Pain Physician 2022; 25:483-490 • ISSN 1533-3159

Randomized Trial

Comparison of Thoracic Erector Spinae Plane Block With Thoracic Paravertebral Block for Pain Management in Patients With Unilateral Multiple Fractured Ribs

Abdelreheem Elawamy, MD, Mohamed R. Morsy, MD, and Mohamed A. Y. Ahmed, MD

From: Department of Anesthesia and Intensive Care, Assiut University, Asyut, Egypt

Address Correspondence: Abdelreheem Elawamy, MD Department of Anesthesia and Intensive Care, Assiut University Asyut, Egypt 71515
E-mail: arawamyyy@yahoo.com

Disclaimer: There was no external funding in the preparation of this manuscript.

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 manuscript.

Manuscript received: 10-02-2021
Revised manuscript received: 01-07-2022
Accepted for publication: 02-25-2022

Free full manuscript: www.painphysicianjournal.com

Background: Rib fractures occur most commonly because of blunt thoracic trauma and occur in up to 12% of all trauma patients. Adequate analgesia is paramount in enhancing pulmonary hygiene aimed at preventing atelectasis and pneumonia. Erector spinae plane block, one of the novel multiple thoracic ultrasound-guided techniques, can provide analgesia to both the anterior and posterior hemithorax, making it particularly useful in the management of pain after extensive thoracic trauma.

Objectives: This work aimed to compare the analgesic efficacy and safety of ultrasound-guided erector spinae plane block versus ultrasound-guided thoracic paravertebral block in patients suffering multiple rib fractures.

Study Design: A double blinded randomized clinical trial.

Setting: A university hospital.

Methods: The study was conducted with 60 patients with multiple fracture ribs. Patients were randomly allocated into 2 equal groups of 30 patients.

Results: Both techniques were effective in reducing pain scores and opioid consumption with no significant difference between the 2 groups. Time to first analgesic administration was comparable between the 2 groups. Twenty patients in the thoracic erector spinae plane group required rescue morphine compared to 17 patients in the thoracic paravertebral block group ($P > 0.05$). Visual Analog Scale scores at rest and on coughing were also comparable between the groups at all measuring points except at 0.5 hours following the block performance. Occurrence of hypertension was higher in the thoracic paravertebral block group compared to the thoracic erector spinae plane group ($P = 0.024$).

Limitations: There was no catheter inserted and we use intermittent injections, which is not the ideal, continuous block with fixed catheter is the ideal. We use dexamethasone as adjuvant with local anesthetics, which delay the need for booster dose of local anesthetics and make comparison between the 2 techniques not ideal. The sample size is small to some extent. We did not exclude addict patients.

Conclusion: Ultrasound-guided thoracic erector spinae plane block was as effective as thoracic paravertebral block for pain alleviation in patients with unilateral multiple fractured ribs with a comparable duration of analgesic effect, reduction of opioid consumption, and stable hemodynamic profile. However, thoracic erector spinae plane block had the advantage of a lower adverse effect incidence. Clinicians could choose either of the 2 techniques according to their clinical experience and personal choice.

Key words: Multiple fracture rib, anesthesia, ultrasound-guided erector spinae plane block (ESPB), thoracic paravertebral block (TBVP), rescue analgesia, visual analog scale, pain

Pain Physician 2022: 25:483-490

Rib fractures occur most commonly because of blunt thoracic trauma and occur in up to 12% of all trauma patients (1,2). Rib fractures themselves pose a significant health care burden with its associated morbidity, long-term disability, and mortality (3,4). An estimated one-third of patients with traumatic rib fractures developed secondary pulmonary complications, with an associated mortality rate as high as 65% (5–7). Pulmonary morbidity is increased in these patients because of diminished gas exchange from fracture-induced pulmonary injury and from inadequate analgesia, compromising both ventilation and pulmonary mechanics (1). Various factors affect outcome and mortality after rib fractures, including the number of ribs fractured, preexisting comorbidities, advanced age, and level of associated pain (8–13).

Patients with fracture of one or 2 ribs have low incidences of complications and can easily be managed with oral analgesic drugs (nonsteroidal anti-inflammatory drugs, acetaminophen) (8,14,15). In cases of multiple rib fractures, pain is usually more severe and frequently alters pulmonary mechanics. Increased pain during breathing causes shallow breath and ineffective coughing, which results in insufficient clearance of airway secretions and retention of sputum, which often precipitates secondary complications (8,16,17).

Adequate analgesia is paramount in enhancing pulmonary hygiene aimed at preventing atelectasis and pneumonia. Systemic analgesia is usually sufficient in younger patients with fewer displaced fractures without a flail segment. Regional techniques are particularly useful in elderly patients (> 65 years), patients with multiple rib fractures, and in patients with severe pain or compromised pulmonary function (15).

Conventional regional techniques used to manage rib fractures include thoracic epidural analgesia, paravertebral block (PVB), intercostal, and intrapleural block (1). Some of these techniques, particularly thoracic epidural analgesia and PVB, may not be feasible in the presence of anticoagulation, multisystem trauma, or in patients unable to be optimally positioned. Recently, multiple thoracic ultrasound-guided regional anesthesia techniques have been developed, that use local anesthetic injections (both single injection and continuous catheter techniques) into fascial planes from the thoracic spinal lamina to the sternum to anesthetize various regions of the thorax. These offer the advantages of being less invasive and provide adequate analgesia after rib fractures (18). The erector spinae plane block (ESPB), one of these novel ultrasound-guided regional anesthesia techniques, can provide analgesia to both the anterior and posterior hemithorax, making it particularly useful in the management of pain after extensive thoracic trauma (19).

This study aimed to compare the analgesic efficacy and safety of ultrasound-guided ESPB versus ultrasound-guided thoracic paravertebral block (TPVB) in patients suffering multiple rib fractures.

Method

This interventional, prospective, randomized, double-blinded study was conducted at the trauma unit of University Hospital, from December 1, 2019 through February 20, 2021 after obtaining institutional review board approval from the Medical Ethic Committee (IRB no.:17100726), and registration in clinical trials (NCT03883958). The study was in line with the guidelines of the Helsinki Declaration and fulfilling the Consolidated Standards of Reporting Trials protocol.

A written informed consent was obtained from each patient before participation in the study. All collected data were confidential and were used for the purpose of scientific research only. Every research patient had the complete right and freedom to withdraw at any time from the study without any consequences with the medical service provided.

The following were exclusion criteria for recruitment: patients who are unable to communicate effectively, those with sternal fractures, bilateral rib fractures, a visual analog scale (VAS) score < 7, preexisting spinal deformity, local sepsis at the site of injection, coagulopathy, known allergy to the local anesthetic used in the study, those having significant trauma outside the chest wall, e.g., acute spine or pelvic fracture, severe traumatic brain or spinal cord injury, or abdominal visceral injuries. On the other hand, those who refused to participate or were unable to complete the study for any reason were excluded.

After fulfillment of inclusion and exclusion criteria, a computer-generated randomization table was created for the 60 patients. Patients were randomly allocated into 2 equal groups: TBVP: patients received pain relief by paravertebral injection of plain bupivacaine 0.5% and dexamethasone. TESB: patients received thoracic erector spinae injection of plain bupivacaine 0.5% and dexamethasone.

All patients were subject to systematic assessment including history taking, physical examination, and review of the results of routine investigations. They were given a full and detailed explanation of the

study protocol, educated on the way to report pain by VAS at rest and during coughing, and informed of the potential benefits of the development of a successful technique as well as the potential side effects. Intravenous access was established with an 18G intravenous cannula. Cardiovascular stability was achieved. Any pneumothorax or hemithorax was drained and any surgical procedure required was performed by the surgical team before initiation of the blocks. The level of the fractured ribs was determined by means of chest x-ray or computed tomography scan. Both PVB and ESPB were performed in the awake state after premedication with midazolam (1.5 mg) under ultrasound guidance using GE Ultrasound System (Logiq F6) and under complete aseptic conditions. Electrocariogram, noninvasive blood pressure, and pulse oximetry were connected to the patients during the procedure.

TPVB was performed at a spinal level midway between the uppermost and the lowest fractured rib, or 2 segments below the uppermost fractured rib with the patient in a sitting position. A 6.0 - 13.0 MHz linear ultrasound probe (GE L6-12-RS) was used to identify the spinous process, transverse process, pleura, superior costotransverse ligament, and the paravertebral space at the target vertebral level. After skin and subcutaneous tissue infiltration with 2-3 mL of 2% lignocaine, a 21G 100mm needle (Pajunk) was inserted under ultrasound guidance until the needle tip entered the paravertebral space. This was performed using a lateral to medial in-plane needle insertion technique. One to 2 ml of saline was injected into the paravertebral space while observing the pleura being displaced deeply. A bolus dose (0.3mL/kg) of plain bupivacaine 0.5% plus 8 mg of dexamethasone was injected after negative aspiration to blood and air.

ESPB was carried out with the patient in a sitting position. The target vertebral level was chosen to correspond to the approximate midpoint of the extent of fractured ribs. The tip of the transverse process of the target vertebra was identified using the 6.0 - 13.0 MHz linear transducer placed in a cephalocaudal orientation approximately 3 cm lateral to the spinous process. The skin and subcutaneous tissue were infiltrated with 2-3 mL of 2% lignocaine. With the transducer fixed over the targeted transverse process, a 21G 100 mm needle (Pajunk) was advanced in-plane to the ultrasound beam in a cephalocaudal direction to contact the transverse process. Correct needle tip position was confirmed by doing alternating aspiration to confirm the lack of inadvertent vascular puncture with injection of one-2 mL of saline and visualizing the linear fluid spread deep into the erector spinae muscle, separating it from the transverse process. A bolus dose (0.3 mL/kg) of plain bupivacaine 0.5% plus 8 mg of dexamethasone was injected. Nerve block success was established by the patient reporting a sensation of paresthesia and pain relief while awake, and the loss of pin prick on examination.

Intravenous acetaminophen, one g every 6 hours was administered to all patients in both groups. Rescue analgesia was administered, if VAS was > 4 at rest or on the patient's demand, with intravenous morphine, 0.1 mg/kg. A physician, who was blind to the technique of the performed block, evaluated the patients and collected the data.

Statistical Analysis

The power analysis of this study using the G-Power 3.1.9.7 calculator suggested that 60 patients were sufficient to demonstrate relevant differences of 0.2 between the 2 groups, regarding comparing the 24-hour opioid requirements and the time to first rescue analgesia of thoracic ESPB versus TPVB for pain management in patients with unilateral multiple fractured ribs with an α error of 0.05 and power of the study of 90%.

Data processing was conducted using SPSS version 24 (IBM Corporation). Data were presented as number, percentage, mean, standard deviation, median and range. χ-square test/Fisher's exact test was used to compare frequencies in qualitative variables. Independent samples t-test was used to compare quantitative variables between groups in case of parametric data, while the Mann-Whitney test was used for nonparametric data. Wilcoxon's signed rank test was used to compare quantitative variables between before and after treatment in case of nonparametric data. The mean time to first analgesic administration was analyzed by Kaplan–Meier survival analysis and log rank statistics together. A *P* value of < 0.05 was considered statistically significant.

Results

The present study was conducted on with patients in a trauma unit, in a university hospital, in the period from December 1, 2019 to through February 20, 2021. The study was carried out on patients suffering from unilateral multiple rib fractures. After reviewing the inclusion and exclusion criteria, these patients were allocated and divided randomly into one of the two equal study groups. Group TPVB: 30 patients received

paravertebral block by injection of (0.3 mL/kg) bupivacaine 0.5% plus 8mg of Dexamethasone. Group TESB: 30 patients received thoracic erector spinae block by injection of (0.3 mL/kg) bupivacaine 0.5% plus 8mg of Dexamethasone.

Figure 1 shows the flow diagram of the current study.

The 2 groups were comparable with respect to the age, weight, height, gender ratio, body mass index, mean number of fractured ribs, side, and site of fractures ($P > 0.05$) (Table 1).

Table 2 and Fig. 2 show the different mechanisms of injury in the 2 study groups. The commonest mechanism, a road traffic accident, represents 70% (n = 42), followed by fall from height, direct blow, and hit by animal (21.7%, 6.7%, and 1.6%, respectively). These differences were statistically insignificant ($P > 0.05$).

The difference in morphine consumption, including the total 24 hour dose of rescue morphine, and the time to first rescue analgesia, is illustrated in Table 3. The current study shows that 20 patients in group TESB required rescue morphine compared to 17 patients in the group TPVB ($P > 0.05$). The median (quartiles) of rescue morphine consumption was comparable between groups (6.45 mg [0–26 mg]) in group TPVB compared to (7.85 mg [0–25.5 mg] in group TESB ($P > 0.05$).

Figure 3 depicts the Kaplan–Meier curve for the time to first rescue analgesic administration. The time to first rescue analgesic administration was comparable between the 2 groups ($P = 0.202$). This was not statistically significant.

This study shows that analgesia was adequate in TPVB and TESB groups up to 24 hours. VAS pain scores at rest and on coughing were measured at regular intervals throughout the study period. The values at baseline, 30 minutes, 3, 6, 12, 18 and 24 hours were compared to assess the response to treatment in the 2 groups. There was a significant decrease in VAS scores at rest and on coughing at all time points after administration of the blocks in both groups ($P < 0.001$). However, no significant intergroup difference was found in VAS scores either at rest or on coughing at all measuring points ($P > 0.05$ for each time point) except at 30 minutes, where the median VAS was higher in TESB group both at rest and during cough ($P < 0.05$) (Table 4).

For the difference in heart rate (HR), there was a statistically significant decrease in the HR compared to the baseline readings at all time points within both groups ($P < 0.05$). However, no significant difference was detected between the 2 groups at all measuring time points ($P > 0.05$) (Fig. 4). There were no statistically significant differences ($P > 0.05$) in systolic blood pressure or diastolic blood pressure readings within or between groups at all time points. Moreover, there were no statistical differences between the level of SpO_2 in both groups at all measuring points except at 18 hours after the block where SpO_2 was significantly higher in group TESB ($P < 0.05$), with no clinical significance (Fig. 5).

Table 5 demonstrates the rate of complications and adverse effects of both techniques. The rate of hypotension was

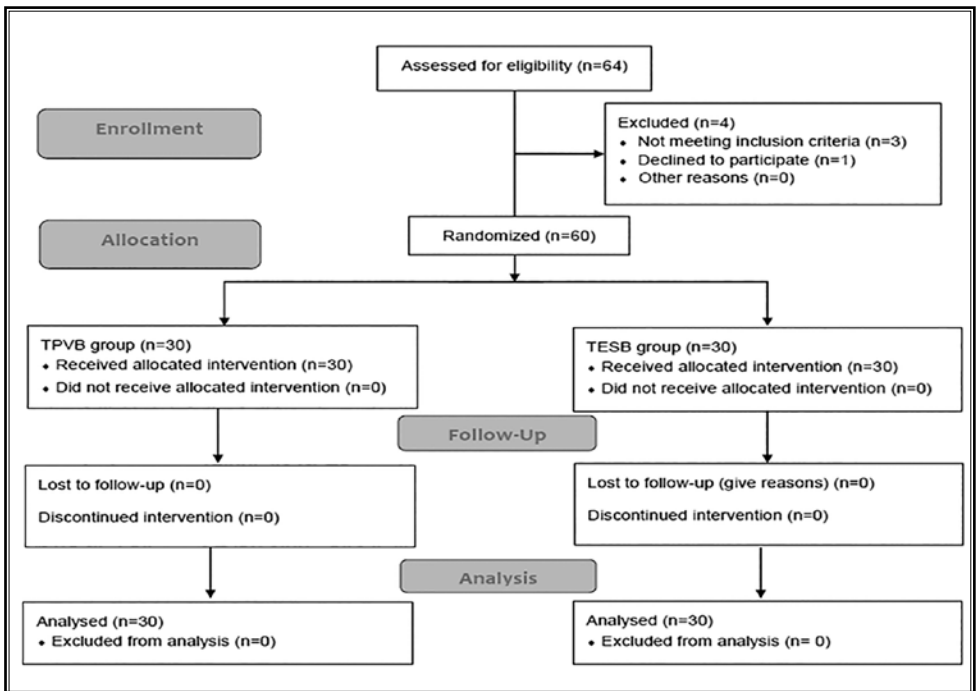

Fig. 1. *Flow chart diagram for the study patients.*

significantly more in group TPVB ($P < 0.05$); 6 patients (20%) developed hypotension within 30 minutes after the block compared to none in group TESB, that was managed by normal saline boluses without need for vasopressors. There were no significant differences regarding other recorded complications between the groups (Table 5).

Discussion

Traumatic rib fractures are common and have a significant health care burden with its associated morbidity, long-term disability, and mortality. Pulmonary condition is worsened in these patients because of diminished gas exchange (1-4). Pain associated with traumatic multiple fracture ribs is usually severe, difficult to control, frequently alters pulmonary mechanics, and may even limit movement ability (16-17).

Adequate analgesia is important for enhancing pulmonary hygiene to prevent serious complications such as atelectasis and pneumonia. Nonsteroidal anti-inflammatory drugs are usually sufficient, especially in young patients with fracture of one or 2 ribs. Opioids are effective but have inherent limitations of respiratory reserve together with other complications, which are dose dependent. Regional techniques are particularly useful in elderly patients, patients with multiple rib fractures, severe pain or compromised pulmonary function and are the preferred choice over opioids for pain relief in rib fractures (15). Recently, several thoracic wall blocks have been introduced including ESPB, a new myofascial plane block which requires less technical expertise

Table 1. *Patients' Characteristics of both study groups*

Personal data	TPVB (n = 30)		TESB (n = 30)		*P* value
	Mean ± SD				
Gender: No. (%)					
Men	25	83.3%	26	86.7%	1.000*
Women	5	16.7%	4	13.3%	
Age (years)	35.60 ± 12.45		36.33 ± 11.45		0.813
Weight (kg)	78.30 ± 9.57		76.70 ± 8.27		0.491
Height (cm)	176.63 ± 6.11		176.50 ± 7.58		0.940
BMI (kg/m^2)	25.04 ± 2.35		24.57 ± 1.57		0.364
Side:					
Right	12	40.0%	13	43.3%	0.793
Left	18	60.0%	17	56.7%	
Site of the fracture:					
Anterior	7	23.3%	9	30.0%	0.812
Posterior	13	43.3%	11	36.7%	
Lateral	10	33.3%	10	33.3%	
Number of fractured ribs	4.73 ± 1.28		4.43 ± 1.10		0.336

Data are presented as mean ± SD or n (%). n: number of patents; %: percentage; n, total number of patients; No: number; SD: Standard deviation; BMI: Body mass index; P< 0.05 is considered statistically significant

Table 2. *Mechanism of trauma in TPVB vs. TESB groups*

Mechanism of trauma	TPVB (n = 30)		TESB (n = 30)		Total (n = 60)		*P* value
	No.	%	No.	%	No.	%	
Traffic accident	22	73.3%	20	66.7%	42	70%	.537
FFH	6	20.0%	7	23.3%	13	21.67%	
Direct blow	1	3.3%	3	10.0%	4	6.67%	
Animal hit	1	3.3%	0	0.0%	1	1.66%	

Data are presented as number of patients (n) and percentage (%). FFH: Fall from height; No: number. $P < 0.05$ is considered statistically significant

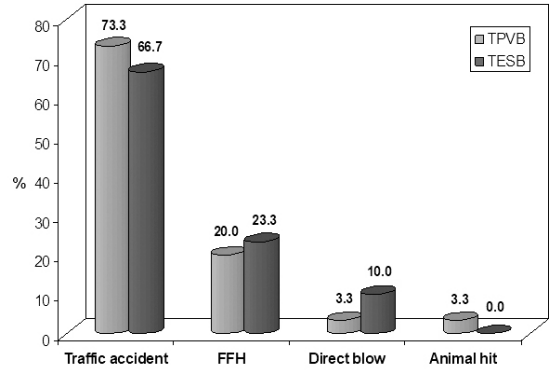

Fig. 2. *Mechanisms of injury in the studied groups.*

Table 3. *Rescue analgesic consumption*

	TPVB (n = 30)	TESB (n = 30)	*P* value
Time to first rescue analgesia (hours) mean (Std. Error)	19.67 (.815)	17.70 (.962)	0.202
Total dose of rescue morphine (mg) Median (Range)	6.45 (0.0-25.8)	7.85 (0.0-25.5)	0.198
No. of patients who required rescue morphine (%)	17 (56.67%)	20 (66.67%)	0.426

Data are presented as mean, Std. Error and n (%); n: number of patients; $P < 0.05$ is considered statistically significant.

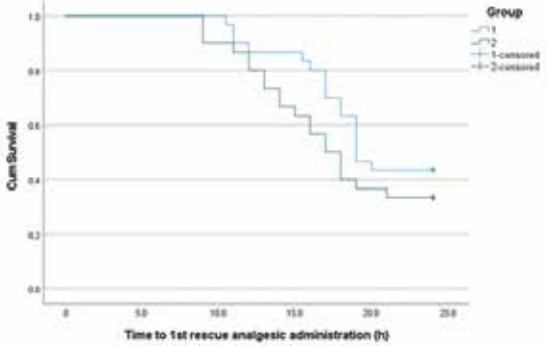

Fig. 3. *Kaplan–Meier curve for the time to first rescue analgesic administration.*

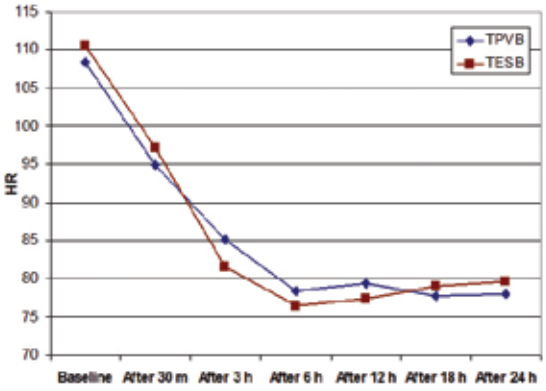

Fig. 4. *Mean HR differences between both study groups.*

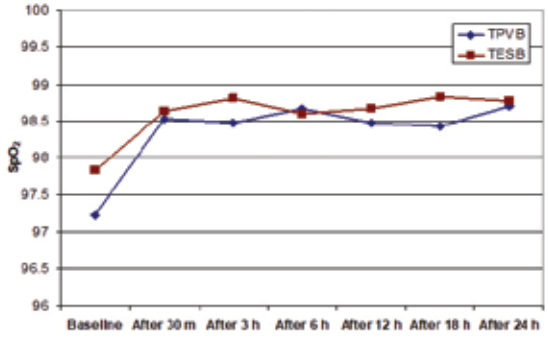

Fig. 5. *Mean SpO_2 differences between both study groups.*

Table 4. *VAS at rest and during Cough in TPVB vs. TESB groups.*

	TPVB (n = 30)	TESB (n = 30)	*P* value
	Median (Range)		
VAS at rest			
Baseline	8.0 (7.0-10.0)	8.0 (7.0-9.0)	0.569
After 30 m	0.5 (0.0-2.0)	1.0 (0.0-3.0)	0.049*
After 3 h	1.0 (0.0-2.0)	1.0 (0.0-2.0)	0.591
After 6 h	1.0 (0.0-3.0)	1.0 (0.0-4.0)	0.988
After 12 h	2.0 (1.0-5.0)	2.0 (1.0-5.0)	0.707
After 18 h	2.0 (0.0-5.0)	3.0 (1.0-5.0)	0.311
After 24 h	3.0 (1.0-4.0)	3.0 (1.0-4.0)	0.166
VAS on Cough			
Baseline	10.0 (8.0-10.0)	10.0 (8.0-10.0)	0.142
After 30 m	1.5 (0.0-3.0)	2.0 (0.0-4.0)	0.041*
After 3 h	2.0 (0.0-4.0)	2.0 (0.0-3.0)	0.801
After 6 h	2.0 (0.0-5.0)	2.0 (1.0-6.0)	0.565
After 12 h	3.0 (2.0-6.0)	3.0 (2.0-6.0)	0.975
After 18 h	3.0 (2.0-6.0)	4.0 (2.0-6.0)	0.642
After 24 h	4.0 (2.0-6.0)	4.0 (2.0-6.0)	0.352

Data are presented as median (interquartile range). n: number of patents; VASR: visual analog scale at rest; *$P < 0.05$ is considered statistically significant.

Table 5. *Complications of the techniques.*

Complications	TPVB (n = 30)		TESB (n = 30)		*P* value
	No.	%	No.	%	
Hypotension	6	20.0%	0	0.0%	0.024*
Bradycardia	2	6.67%	0	0.0%	0.492
Vascular puncture	3	10.0%	0	0.0%	0.237

Data are presented as n (%). n: number of patents; *$P < 0.05$ is considered statistically significant.

and is an expected alternative to TPVB (20). Previous case reports have described its analgesic efficacy including management of acute pain with rib fractures, acute postoperative pain management after ventral hernia repair, thoracic surgery, breast reconstructive surgery, bariatric surgery, postthoracotomy pain syndrome, and chronic shoulder pain (21-24).

In the present study, the efficacy of PVB and ESPB was investigated by time to first rescue analgesia and the 24-hour total consumption of morphine after the block. The results of the current study indicate that injecting a local anesthetic into the fascial deep into the erector spinae muscle resulted in analgesia comparable to that resulting from injecting a local anesthetic into the paravertebral space when both techniques are used as a part of multimodal analgesia for multiple fracture ribs. In addition, both ESPB and TPVB were found to be

effective in reducing pain scores; the degree of pain relief provided by the 2 techniques was comparable.

These 2 techniques were also comparable with respect to changes in hemodynamic state and development of side effects and complications. However, the incidence of hypotension was seen more with TPVB. TPVB has been used to provide pain relief in patients with blunt chest trauma in several trials and was found to be effective and improved the overall outcome (16, 25,26). On the other hand, Adhikary et al (27) analyzed the efficacy of TESB in patients with unilateral multiple rib fractures. There was improvement in respiratory outcome and a modest reduction in pain scores and opioid consumption, as well as hemodynamic stability after the initial treatment.

To the best of our knowledge, no study has tried to compare the analgesic effects between ESPB and PVB in multiple rib fractures. However, efforts to compare them for postoperative pain relief have given conflicting results. Fang et al (28) could not find any difference between TPVB and ESPB in patients either in pain scores at rest or during cough. Aoyama et al (29) revealed that ESPB and TPVB provided comparable postoperative analgesia for 24 hours in patients undergoing breast surgery in terms of postoperative fentanyl consumption and area under the curve (AUC) for pain scores. In a study by El Ghamry et al (30), no significant difference was noticed in VAS scores between ESPB and TPVB over the 24 hours of the study. Gürkan et al (31) reported that there was a significant difference between PVB and control groups for the Numeric Rating Scale at postoperative hours one and 6. Also, Mostafa et al (32) found that the time to first analgesic requirement and morphine consumption postoperatively was insignificant between the groups.

Our study reveals that 20% (n = 6) of the TPVB group developed hypotension within the first 30 minutes after performance of the block, which was managed by intravenous normal saline without need for vasopressors. This was significantly higher than the TESB(consistency} group (P = 0.024). In addition, 2 patients (6.67%) developed bradycardia and 3 patients (10%) experienced vascular puncture; although these were statistically insignificant, bradycardia was clinically significant. This agreed with Adhikary et al (27).

Complications with TESB are very rare because the site of injection is far from the pleura, major blood vessels, and the spinal cord. Local anesthetic toxicity/allergy, vascular puncture, pleural puncture, pneumothorax, and failed block are the primary complications. Because of few published data, further investigations are required to verify safety, complications rates, and efficacy of this technique. Though the level of difficulty in performing a particular technique was not objectively graded in this study, paravertebral block seemed to be more difficult compared with TESB. In the TPVB group, 3 patients required multiple attempts and a change in the level of injection after vascular puncture.

This study encountered several limitations. First, sensory testing couldn't be done to find out the dermatomal distribution of these 2 blocks. Second, it would be better to show and compare the exact limits of the blocks for further investigations. Third, a third control (intravenous opioid) group was not included. Fourth, time to block was not measured so that our study did not show the advantage of ESPB over PVB in terms of simplicity. Fifth, a catheter technique could be used instead of single injection to extend the duration of analgesia and to increase the follow-up period to evaluate the outcomes in term of hospital and intensive care department stay and long-term complications.

Limitations

There was no catheter inserted and we use intermittent injections, which is not the ideal, continuous block with fixed catheter is the ideal. We use dexamethasone as adjuvant with local anesthetics, which delay the need for booster dose of local anesthetics and make comparison between the 2 techniques not ideal. The sample size is small to some extent. We did not exclude addict patients.

Conclusion

Ultrasound-guided ESPB is as effective as PVB for pain alleviation in patients with unilateral multiple fractured ribs with a comparable duration of analgesic effect, reduction of opioid consumption, and stable hemodynamic profile. However, ESPB has the advantage of a lower adverse effect incidence. Clinicians could choose either PVB or ESPB according to their clinical experiences and personal choices.

References

1. May L, Hillermann C, Patil S. Rib fracture management. *BJA Educ* 2016; 16:26-32.
2. Tignanelli CJ, Rix A, Napolitano LM, Hemmila MR, Ma S, Kummerfeld E. Association between adherence to evidence-based practices for treatment of patients with traumatic rib fractures and mortality rates among US trauma centers. *JAMA Netw Open* 2020; 3: e201316.
3. Bugaev N, Breeze J, Alhazmi M, et al. Magnitude of rib fracture displacement predicts opioid requirements. *J Trauma Acute Care Surg* 2016; 81:1.
4. Piraccini E, Byrne H. Is erector spinae plane block useful in preventing the transition from acute to chronic pain after multiple rib fractures? *Turk J Anaesthesiol Reanim* 2020; 48:168-169.
5. Gongola A, Bradshaw JC, Jin J, et al. Retrospective study on rib fractures: Smoking and alcohol matter for mortality and complications. *Trauma Surg Acute Care Open* 2021; 6:e000732.
6. Lynch N, Salottolo K, Foster K, et al. Comparative effectiveness analysis of two regional analgesia techniques for the pain management of isolated multiple rib fractures. *J Pain Res* 2019; 12:1701-1708.
7. Duong W, Grigorian A, Nahmias J, et al. An increasing trend in geriatric trauma patients undergoing surgical stabilization of rib fractures. *Eur J Trauma Emerg Surg* 2020; 23:1-6.
8. Beks RB, Reetz D, de Jong MB, et al. Rib fixation versus non-operative treatment for flail chest and multiple rib fractures after blunt thoracic trauma: A multicenter cohort study. *Eur J Trauma Emerg Surg* 2019; 45:655-663.
9. Bhalla PI, Solomon S, Zhang R, Witt CE, Dagal A, Joffe AM. Comparison of serratus anterior plane block with epidural and paravertebral block in critically ill trauma patients with multiple rib fractures. *Trauma Surg Acute Care Open* 2021; 6:e000621.
10. Liebsch C, Hübner S, Palanca M, Cristofolini L, Wilke HJ. Experimental study exploring the factors that promote rib fragility in the elderly. *Sci Rep* 2021; 11:9307.
11. Battle CE, Hutchings H, Evans PA. Risk factors that predict mortality in patients with blunt chest wall trauma: A systematic review and meta-analysis. *Injury* 2012; 43:8-17
12. Kapicibasi HO. Age differences in blunt chest trauma: A cross-sectional study. *Kardiochir Torakochirurgia Pol* 2020; 17:123-126.
13. Prins JTH, Wijffels MME, Pieracci FM. What is the optimal timing to perform surgical stabilization of rib fractures? *J Thorac Dis* 2021; 13:S13-S25.
14. Dogrul BN, Kiliccalan I, Asci ES, Peker SC. Blunt trauma related chest wall and pulmonary injuries: An overview. *Chin J Traumatol* 2020; 23:125-138.
15. Kim M, Moore JE. Chest Trauma: Current recommendations for rib fractures, pneumothorax, and other injuries. *Curr Anesthesiol Rep* 2020; 10:61-68.
16. Kim J, Lee HJ, Lee YJ, Lee CS, Yoo Y, Moon JY. Ultrasound-guided thoracic paravertebral block as a sympathetic blockade for upper extremity neuropathic pain: A prospective pilot study. *J Pain Res* 2020; 13:3395-3403.
17. Deng G, Gofeld M, Reid JN, Welk B, Agur AM, Loh E. A retrospective cohort study of healthcare utilization associated with paravertebral blocks for chronic pain management in Ontario. *Can J Pain* 2021; 5:130-138.
18. Jadon A. Pain management in multiple fractured ribs; Role of regional analgesia. *Am J Anesth Clin Res* 2017; 3:20-26.
19. Bang S, Chung K, Chung J, Yoo S, Baek S, Lee SM. The erector spinae plane block for effective analgesia after lung lobectomy: Three cases report. *Medicine (Baltimore)*. 2019; 98:e16262.
20. Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ. The erector spinae plane block: a novel analgesic technique in thoracic neuropathic pain. *Reg Anesth Pain Med* 2016; 41:621-627.
21. Chin KJ, El-Boghdadly K. Mechanisms of action of the erector spinae plane (ESP) block: A narrative review. *Can J Anaesth* 2021; 68:387-408.
22. Leyva FM, Mendiola WE, Bonilla AJ, Cubillos J, Moreno DA, Chin KJ. Continuous erector spinae plane (ESP) block for postoperative analgesia after minimally invasive mitral valve surgery. *J Cardiothorac Vasc Anesth* 2018; 32:2271-2274.
23. Cornish PB. Erector spinae plane block: The "happily accidental" paravertebral block. *Reg Anesth Pain Med* 2018; 43:644-645.
24. Tulgar S, Kapakli MS, Senturk O, Selvi O, Serifsoy TE, Ozer Z. Evaluation of ultrasound-guided erector spinae plane block for postoperative analgesia in laparoscopic cholecystectomy: A prospective, randomized, controlled clinical trial. *J Clin Anesth* 2018; 49:101-106.
25. Giang N, Nam N, Trung N, Anh L, Nguyen K. Thoracic paravertebral analgesia for treatment blunt chest trauma with multiple rib fractures. *J Clin Trials* 2017; 07.
26. Yeying G, Liyong Y, Yuebo C, et al. Thoracic paravertebral block versus intravenous patient-controlled analgesia for pain treatment in patients with multiple rib fractures. *J Int Med Res* 2017; 45:2085-2091.
27. Adhikary SD, Liu WM, Fuller E, Cruz-Eng H, Chin KJ. The effect of erector spinae plane block on respiratory and analgesic outcomes in multiple rib fractures: A retrospective cohort study. *Anaesthesia* 2019; 74:585-593.
28. Fang B, Wang Z, Huang X. Ultrasound-guided preoperative single-dose erector spinae plane block provides comparable analgesia to thoracic paravertebral block following thoracotomy: a single center randomized controlled double-blind study. *Ann Transl Med* 2019; 7:174.
29. Aoyama Y, Sakura S, Tsuchiya R, Wittayapairoj A, Saito Y. Erector spinae plane block and paravertebral block for breast surgery: A retrospective propensity-matched noninferiority trial. *J Pain Res* 2020; 13:2367-2376.
30. El Ghamry MR, Amer AF. Role of erector spinae plane block versus paravertebral block in pain control after modified radical mastectomy. A prospective randomised trial. *Indian J Anaesth* 2019; 63:1008.
31. Gürkan Y, Aksu C, Kuş A, Yörükoğlu UH. Erector spinae plane block and thoracic paravertebral block for breast surgery compared to IV-morphine: A randomized controlled trial. *J Clin Anesth* 2020; 59:84-8.
32. Moustafa MA, Alabd AS, Ahmed AMM, Deghidy EA. Erector spinae versus paravertebral plane blocks in modified radical mastectomy: Randomised comparative study of the technique success rate among novice anaesthesiologists. *Indian J Anaesth* 2020; 64:57-62.