 µg/kg) based on heart rate (HR) or mean arterial pressure (MAP) increases by 25% from the baseline, provided that other reasons (such as lighter plane of anaesthesia, muscle relaxation, need for fluid replacement, or recent vasopressor injection) were fulfilled. By the end of surgery, all patients received IV paracetamol (1 g) and IV ketorolac (30 mg) before being extubated. For postoperative analgesia, patients received IV paracetamol (1 g/6 h) and ketorolac (30 mg/8 h) on a regular basis. When the VAS score exceeded 3, IV morphine was titrated on a regular dose of 0.05 mg/kg bolus and was repeated every

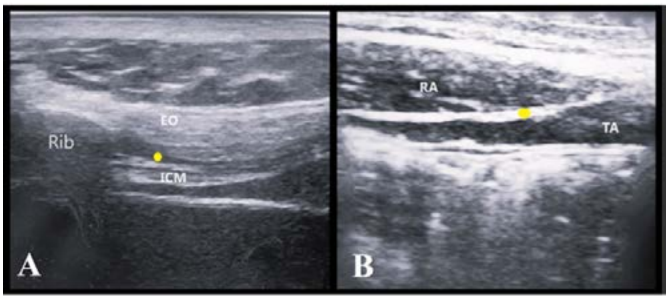

Figure 1: Ultrasound imaging of (A) external oblique intercostal plane and (B) subcostal transversus abdominis plane; yellow dot indicates the site of local anaesthetic injection

EO – external oblique, ICM – intercostal muscles, RA – rectus abdominis, TA – transversus abdominis

5–10 minutes until response.[8] After the study, patients were requested to evaluate their level of satisfaction regarding the analgesia regimen using a 5-point Likert scale, where 1 indicates "extremely dissatisfied", 2 "unsatisfied", 3 "unsure", 4 "satisfied", and 5 "extremely satisfied".

The primary outcome of the study was the amount of morphine consumption in the first 24 postoperative hours. The secondary outcomes were postoperative VAS scores during rest and coughing at 0, 2, 6, 12, 18, and 24 hours, time to first opioid request (VAS > 3), intraoperative fentanyl consumption, intraoperative vital signs including MAP and HR (before and after surgical incision, after one hour, and at the end of surgery), block-related complications (haematoma, viscus or pleural injury, LA toxicity, and respiratory depression), length of hospitalisation, and the degree of patient satisfaction.

The patients' data were statistically analysed using Statistical Package for Social Sciences (SPSS) v.25 software (IBM, Armonk, New York, United States). The normality of quantitative variables was determined by the Shapiro-Wilk test and Q-Q plots. Mean (± standard deviation, SD) and median (± interquartile range, IQR) were used to report continuous variables. Frequencies and percentages were used to report categorical variables. The analysis of variance (ANOVA) was used to analyse the numerical data (opioid use, pain scores, vital signs, and hospital stay) of the three groups, and post hoc analysis with Bonferroni correction was utilised to identify significant differences between each two groups, while the chi-square test (χ2) was employed to assess qualitative data (demographic criteria, type of surgeries, and patient satisfaction). The t-test was used to compare the time of block performance values. A *p*-value below 0.05 was regarded as statistically significant.

The sample size was estimated using the outcomes of a pilot trial with seven patients in each group, which revealed that the means of the 24-hour morphine intake in the EOIB, subcostal TAP, and control groups were 7.86, 8.57, and 11.86 mg, respectively, and the SD was 3.78. According to G*Power 3.1 (Heinrich Heine University, Düsseldorf, Germany), a sample size of 21 patients in each group was required when effect size = 0.461, α-error = 0.05 (statistically significant level), and 1-β = 0.9 (power of a test) were given.

Results

Initially, 68 patients scheduled for elective surgical procedures involving upper abdominal incisions were eligible to join the study. Five patients were excluded due to declining to participate (two patients) or not meeting the inclusion criteria (two patients for coagulopathy and one for sepsis). A total of 63 patients fulfilled the inclusion criteria, and their data were utilised for final analysis (Figure 2). The demographic criteria of the patients and clinical criteria of the anaesthetic and surgical procedures were comparable among the three groups, with no statistically significant differences (Table I).

Regarding the 24-hour postoperative morphine requirements, patients receiving EOIB or subcostal TAP had significantly

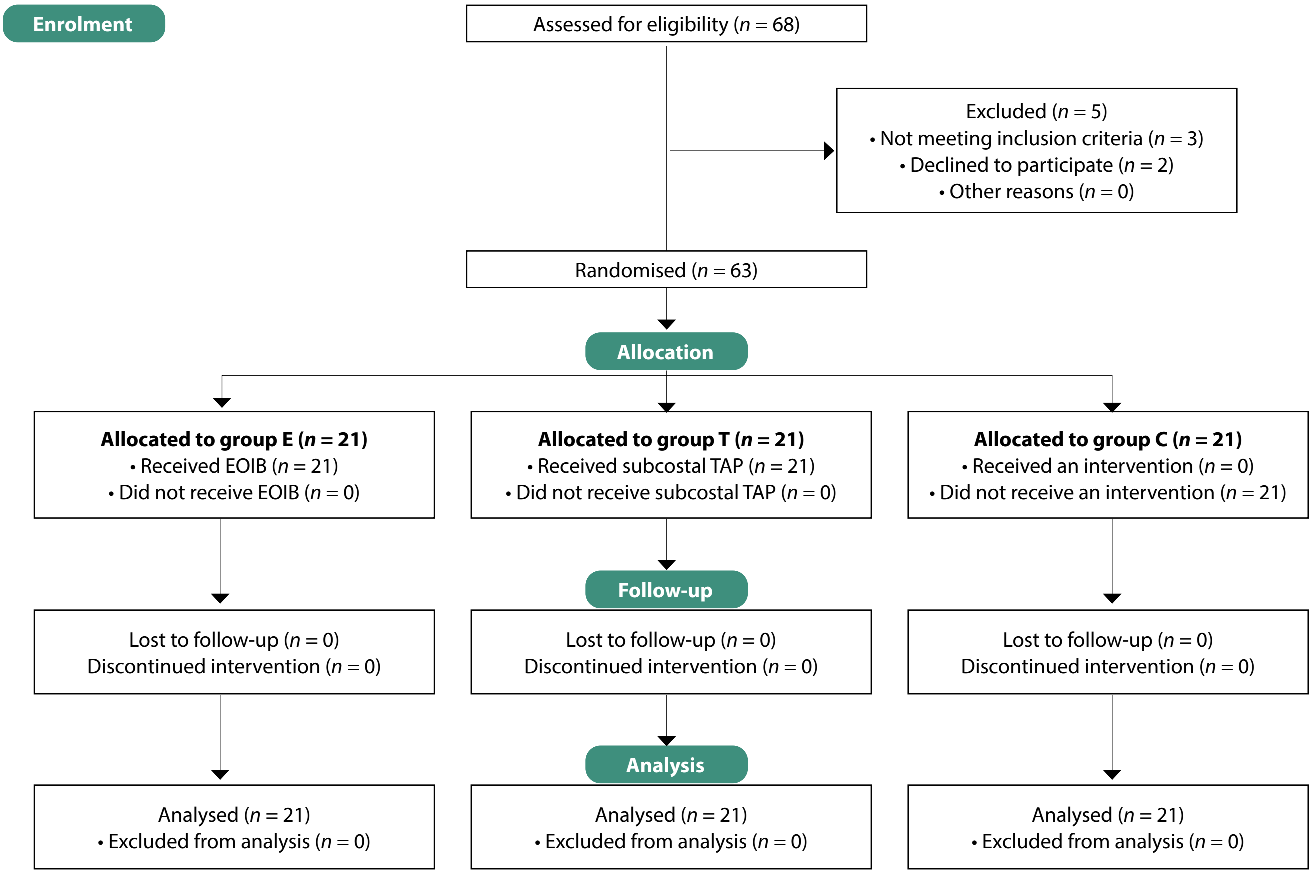

Figure 2: CONSORT flow chart of the studied groups

Table I: Demographic and clinical characteristics of the three study groups

			Group E (*n* = 21)	**Group T (*n* = 21)**	**Group C (*n* = 21)**	***p*-value**
Age (years)			38.65 (13.45)	35.45 (13.26)	37.95 (14.04)	0.737
BMI (kg/m²)			23.65 (3.67)	24.4 (4.89)	23.75 (4.28)	0.837
Gender *n* (%)	**Male**		11 (52.4)	12 (57.1)	9 (42.9)	0.641
	Female		10 (47.6)	9 (42.9)	12 (57.1)	
ASA status *n* (%)	**I**		12 (57.1)	14 (66.7)	11 (52.4)	0.632
	II		9 (42.9)	7 (33.3)	10 (47.6)	
History of previous surgeries	**Yes *n* (%)**		7 (33.)	6 (28.6)	5 (23.8)	0.792
	No *n* (%)		14 (66.7)	15 (71.4)	16 (76.2)	
Type of surgery *n* (%)	**Midline incision**	**Herniotomy**	6 (28.6)	7 (33.3)	9 (42.9)	0.968
		Gastrectomy	2 (9.5)	2 (9.5)	1 (4.7)	
	Lateral incision	**Cholecystectomy**	10 (47.6)	9 (42.9)	9 (42.9)	
		Splenectomy	3 (14.3)	3 (14.3)	2 (9.5)	
Duration of surgery (minutes)			112.25 (22.76)	116.25 (21.88)	109.5 (20.83)	0.619
Duration of anaesthesia (minutes)			122.25 (22.97)	125.5 (21.64)	120.5 (22.12)	0.772
Time to perform the block (minutes)			6.4 (1.54)	7.35 (1.66)	___	0.068

Data presented as mean (SD) and number (%).
BMI – body mass index, ASA – American Society of Anesthesiology

Table II: Opioid utilisation and postoperative outcomes

		Group E (*n* = 21)	**Group T (*n* = 21)**	**Group C (*n* = 21)**	**95% CI**	***p*-value**
Total postoperative morphine demand (mg/24 h)		9.2 (3.36)	10.5 (4.56)	16.3 (4.96)	10.62 to 13.35	< 0.001*
Time to first rescue analgesic request (h)		6.65 (1.95)	5.8 (2.21)	2.12 (0.94)	4.17 to 5.54	< 0.001*
Total intraoperative fentanyl demand (µg)		130.25 (28.21)	150.5 (24.06)	203.75 (23.33)	151.19 to 171.81	< 0.001*
Hospital stays (days)		2.25 (1.02)	2.35 (1.14)	2.7 (1.30)	2.13 to 2.73	0.440
Patient satisfaction score *n* (%)	**Unsatisfied**	3 (14.3)	2 (9.5)	6 (28.6)	3.34 to 3.82	0.310
	Unsure	3 (14.3)	5 (23.8)	7 (33.3)		
	Satisfied	10 (47.6)	11 (52.4)	6 (28.6)		
	Extremely satisfied	5 (23.8)	3 (14.3)	2 (9.5)		

Data presented as mean (SD), number (%), and median (IQR).
* Statistically significant at $p \leq 0.05$
CI – confidence interval

Table III: Mean arterial pressure and heart rate of the studied groups at different timepoints

	Group E (*n* = 21)	**Group T (*n* = 21)**	**Group C (*n* = 21)**	***p*-value**
MAP basal	95.05 (6.3)	93.85 (4.08)	94.45 (8.45)	0.845
MAP at skin incision	91.3 (4.12)	93.25 (4.76)	98.95 (10.3)	0.003*
MAP at 1 h	90.9 (6.16)	91.6 (5.29)	93.75 (6.72)	0.311
MAP at surgery end	89.35 (3.01)	90.5 (3.24)	92.05 (2.96)	0.026*
HR basal	83.35 (5.37)	81.45 (4.05)	82.1 (4.45)	0.428
HR at skin incision	82.05 (10.41)	84.9 (11.57)	96.75 (12.49)	< 0.001*
HR at 1 h	74.9 (9.85)	76.75 (11.38)	83.55 (11.64)	0.040*
HR at surgery end	73.75 (8.88)	77.15 (10.88)	80.65 (11.50)	0.124

Data presented as mean (SD) and number (%).
* Statistically significant at $p \leq 0.05$
HR – heart rate, MAP – mean arterial pressure

lower doses than those receiving no block ($p < 0.001$), with an insignificant difference between the two groups. Also, the time needed to request rescue opioids was longer in patients receiving blocks than in controls ($p < 0.001$) (Table II).

The intraoperative fentanyl demand was lower in group E and group T than in group C ($p < 0.001$). However, group E was superior to group T in terms of lower fentanyl utilisation intraoperatively ($p = 0.04$). No significant differences were noted among the studied groups regarding the length of hospitalisation and patient satisfaction score (Table II). Also, no block-related complications were observed in the intervention groups.

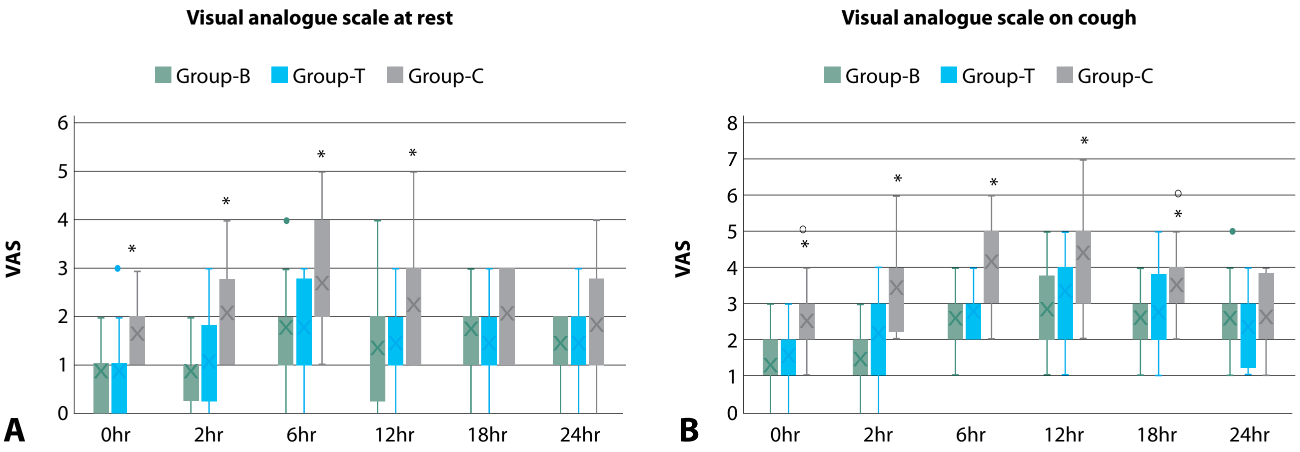

Figure 3: VAS scores for pain at rest (A) and on cough (B) at various timepoints over the first 24 hours after surgery; values are presented as median (IQR)
* Statistically significant at $p \leq 0.05$

The MAP and HR readings at skin incision increased significantly in the control group compared to the intervention groups (*p* < 0.05). Group E showed lower MAP by the end of surgery and lower HR one hour after surgical incision than the control group (*p* = 0.02 and *p* =0.04, respectively). However, group T did not achieve any significant differences compared to controls at the same timepoints. Otherwise, no significant differences between the intervention groups were observed (Table III).

Postoperative VAS scores at rest were significantly lower in the intervention groups than controls at timepoints (0 h, 2 h, 6 h). The VAS scores during cough were significantly lower (0 h, 2 h, 6 h, 12 h) with no statistically significant difference between the EOIB and subcostal TAP groups. However, group E showed lower VAS scores at 12 hours during rest and 18 hours on coughing than the control group (*p* = 0.03 and *p* = 0.03, respectively). Nonetheless, group T did not achieve any significant differences compared to controls at the same timepoints (Figure 3).

Discussion

Our study compared the effectiveness of the EOIB versus the subcostal TAP block and controls in patients undergoing abdominal surgeries involving supraumbilical incisions. Our results demonstrated a better analgesic profile (perioperative opioid requirements, time to first rescue opioid request, and VAS scores) and more intraoperative haemodynamic stability without evident complications associated with EOIB and subcostal TAP block compared to controls. Despite the comparable results observed in both intervention groups, the EOIB group achieved statistically significant lower fentanyl requirements intraoperatively than the subcostal TAP group. The EOIB showed better control of MAP and HR compared to controls at different timepoints, but subcostal TAP did not achieve a similar difference compared to controls. Also, the EOIB allowed longer control of pain scores during rest (up to 12 h) and with cough (up to 18 h) than controls, while subcostal TAP reduced pain scores up to six hours at rest and 12 hours with cough compared to controls.

Our results are consistent with the retrospective study by Coşarcan et al.[9] on 120 patients who underwent laparoscopic bariatric surgeries. They noted that subcostal TAP and EOIB techniques reduced opioid usage significantly in the first 24 postoperative hours compared to anaesthesia deficient of regional techniques with no intergroup differences.[9]

To date, there are few clinical trials, mostly case reports, assessing the analgesic efficacy of EOIB, with no previous randomised clinical trial comparing EOIB with subcostal TAP block for upper abdominal incisions. O'Donovan and Martin's case report observed a remarkable decrease in opioid needs with the application of a surgically positioned catheter superficial to the external oblique muscle during open cholecystectomy in a high-risk patient.[6] The VAS scores, immediately postoperative, were 0/10 at rest and 3/10 with palpation or movement.[6] Coşarcan and Erçelen, in their case reports of three different surgeries, observed that performing EOIB in combination with TAP block lowered the Numeric Rating Scale (NRS) scores in the recovery room, reduced opioid needs in the first 72 postoperative hours, and had greater patient satisfaction.[10] Also, White and Ji described two occasions of EOIB with catheter placement in morbidly obese patients who were contraindicated for paravertebral and thoracic epidural blocking, and they reported decreased pain scores (0/10) at rest and on deep breath in the early postoperative period.[11]

The superior analgesic properties of EOIB over subcostal TAP are likely due to the type of blocked nerves and the injection site. The initial report by Hamilton et al.[12] hypothesised that EOIB could provide analgesia to the anterior and lateral abdominal walls, supporting their hypothesis by a cadaver study that examined the dye distribution after performing EOIB. The study showed that the anterior divisions of the lateral cutaneous branches of the thoracoabdominal nerves from T6 to T10 were effectively stained.[12]

A cadaveric and retrospective study by Elsharkawy et al.[13] confirmed the previous results by collecting the data from 22 patients who received either single injections or continuous EOIB. They stated that the sensory dermatomal block extended to cover the area from the midline medially to the posterior axillary line laterally, with sensory dermatomal spread from T6 to T10 in all patients. Also, after performing ultrasound-guided EOIB in two cadaveric specimens, the dye spread widely to stain both lateral and anterior divisions of intercostal nerves from T7 to T10. They described the EOIB as a promising technique that targets the upper abdominal region, which the previous fascial plane blocks have not adequately covered.[13]

Conversely, the subcostal TAP block failed to adequately block the lateral regions of the upper abdomen even with its variable approaches. Injecting LA medial to the linea semilunaris, near the xiphoid process, produced spread around T6–T7, while injecting LA lateral to the linea semilunaris offered a block centred around T10–T11.[14,15] Since the lateral cutaneous branches were not blocked in either scenario, the subcostal TAP block applicability could be restricted in variable abdominal operations, including cholecystectomy, nephrectomy, or hepatic surgeries.[16]

Finally, the accessibility of the superficial external oblique intercostal plane compared to the traditional deep plane blocks represents a great advantage in obese patients, as described by Coşarcan et al.[9] and White and Ji's studies.[11] Coşarcan et al.[9] noted that the EOIB was easier to perform in patients with a mean BMI of 41.8 compared to TAP blocks because less adipose tissue is deposited at the target site, leading to better sonographic pictures and needle access. White and Ji also reported two cases with BMIs of 36 and 56, whose EOIB planes were accessible at 3 and 4 cm, respectively, when compared to the depth of the space required to do an erector spinae plane block (7–8 cm) in the second patient.[11]

Our study has some limitations that should be addressed. Firstly, we did not restrict the type of upper abdominal surgery, surgery duration, or incisional wound size. Such variabilities might result in different magnitudes of pain. Secondly, we did not examine the sensory block success in the early postoperative period because general anaesthetic agents may interfere with the accuracy of assessment. Instead, we relied on the pain score (VAS) as an indicator for indirect assessment of the blockade efficacy. Lastly, our study investigated the short-term outcomes of the first 24 hours following surgery, but long-term outcomes are undetermined.

Conclusion

In patients undergoing open supraumbilical surgeries, ultrasound-guided EOIB was as effective as subcostal TAP block with comparable postoperative cumulative morphine consumption, time to first opioid request, VAS scores, and patient satisfaction for 24 hours after surgery. However, the EOIB group revealed less fentanyl supplementation than subcostal TAP and better intraoperative haemodynamic stability with longer postoperative tolerable pain periods than the controls.

Conflict of interest

The authors declare no conflict of interest.

Funding source

None.

Ethical approval

International Review Board permission: Benha Faculty of Medicine ethical committee approval was obtained with reference number RC.1-5-2022. All procedures followed the ethical standards of the responsible committee on human experimentation (institutional and national) and complied with the Helsinki Declaration of 1975, as revised in 2008. Informed written consent was obtained from all patients included in the study. The trial was registered at clinicaltrials.gov with study ID number NCT05432557. The authors declare that this submission follows the principles laid down by the Responsible Research Publication Position Statements.

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