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Randomized Controlled Trial

Thoracic Intervertebral Foramen Blocks Compared to Midpoint-to-Pleura Transverse Process Blocks for the Management of Acute Rib Fracture Pain

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Disclaimer: This study received approval from the institutional review board of the ethics committee of the cities of L'Aquila and Teramo, Abruzzo, Italy, with decision number 10814/21. The trial is registered at clinicaltrials.gov (ID: NCT05348330).

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

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Background: Rib fractures can lead to intense acute pain, chest wall instability, and pulmonary complications in trauma patients, necessitating their admission to critical care units. Furthermore, these lesions represent a source of neuropathic disturbances.

Objectives: The goal was to compare continuous thoracic intervertebral foramen blocks (CTIFBs) to continuous midpoint-to-pleura transverse process blocks (CMTPBs), both guided by ultrasound, for their efficacy in managing acute pain caused by rib fractures.

Study Design: A double-blind, randomized controlled trial.

Setting: This research was conducted in the Intensive Care Unit (ICU) of San Salvatore Academic Hospital (L'Aquila, Italy) from December 2022 to November 2024.

Methods: Ninety-six adult trauma patients with rib fractures were randomized to receive either the CTIFB (experimental group; n = 48) or the CMPTB (control group; n = 48). The former block was performed by placing the tip of the needle over and behind the transverse process of the vertebra. In the latter block, the needle tip involved the midpoint between the pleura and transverse process. All patients received an initial bolus of 5 mL of levobupivacaine 0.25% with 4 mg of dexamethasone at each fracture level, followed by a continuous infusion (5 mL/h of levobupivacaine 0.25% with 16 mg of dexamethasone). The primary outcome was the proportion of patients who achieved pain control (Numeric Rating Scale [NRS] score ≤ 3) by 2 hours after the block. The secondary outcomes included neuropathic disturbances (assessed by von Frey hair and Lindblom tests), respiratory parameters (P/F ratio, spirometry, and diaphragmatic motion), and daily morphine consumption.

Results: Success (NRS score ≤ 3) was achieved in 21/48 patients (44%) in the experimental group and 3/48 patients (6%) in the control group ($P < 0.001$). Patients in the experimental group showed significant reductions in neuropathic disturbances ($F(5,470) = 18.5$, $P < 0.001$) and required less daily morphine (10.1 ± 3.9 mg versus 20.8 ± 4.5 mg, $P < 0.001$). Both groups demonstrated improved respiratory parameters, but patients in the experimental group showed superior airflow rates by 48 hours ($P = 0.004$) after the block.

Limitations: The anesthetic procedures were performed under ultrasound rather than fluoroscopic guidance. These techniques may have utility in chronic pain management, requiring fluoroscopy rather than ultrasound. This aspect of our research is not generalizable to chronic pain practice. Additionally, this study had a single-center design, and patients undergoing anticoagulation therapy, an important subgroup of trauma care, were excluded. Those factors might have limited generalizability to other clinical settings. Third, the follow-up period was relatively short, precluding the assessment of long-term outcomes such as chronic pain development or functional recovery. Finally, although improved respiratory parameters were observed, the study was not equipped to detect differences in clinical outcomes such as pneumonia rates or mortality.

Conclusion: For patients with rib fractures, the CTIFB offered superior pain management, fewer requests for opioids, and better respiratory function than did the CMTPB.

Key words: Rib fractures, acute pain, neuropathic disturbances, paravertebral catheters, midpoint transverse process to the pleura, intervertebral foramen, respiratory function, opioid-sparing techniques

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Rib fractures are very common in adult trauma patients. Multiple rib fractures cause severe pain, and these patients may benefit from opioid-sparing techniques (1,2) such as epidural analgesia (EA) and thoracic paravertebral blocks (TPVBs) (3). However, for trauma patients who also have thoracolumbar spine fractures, traditional regional anesthetic techniques may be inappropriate (4).

Rib fractures can lead to chest wall instability and pulmonary complications, necessitating the admission of the affected patients to critical care units (5). Furthermore, these lesions represent a source of neuropathic disturbances (NDs), which may result in chronic chest pain that leads to disabling discomforts (6) and a reduced quality of life. Safe and effective analgesia can be achieved using ultrasound-guided (USG) paravertebral catheters (7). Costache et al (8) described the midpoint transverse process to the pleura block (MTP), which involves the midpoint between the pleura and transverse process (TP) block, with paravertebral diffusion of the anesthetic solution. The continuous MTP block (CMTPB) has been demonstrated to be an effective technique for inducing analgesia in patients with multiple rib fractures (9).

Based on virtual dissections, cadaveric studies (10), and clinical observations, an alternative method was hypothesized to provide the analgesic solution spread into the thoracic paravertebral space (TPVS). A cadaveric study verified that the TPVS, retropleural organs, and epidural space (ES) were reachable by dye via the thoracic intervertebral foramen (TIF), in accordance with Shaw's hypothesis (11). This technique is identified as the TIF block (TIFB) (12,10).

This study hypothesized that the continuous TIF block (CTIFB, given to the experimental group [EG]) would be more effective in controlling acute pain syndrome than the CMTPB (given to the control group [CG]) in adult trauma patients with rib fractures.

Methods

The institutional review board of the ethics committee of the cities of L'Aquila and Teramo, Abruzzo, Italy (approval number: 10814/21; clinicaltrials.gov identifier: NCT05348330) approved the study for an exemption from formal review; the research was conducted in the intensive care units (ICUs) of San Salvatore Academic Hospital (L'Aquila, Italy). All patients or their legal representatives provided written informed consent.

The Consolidated Standards of Reporting Trials (CONSORT) protocol was followed in accordance with EQUATOR (Enhancing the QUAlity and Transparency of health research) guidelines. To meet the inclusion criteria, the patients needed to be between 18 and 75 years old and have multiple rib fractures without the need for surgical fixation. Patients who had any of the following conditions were excluded: spontaneous rib fractures, pregnancy, allergy to anesthetics, primary or secondary neurological impairment diseases, moderate-to-severe traumatic brain injury (TBI) (Glasgow Coma Scale [GCS] score from 3 to 12, measured on admission), chronic obstructive pulmonary diseases, infection and/or tumors within the skin close to the blockage site, or a history of lung cancer, chronic pain, or drug abuse. Data collection forms designed for the study were used to collect information from patients through a medical chart review. The recorded information included patient gender, age, body mass index (BMI, kg/m^2), number of fractured ribs, injuries to other organs and systems, and comorbidities. Treatment allocations were unknown to all outcome assessors, including research nurses, respiratory therapists, radiologists, and physicians. The anesthesiologist who performed the blocks was not part of the subsequent assessments. The procedure room was set up similarly for both techniques, using the same equipment and medications. Identical dressings were used to cover the catheter insertion sites and prevent visual identification. Patient charts were kept in separate sealed files until the study was completed and patient identification numbers were used in the data collection forms.

The group allocations were unknown to the statistician conducting the analysis, so they were labeled as A and B until the primary analysis was completed.

Randomization was conducted using sealed opaque envelopes prepared by a coordinator who was

not involved in the patient care. A computer-generated random sequence established a one-to-one allocation between the CTIFB (EG) and CMTPB (CG) groups, with each envelope containing a card indicating the assigned treatment. The anesthesiologist opened the envelopes sequentially for each patient before the procedure, and the randomization sequence remained confidential until trial completion.

The CTIFB was performed at the level and site of the rib fracture while the patient was in a sitting position. Ultrasound (US) countdown was performed from the seventh cervical spinous process (SP) to the twelfth (T12) SP. The tip of the SP from the T2 to T12 vertebra was identified using a transverse-placed high-frequency (15-6 MHz) linear array US transducer (Edan Acclarix AX4, EdanUSA). That tip was also signed with a skin marker pen. US scanning began in the transverse plane, and the tip of the SP was visualized as hyperechoic circles with acoustic shadowing underneath. The US transducer was protected by a plastic sheath. The probe was moved slightly from the medial to the lateral direction while the clinician maintained a transverse orientation for the probe and controlled the angle between the SP and TP, which was visualized as a caved structure that lay deep in the fascial plane of the erector spinae muscle (ESM). A Tuohy needle (18-gauge, 90 mm Contiplex®, B. Braun) was inserted in-plane to the US beam in a lateral-to-medial direction to contact the SP gently into the skeletal muscle plane of the ESM (Fig. 1). The needle tip was then moved from the cephalic to the caudal direction by tilting the probe in the same direction when the angle between the TP and SP was reached. Subsequently, the needle tip was gently advanced to 2 mm along the superior limit of the vertebral pedicle until bone contact was lost. Then, a combination of 5 mL of levobupivacaine 0.25% and 4 mg of dexamethasone was injected at each level and site of fracture, and a continuous catheter set was inserted and threaded one cm from the needle tip, from the caudal to cephalic direction (Fig. 2).

CMTPBs were performed using parasagittal scans with in-plane needle insertion from the caudal to the cephalic direction (8). Patients were in a sitting position.

The high-frequency linear array US transducer was moved slightly from the lateral to the medial direction over the fractured rib until a US image of the tips of the TP was obtained. The needle tip was placed at the midpoint between the TP and the pleura, aiming toward the TPVS. Once the needle tip reached the midpoint between the transverse process and pleura, the same

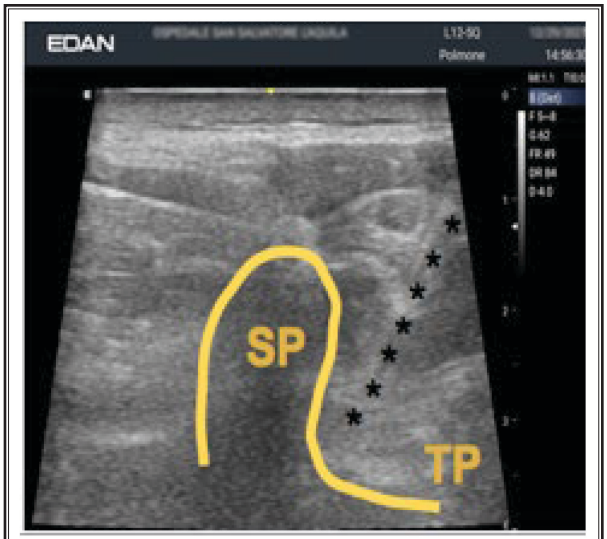

Fig. 1. *Ultrasound-assisted thoracic intervertebral foramen block*.
The anesthesiologist inserts the needle deeply into the erector spinae muscle (ESM) plane until reaching the angle (a) between the spinous (SP) and transverse process (TP) of the vertebra,.

anesthetic solution was injected, and a continuous catheter set was inserted (Fig. 3).

During the performance of the 2 anesthetic techniques, the half-the-air technique through the 3-way stopcock (13) was used to maintain the injection pressure below 15 psi (14).

In cases of 2 or more fractures, catheters were placed at the midpoint between the fracture levels.

After the anesthetic blocks were completed, a second control on the US scan of the TPVS was performed. The US images were collected, recorded, stored, and revised by a blinded radiologist.

All patients received a continuous infusion of levobupivacaine 0.25% combined with 16 mg of dexamethasone at 5 mL/h through an elastomeric pump.

The primary objective of this study was to determine whether the presence of acute pain 2 hours after treatment was related to the type of anesthetic block used (CTIFB vs. CMTPB). Acute pain was assessed using the Numeric Rating Scale (NRS), an 11-point scale ranging from 0 (no pain) to 10 (worst imaginable pain), by patients who were at rest in either the sitting or supine position. Patients were diagnosed with acute pain if their NRS scores were > 4.

The NDs of pain were assessed by testing the skin of the thorax corresponding to the rib fracture, using the von Frey hair test, Lindblom test (15), and NRS. The

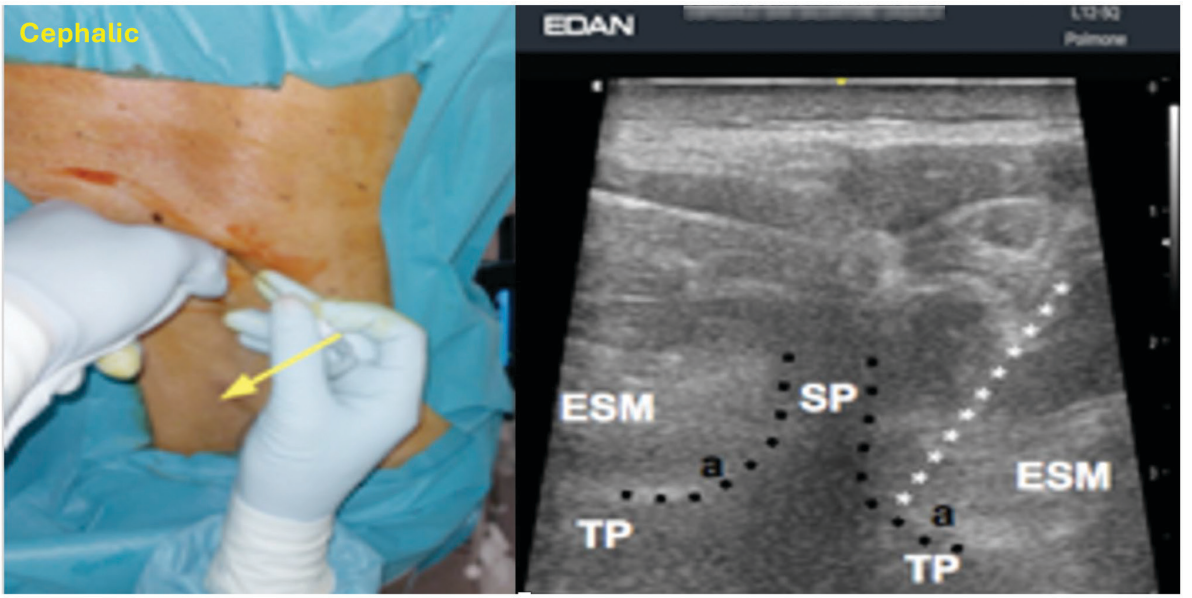

Fig. 2. *Continuous ultrasound-assisted thoracic intervertebral foramen block.*
The anesthesiologist inserts the catheter deeply into the erector spinae muscle (ESM) plane by overcoming the angle (a) between the spinous (SP) and transverse process (TP) of the vertebra. The tip of the catheter (white stars) is placed and moved in a caudal-to-cephalic direction (yellow arrow).

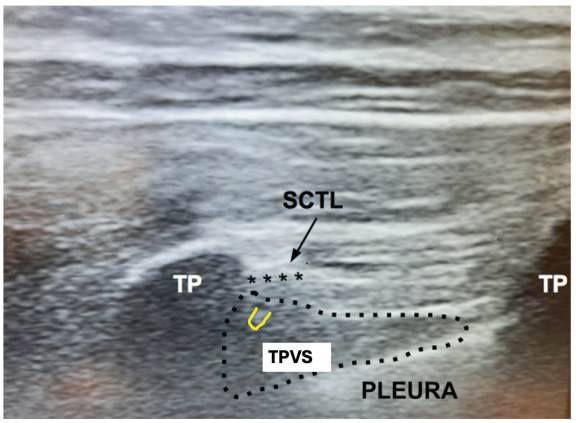

Fig. 3. *Continuous ultrasound-guided midpoint-to-pleura transverse process block.*
The catheter tip (yellow line) is placed at the midpoint between the TP and the pleura, aiming towards the thoracic paravertebral space (black points).
SCTL: superior costotransverse ligament.

examination was considered normal and complete if normal cutaneous sensation was documented. Lack of response indicated diminished light touch sensitivity, which was considered hypoesthesia, whereas a painful first touch stimulus was recorded as allodynia. Hyperesthesia was defined as an increased sensitivity to stimuli that were previously regarded as normal. Dysesthesia was considered when a normal touch stimulus was described as an unpleasant sensation (16,17). Positive tests for one of the evaluated features (allodynia, dysesthesia, hypoesthesia, and hyperesthesia) were considered signs of NDs.

Diaphragmatic motion was assessed by evaluating the mean percentage of diaphragmatic thickening (TFdi%), measured as thickness at end-inspiration minus thickness at end-expiration divided by thickness at end-expiration for both hemidiaphragms during quiet breathing, as described by Boon (18,19). In this study, the mean percentage of thickening during quiet breathing was between 30 and 35% on both sides in men and women, in keeping with the observations made by Bousuges et al (20). The TFdi% of both hemidiaphragms was recorded using M-mode ultrasonography. The lung US score (LUS) was also measured (21) to promptly identify life-threatening conditions that might have required direct intervention or to detect acute pathologies that were often initially radiographically occult. A total of 12 regions were assessed using a 2-dimensional view, and a semiquantitative score ranging from 0 to 3 was evalu-

ated according to the indications made by Zhang et al (22). The aeration score was built from the sum of all the areas, with a minimum of 0 and a maximum of 36 according to the aeration loss (23).

The ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (P/F) was evaluated using arterial blood gas analysis (ABGA). The patient airflow rate (mL/s) was measured using an incentive spirometer with 3 balls (Triflo II™, Tyco Healthcare) (24).

We also collected data on the requests for vasoactive medications (e.g., vasopressors and/or inotropes administered when the blood pressure was lower than 80/50 mmHg in a supine patient) and the needs for oxygen support with nasal prongs, noninvasive mechanical ventilation (NIV) or tracheal intubation, mechanical ventilation (MV), and opioids.

Finally, lung and pleural injuries, hematomas, pain, and infections were evaluated and recorded as related instances of iatrogenic damage to the anesthetic procedure, as was neurological impairment caused by root damage in turn due to the accidental puncture of intervertebral blood vessels and nerve rootlets.

Selected Variables

Primary Endpoint

Treatment success was defined as the absence of acute pain (NRS ≤ 3) 2 hours after the intervention.

Secondary Endpoints

Pain and Sensory Outcomes:

- Acute pain was assessed at 30 min and at 2, 12, 24, 48, and 72 hours (NRS).
- The intensity of NDs was assessed at 30 min, 2, 12, 24, 48, and 72 hours (NRS).

Respiratory Function:

- The P/F ratio was measured at baseline and at 2, 12, 24, 48, and 72 hours.
- The patient airflow rate (mL/s) was measured at 24, 48, and 72 hours.
- Diaphragmatic motion (TFdi%, defined as normal [≥ 30%]/impaired [< 30%]) was measured at admission, at 72 hours, and at discharge.

Safety and Clinical Outcomes:

- Use of vasoactive medications (yes/no).
- Daily consumption of morphine milligram equivalents (MMEs).
- Iatrogenic complications (pneumothorax, hemothorax, hematomas, infections at the puncture site, pain, and neurological deficits).

Hospital Course:

- Duration (days) of oxygen support (nasal prongs or NIV).
- Duration (days) of MV.
- Length of hospital stay (days).

Descriptive Statistics

Statistical Methodology

The sample size was estimated by assuming that the percentage of difference in success (absence of somatic pain) between the 2 treatments was equal to 30% (alpha = 0.05, beta = 0.20); the estimated total sample size was at least 82 patients (41 per group, as measured in G*Power 3.1 [Heinrich Heine Universität Düsseldorf]). We enrolled 96 patients (48 per group), accounting for an anticipated dropout rate of 9-10%.

Statistical Analysis

An intention-to-treat analysis was conducted for all patients and based on their randomized treatment-group assignments. Descriptive statistics summarized patients' demographic and clinical characteristics, presenting frequencies and proportions for categorical variables and means with SD for continuous variables.

For the primary outcome, a chi-square test was used to evaluate the association between treatment type and success, and 95% CIs were calculated using the Wilson score method. The secondary endpoints (acute pain, NDs, P/F, and patient airflow rate) were analyzed using repeated measures of variance analysis (RM-ANOVA). The treatment group served as the between-patients factor, while time and time-by-group interaction were within-patients factors. For the analysis of repeated binary outcomes (diaphragmatic motion), we used multilevel mixed-effects logistic regression with group, time, and their interaction as fixed effects and the patient as a random effect. Results are presented as odds ratios (OR) with 95% confidence intervals (CIs).

All statistical tests were reported with their corresponding degrees of freedom (df): chi-square tests as χ^2(df), t-tests as t(df), and F-tests as F(df1,df2). The Greenhouse–Geisser (G–G) correction was applied when sphericity was violated, and the Bonferroni adjustment was used for multiple comparisons. Independent t-tests or nonparametric tests were used to compare the continuous and categorical variables for the remaining

endpoints. All statistical analyses were performed using STATA 14 (StataCorp LLC), with the significance level set at $\alpha = 0.05$.

Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available, since the decedents' proxies or legal surrogates have reserved all rights to them, but are available from the corresponding author on reasonable request.

Results

Ninety-six patients were randomized to receive either CTIFB (n = 48) or CMPTB (n = 48) (Fig. 4) between December 2022 and November 2024. The demographic and clinical characteristics of the patients are reported in Table 1. None of the variables investigated was significantly different between the control and experimental groups.

Principal Endpoint

Treatment success (NRS ≤ 3) was achieved in 21 patients (44%; 95% CI: 31-58%) in the EG compared to 3 patients (6%, 95% CI: 2-17%) in the CG, demonstrating a significant difference between the groups ($\chi^2(1) = 18.0$, $P < 0.001$, Cramér's V = 0.43) (Fig. 5).

Secondary Endpoints

Pain and Sensory Outcomes

Analysis of acute pain scores showed the significant main effects of group (F(1,94) = 35.3, $P < 0.001$), time (F(3.89,366.12) = 259.5, $P < 0.001$), and group-by-time interaction (F(3.89,366.12) = 16.9, $P < 0.001$). Because of the violation of sphericity (Mauchly's W = 0.437, $P < 0.001$), the G–G correction was applied ($\varepsilon = 0.779$). As shown in Fig. 6, the experimental group showed a more rapid reduction in pain scores, particularly during the first 24 hours of treatment. At baseline, pain scores were similar between the groups (CG: 7.27 ± 1.6 vs. EG: 7.12 ± 1.5). The EG showed a more rapid reduction in pain scores at 2 hours (EG: 3.96 ± 1.2 vs CG: 6.27 ± 1.7, $P < 0.001$) and 12 hours (EG: 3.0 ± 0.9 vs. CG:4.29 ± 1.2, $P < 0.001$).

The analysis of NDs showed the significant main effects of group (F(1,94) = 22.04, $P < 0.001$), time (F(4.34,407.83) = 296.7, $P < 0.001$), and group-by-time interaction (F(4.34,407.83) = 18.5, $P < 0.001$). Due to the violation of sphericity (Mauchly's test, $P < 0.001$), the G–G correction was applied ($\varepsilon = 0.8677$).

At baseline, the CG showed higher ND scores compared than did the EG (EG: 7.65 ± 1.5 vs. CG: 6.08 ± 1.2, $P < 0.001$). Both groups showed improvements over time but with different patterns. The EG demonstrated a more rapid reduction at 2 hours (EG: 4.87 ± 1.1 vs. CG: 6.54 ± 1.1, $P < 0.001$) and maintained lower ND scores through 12 hours (EG: 3.89 ± 1.1 vs. CG: 3.92 ± 1.0, $P = 1.000$). At 72 hours, both groups reached similar levels (EG: 2.31 ± 1.0 vs. CG: 2.25 ± 0.9, $P = 1.000$), as reported in Fig. 7.

Respiratory Function

Analysis of the P/F ratio showed an improvement over time for both groups. A repeated measures ANOVA to which the G–G correction was applied for sphericity violation ($\varepsilon = 0.419$) revealed a significant main effect of time (F(2.09,196.88) = 113.71, $P < 0.001$), while neither the time-by-group interaction (F(2.09,196.46) = 0.22, $P = 0.814$) nor the main effect of the group (F(1,94) =

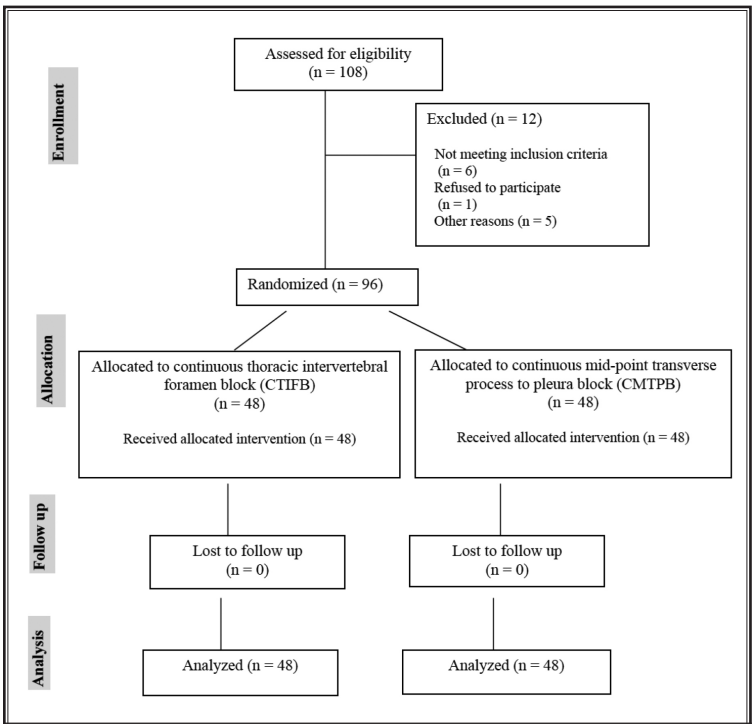

Fig. 4. *CONSORT flow diagram.*

Table 1. *Demographic and clinical characteristics of patients by groups*

	Control group n = 48	Experimental group n =48
	n (%) or mean (SD)	n (%) or mean (SD)
Age	46 (19.2)	49 (16.7)
Sex		
Female	14 (29.2%)	11 (22.9%)
Male	34 (70.8%)	37 (77.1%)
BMI (kg/m^2)	22.5 (2.4)	22.9 (2.7)
Number of fractures	5.9 (1.7)	5.2 (1.4)
Visceral injuries of the abdomen		
No	24 (50.0%)	28 (58.3%)
Yes	24 (50.0%)	20 (41.7%)
Mild brain injuries		
No	28 (58.3%)	25 (52.1%)
Yes	20 (41.7%)	23 (47.9%)
Intrathoracic injuries		
No	31 (64.6%)	24 (50.0%)
Yes	17 (35.4%)	24 (50.0%)
Cardiovascular diseases		
No	5 (10.4%)	2 (4.2%)
Yes	43 (89.6%)	46 (95.8%)
Respiratory diseases		
No	27 (56.2%)	25 (52.1%)
Yes	21 (43.8%)	23 (47.9%)
Metabolic diseases		
No	29 (60.4%)	28 (58.3%)
Yes	19 (39.6%)	20 (41.7%)
Neurological diseases		
No	36 (75.0%)	38 (79.2%)
Yes	12 (25.0%)	10 (20.8%)
Nephrological diseases		
No	35 (72.9%)	38 (79.2%)
Yes	13 (27.1%)	10 (20.8%)
Cancer		
No	40 (83.3%)	37 (77.1%)
Yes	8 (16.7%)	11 (22.9%)
Other diseases		
No	20 (42%)	17 (35%)
Yes	28 (58%)	31 (65%)
Needing of tracheal intubation		
No	32 (66.7%)	26 (54.2%)
Yes	16 (33.3%)	22 (45.8%)
LUS score	28.7 (SD=5.1)	30.5 (SD=4.5)

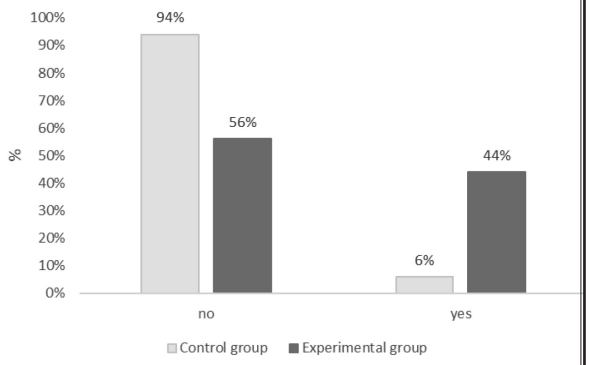

Fig. 5. *Success distribution (NRS ≤ 3), by groups.*

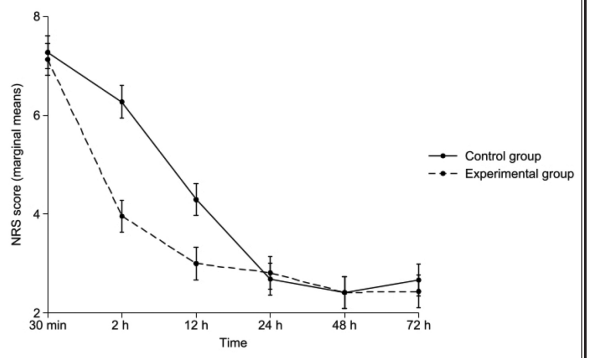

Fig. 6. *Gradual acute pain between the groups (represented by NRS scores).*

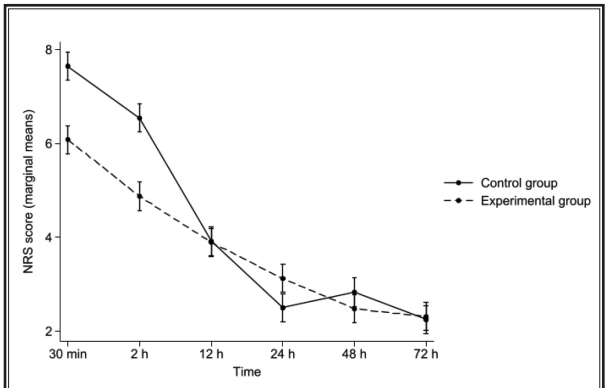

Fig. 7. *Gradual neuropathic disturbances between the groups (represented by NRS scores).*

0.80, $P = 0.373$) was significant. The P/F ratio increased from baseline (CG: 145.20 ± 47.9, EG: 149.37 ± 43.29) to the 72-hour mark (CG: 184.37 ± 34.7, EG: 192.50 ± 36.7). Although the EG maintained slightly higher values throughout the study period, this difference was not statistically significant (Fig. 8).

The airflow rates showed significant changes over time and differed between the groups, even after correcting for sphericity violations (G–G $\varepsilon = 0.905$). Repeated measures ANOVA revealed a significant main effect of time ($F(1.81,170.14) = 135.76$, $P < 0.001$) and a significant time-by-group interaction ($F(1.81,170.14) = 4.67$, $P = 0.013$). The patient airflow rate analysis showed similar baseline values between the 2 groups (322.92 ± 77.8 mL/s vs 351.04 ± 71.1 mL/s). The EG showed faster initial improvement at 24 hours (470.83 ± 84.9 mL/s vs. CG: 400.00 ± 103.1 mL/s, $P = 0.004$). At 48 hours, both groups reached similar values (EG: 520.83 ± 87.4 mL/s vs. CG: 516.67±127.7 mL/s) and continued improving through 72 hours (EG: 700.00 ± 128.8 mL/s vs. CG: 725.00 ± 129.6 mL/s), as illustrated in Fig. 9.

For diaphragmatic motion assessment, the analysis showed no significant difference between the groups (OR = 1.09, 95% CI: 0.48-2.51, $P = 0.832$). While both groups showed changes over time, with decreased odds of normal diaphragmatic motion at time one compared to baseline (OR = 0.17, 95% CI: 0.05-0.54, $P = 0.003$), the group-by-time interaction was not significant ($P = 0.664$).

Safety and Clinical Outcomes

Mean daily MME consumption was significantly lower in the EG (10.1 mg, SD = 3.9) than in the CG (20.8 mg, SD = 4.5; $t(94) = 12.3$, $P < 0.001$). Vasoactive medication use was similar between the groups (CG, n = 8; EG, n = 9; $\chi^2(1) = 0.07$, $P = 0.791$).

No iatrogenic injuries were reported.

Traumatic pneumothorax with pleural effusion was observed in 5 patients from the CG and 4 patients from the EG, with no statistical significance ($\chi^2(1) = 0.123$, $P = 0.726$).

Hospital Course

Table 2 summarizes the time spent on MV, nasal prongs, and NIV.

The length of hospital stay differed between the groups: 15 days (SD = 6) in the CG and 11 days (SD = 6) in the EG ($P = 0.0024$).

The US images collected, recorded, stored, and revised by the blinded radiologist documented that the spread of the anesthetic solution flowed predominantly into the TPVS, with scanty dissemination deep into the ESM plane or in the angle between the TP and SP of the vertebra along the lamina.

Discussion

Managing pain in patients with rib fractures is a significant challenge in trauma care. This randomized controlled trial demonstrated that the acute pain control associated with the CTIFB was superior to that associated with the CMTPB for adult trauma patients with rib fractures (Fig. 1).

At the 2-hour post-block assessment, patients in the CTIFB group reported significantly lower NRS scores. This finding supports the notion that this technique provides immediate pain relief and improves the overall success rate of managing pain caused by rib fractures.

The average daily MME was lower for patients

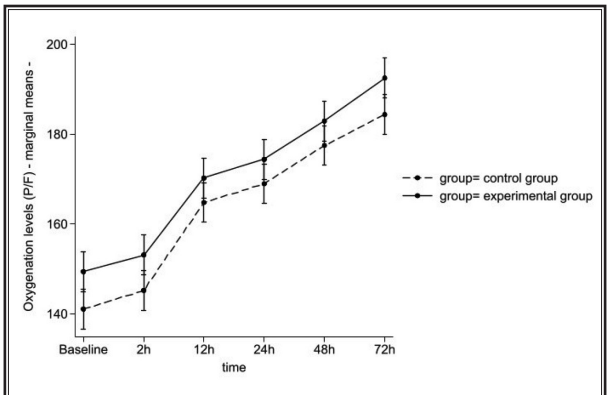

Fig. 8. *Gradual oxygenation levels (P/F) between the groups.*

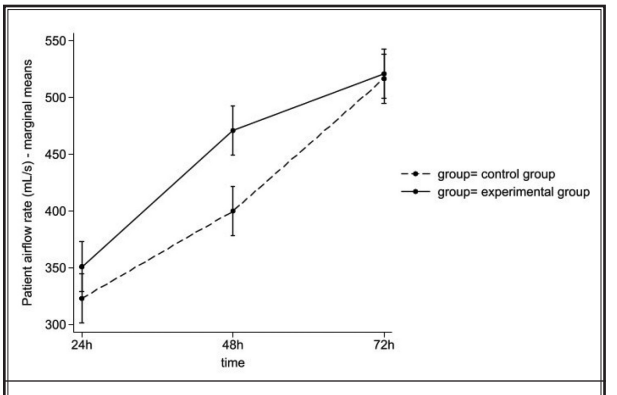

Fig. 9. *Gradual spirometry volume (mL/s) between the groups.*

treated with CTIFBs than for those treated with CMTPBs, with values of 20.8 mg versus 10.1 mg ($P < 0.001$). These findings are consistent with the results observed by Costache et al (8), suggesting that the effectiveness of regional anesthetic techniques can decrease the level of opioids requested by and the related side effects seen in these patients.

Sensory evaluations indicated a lower score in the CTIFB group, supporting findings made by Rabiou et al (6), who noted that rib fractures could lead to chronic chest pain-related disabilities.

Traditionally, US-guided TPVB or US-assisted EA have been described as and considered useful opioid-sparing procedures for controlling post-traumatic acute or chronic pain after rib fracture. However, questions remain about the long-term outcome benefits of these techniques, and their effects on acute pain control and NDs are not as marked as once thought (25). Paravertebral blocks are readily amenable to inserting catheters for the infusion of analgesic solutions and should be considered a standard practice for the control of pain caused by rib fractures. However, when anticoagulation therapy is used, anesthesiologists often encounter the challenge of the potential risk of bleeding or thrombosis, especially in cases of discontinuation or interruption of these drugs (26).

Recently, an increasing number of techniques for both patients and cadavers have been described that utilize US guidance for approaching TPVS. The erector spinae plane (ESP) block may be considered the most widely used of these novel techniques and has been employed in perioperative, acute, and chronic pain settings (4).

In this study, neither iatrogenic injuries nor clinical signs of local anesthetic systemic toxicity were recorded, demonstrating the analgesic efficacy and safety of both the procedures. Another important aspect of this investigation was the effect of these blocks on respiratory function. The CTIFB group showed improved diaphragmatic motion, as measured by US, indicating better respiratory mechanics after the anesthetic block. This finding may also be related to the lower total number of daily MME requests made by this group. These results are consistent with those of previous studies that demonstrated that effective pain control could enhance respiratory function in patients with rib fractures (5).

The absence of significant hemodynamic changes further supports the safety profile of the CTIFB, making it a viable treatment option for this patient population. In fact, vasoactive drugs were requested by 8 patients (16.7%) in the CG and 9 patients (18.8%) in the EG.

Table 2. *Time spent (days) with mechanical ventilation, noninvasive mechanical ventilation, and nasal prongs.*

	Control Group (n = 48)	Experimental Group (n = 48)	*P*
	Mean (SD)	Mean (SD)	
Days with nasal prongs	4.6 (3)	4.0 (1.2)	0.4550
Length of stay	15 (6)	11 (5)	0.0024
Days with mechanical ventilation	1 (2)	1 (2)	0.4853
Days with noninvasive ventilation	5. (4)	3 (4)	0.0106

Limitations

This study had several limitations. First, the anesthetic procedures were performed under US rather than fluoroscopic guidance. These techniques may have utility in chronic pain management, requiring the latter rather than the former. This aspect of our research is not generalizable to chronic pain practice. Second, the single-center design may limit the generalizability of the findings to other clinical settings. Third, we excluded patients on anticoagulation therapy, which is an important subgroup of trauma care. Additionally, the follow-up period was relatively short, precluding the assessment of long-term outcomes such as chronic pain development or functional recovery. Finally, although improved respiratory parameters were observed, the study was not equipped to detect differences in clinical outcomes such as pneumonia rates or mortality.

Conclusion

In summary, our findings demonstrate that the CTIFB provides more effective management of acute pain and NDs associated with rib fractures, greater improvements in respiratory function, and reduced opioid consumption than does the CMTPB. Further studies are needed to validate these results.

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All data are available upon reasonable request to the corresponding author.

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