Original Article

Ultrasound guided erector spinae plane block versus thoracic epidural analgesia in traumatic flail chest, a prospective randomized trial

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Abstract

Background and Aims: Pain contributes to flail chest morbidities. The aim of this study was to compare the analgesic effects of ultrasound-guided erector spinae plane block (ESPB) with thoracic epidural analgesia (TEA) in patients with traumatic flail chest.
Material and Methods: Sixty patients aged 18 – 60 years, ASA I-II, with unilateral flail chest were allocated into TEA group with a loading dose of 6 ml bupivacaine 0.25% and 2 μg/ml fentanyl and ESPB group with a loading dose of 20 ml bupivacaine 0.25% and 2 μg/ml fentanyl. This was followed by continuous infusion of 6 ml/hour bupivacaine 0.125% and 2 μg/ml fentanyl in both groups for 4 days. Pain scores at rest and on coughing, rescue analgesic consumption, PaO_2/FIO_2 ratio, $PaCO_2$, pulmonary functions and adverse events were recorded.
Results: In both groups, Visual Analog Scale (VAS) scores at rest and on coughing were significantly decreased after block initiation as compared to pre-block value. At all-time points, VAS scores at rest and on coughing were insignificantly different between both groups. PaO_2/FIO_2 ratio, forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1) were significantly increased and respiratory rate, $PaCO_2$, were significantly decreased as compared to pre-block values of the same group without significant difference between both groups. The incidence of hypotension was significantly higher in TEA group than ESPB group.
Conclusions: ESPB can achieve adequate analgesia in traumatic flail chest equivalent to that of TEA with significant improvement of arterial oxygenation and pulmonary functions and without serious adverse effects.

Keywords: Epidural, flail chest, local anesthetics, pain, ultrasonography

Introduction

Rib fractures has an incidence of about 39% of blunt chest trauma patients.[1] Flail chest is defined as three or more consecutive rib fractures, in two or more locations, creating a flail segment with a subsequent mechanically unstable chest wall.[2] The associated morbidity and mortality are caused by pain induced hypoventilation, impaired gas exchange in damaged lung underlying the fractures, and deranged breathing mechanics. Pain reduces the tidal volume and predisposes to atelectasis, retention of pulmonary secretions and pneumonia. A flail segment may cause contusion and edema of the underlying lung with subsequent impaired gas exchange, intrapulmonary shunting and a decreased PaO_2. Negative intrapleural pressure produces paradoxical movement of the flail segment with failure of underlying lung expansion resulting in higher oxygen consumption and hence reduced PaO_2.[3]

Pain contributes to most of these associated morbidities and adequate analgesia is hence a crucial intervention in managing

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these patients.[4-6] Multiple analgesic modalities have been employed in patients with rib fractures, such as intravenous opioids,[7] interpleural[8] intercostal[9] and paravertebral blocks[10] as well as epidural analgesia.[11-13]

The ultrasound-guided erector spinae plane block (ESPB) performed at the level of the T5 transverse process can provide adequate thoracic analgesia as local anesthetics achieve a craniocaudal spread over several levels with anterior penetration into the thoracic paravertebral space with subsequent block of ventral and dorsal rami of spinal nerves as well as the rami communicants transmitting sympathetic fibers.[14,15]

We hypothesized that continuous ESPB can provide effective analgesia in the patients with unilateral flail chest. The aim of this study is to compare the analgesic effects of ultrasound-guided ESPB versus thoracic epidural analgesia (TEA) in patients with unilateral traumatic flail chest.

Material and Methods

After obtaining approval from the Hospital Ethics Committee (Tanta University, Faculty of Medicine, Research Ethics Committee, Quality Assurance Unit, reference number: 31508/04/17), registration in the Pan African Clinical Trials Registry (PACTR201707002379181), and informed written consent from the patients, 60 patients aged 18 – 60 years, of either gender, ASA I-II, isolated chest trauma with unilateral flail chest were enrolled in the study. The duration of the study was from July 2017 to December 2020.

Exclusion criteria included patient refusal, body mass index (BMI) more than 30 kg/m^2, trauma outside the chest wall such as abdominal, head or spinal cord injury, spine or pelvic fracture, the need for mechanical ventilation on admission or during the study period, unconscious patients, hemodynamic instability, hepatic or renal disease, psychiatric illness, and patients with any contraindications for regional anesthetic techniques as coagulopathy, local infection, deformities of vertebral column or known local anesthetic allergy.

The study protocol and the Visual Analog Scale (VAS) for pain, were explained to each patient before performing the block.

Patients were randomly allocated into two equal groups (30 patients each) using computer generated randomization sequence concealed in sealed opaque envelopes.

Patients received TEA using a loading dose of 6 ml bupivacaine 0.25% and 2 μg/ml fentanyl, followed by continuous infusion of 6 ml/hour bupivacaine 0.125% and 2 μg/ml fentanyl for 4 days.

Patients received ultrasound-guided ESPB with a loading dose of 20 ml bupivacaine 0.25% and 2 μg/ml fentanyl, followed by continuous infusion of 6 ml/hour bupivacaine 0.125% and 2 μg/ml fentanyl for 4 days.

Ultrasound-guided erector spinae plane block:

With the patient in the sitting position, the block was performed at a spinal level midway between uppermost and lowest fractured ribs. After local anesthetic infiltration of skin and subcutaneous tissue using 3 ml of 2% lidocaine, a high-frequency linear ultrasound transducer (Sonoscape SSI-6000, China) was placed longitudinally 3 cm lateral to the spinous process till trapezius, rhomboid major, and erector spinae muscles are adequately visualized just superficial to the hyperechoic transverse process. An 18-gauge epidural Tuohy needle (Perifix, B Braun, Germany) was inserted in a cephalad-to-caudal direction till the tip contacted the transverse process. Correct needle tip position in the fascial plane deep to the erector spinae muscle is confirmed by hydrolocation using 0.5–1 mL of saline to visualize the erector spinae muscle lifted off the transverse process without muscle distention with caudal and cranial spread. A loading dose of 20 ml bupivacaine 0.25% and 2 μg/ml fentanyl was injected. Then a multiport epidural catheter was inserted 5 cm beyond the needle tip followed by a continuous infusion of 6 ml/hour bupivacaine 0.125% and 2 μg/ml fentanyl for 4 days.

Thoracic epidural analgesia technique:

Thoracic epidural analgesia was performed using midline approach at the middle level of the fractured ribs, while the patient in sitting position. Entry site of skin and subcutaneous tissue was infiltrated with 3 ml of 2% lidocaine. The epidural space was identified by loss of resistance to air technique. After a test dose of 3 mL of 2.0% lignocaine with epinephrine (1:200,000), a loading dose of 6 ml bupivacaine 0.25% and 2 μg/ml fentanyl was injected followed by continuous infusion of 6 ml/hour bupivacaine 0.125% and 2 μg/ml fentanyl for 4 days.

After admission to the surgical ICU, patients were monitored using noninvasive blood pressure, ECG, and oximetry. An arterial cannula was inserted in the radial artery for arterial blood gas sampling.

All patients received 4 L/min O_2 via a nasal cannula, 1 g IV paracetamol every 6 h and 30 mg IV ketorolac/8 h. Cardiovascular stabilization and intercostal tube insertion for drainage of hemothorax and/or pneumothorax were performed; if needed; before start of the studied analgesic techniques.

Arterial blood gases and bedside spirometry (spirOx plus, MEDITECH, China) were done before the initiation of the studied blocks. All the blocks were performed in awake patients by the same investigator. All patients were encouraged to perform breathing exercises using an incentive spirometer and received regular chest physiotherapy.

After four days, the local anesthetic infusion was gradually tapered off over a period of six hours. When the patients were completely off local anesthetic infusion and remained pain free on systemic analgesics with no other indications of ICU care, they were shifted to the surgical ward. The patients were followed up every day in the surgical ward until the time of discharge from the hospital.

Pain was assessed at rest and on coughing using VAS on a scale from 0 (no pain) to 100 (worst pain) before the block, at 1, 2, 4, 6, 8, 12, and 24 h after blocks then every 12 h for the next 3 days. A rescue analgesia in the form of 20 mg IV pethidine was given if VAS ≥40. The total consumption of the rescue analgesia was recorded.

The PaO_2/FiO_2 ratio, arterial CO_2 pressure ($PaCO_2$), respiratory rate, forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1) were recorded before block performance, and every day for 4 days after intervention. Any adverse events such as hypotension, bradycardia, pneumonia, respiratory failure requiring mechanical ventilation, and pulmonary embolism were recorded. Hypotension was defined as ≥25% fall in systolic blood pressure below the baseline readings or an absolute value of 80 mm Hg of systolic blood pressure. If hypotension occurred, it was managed with intravenous fluids (500 ml crystalloids) and ephedrine (6 mg increments) if needed. Bradycardia was defined as a decrease of the heart rate below 60 beats/min and was managed with atropine 0.01 mg/kg.

Primary outcome was the VAS score during the first 96 hours after initiation of the block. Secondary outcome was the total pethidine consumption during the first 96 hours after initiation of the block.

Statistical analysis

Calculation of sample size was based on the changes of the VAS score after initiation of either TEA or ESPB. Based on the results of previous study,[16] (pooled SD after epidural 2.2), at least 27 patients were needed to detect 20 mm difference of the VAS score at power of the study of 90% and α error of 0.05. Thirty patients to each group were recruited to avoid dropout cases. The sample size calculation was based on a 2-sample independent *t* test (2-sided) of the visual analog scale score.

The statistical analysis was performed utilizing the statistical software SPSS 16 (SPSS Inc., Chicago, IL). Kolmogorov–Smirnov test and visual inspection of histograms were performed to verify the assumption of normality. The quantitative parameters as mean ± standard deviation and analyzed utilizing independent sample t-test. For within-group analysis, the repeated measures analysis of variance was used to compare means. Categorical data were presented as patients' number or frequencies (%) and were analyzed utilizing the Chi-Square test or the Fisher exact test as appropriate. $P < 0.05$ was considered significant.

Results

Seventy-four patients were evaluated for enrollment in the study. Eleven patients did not match our inclusion criteria, and 3 patients declined to participate in the study. Sixty patients were enrolled [Figure 1].

Table 1 presents demographic data (age, sex, and BMI) as well as the number and side of fractured ribs, number of patients with hemothorax and/or pneumothorax and number of patients who needed chest tube insertion in the studied groups.

In both TEA and ESPB groups, the VAS scores at rest were significantly decreased after the initiation of the allocated block as compared to the pre-block value ($P < 0.05$). At all-time points, VAS scores at rest were insignificantly different between both groups ($P > 0.05$). Figure 2

After initiation of the allocated block, in both TEA and ESPB groups, the VAS scores on coughing were significantly decreased as compared to the pre-block value ($P < 0.05$). The VAS scores on coughing were comparable between both groups at all time points. ($P > 0.05$). Figure 3

The total consumption of rescue analgesia (pethidine) during the first 96 hours after initiation of the block was insignificantly different between the TEA group (188 ± 29.1 mg) and the ESPB group (200.7 ± 30.4 mg) ($P = 0.104$, 95% confidence interval (CI); -2.71; 28.04). Table 2

The pre-block respiratory rate was (23.27 ± 3.47 breaths/min) in the TEA group and (22.97 ± 3.17 breaths/min) in the ESPB group ($P = 0.728$, CI; -1.42; 2.02). Respiratory rate was significantly decreased after initiation of the designed block, TEA or ESPB, as compared to the pre-block value ($P > 0.05$) without significant difference between both groups ($P > 0.05$). Table 3

In both groups, $PaCO_2$ was significantly decreased after blocks as compared to the pre-block value of the same

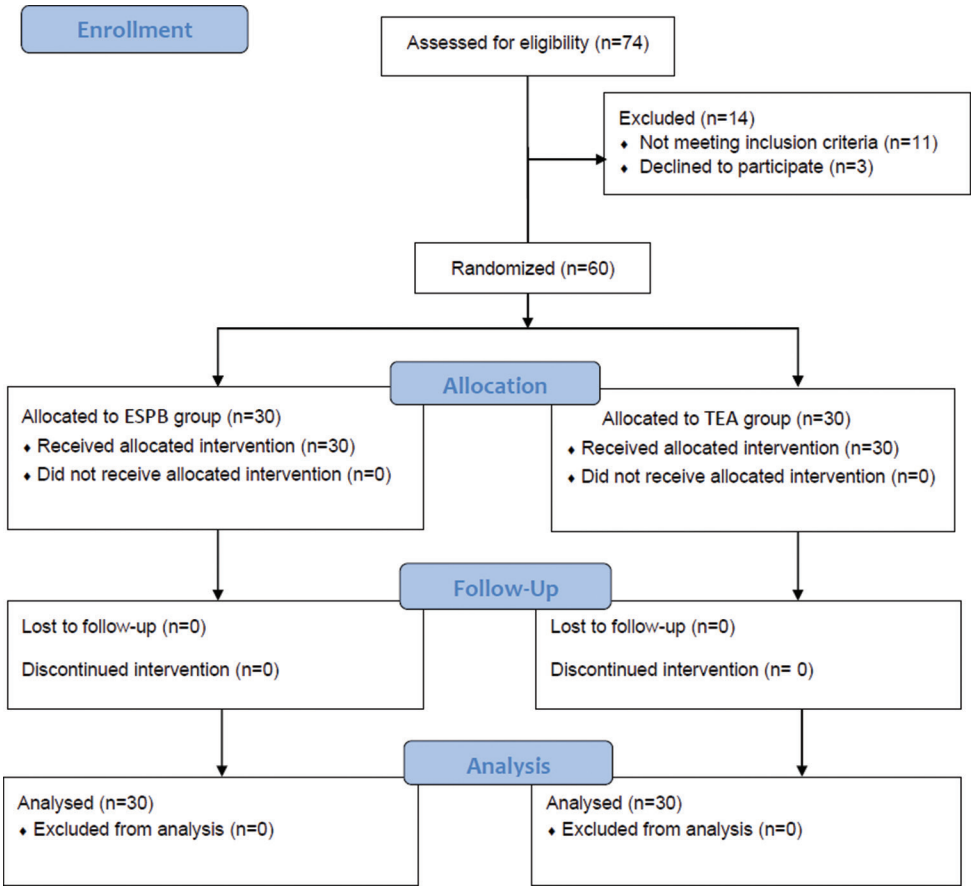

Figure 1: CONSORT flow diagram of participants through each stage of the randomized trial

Table 1: Patients' characteristics

	TEA group	ESPB group	Mean difference	95% CI	*P*
Age (years)	36.90±8.23	38.57±8.35	1.67	-2.6; 5.95	0.439
BMI (kg/m^2)	25.13±2.22	25.70±2.61	0.567	-0.69; 1.8	0.370
Gender (M/F)	19/11	21/9			0.584
Number of fractured ribs	5.17±1.18	5.03±1.27	0.133	-0.5; 0.77	0.675
Side of fractured ribs Rt/Lt	18/12	16/14			0.602
Hemothorax and/or pneumothorax	21 (70%)	18 (60%)			0.417
Chest tube insertion	11 (36.7%)	9 (30%)			0.584

Data presented as mean±SD or patient number (%)

group ($P < 0.05$). The FVC and FEV1 were significantly increased as compared to the pre-block value of the same group ($P < 0.05$). The comparison between both groups regarding the $PaCO_2$, FVC and FEV1 was insignificantly different ($P > 0.05$). Table 3

The pre-block PaO_2/FIO_2 ratio was insignificantly different between the TEA group (210.0 ± 12.6) and the ESPB group (213.9 ± 12.5) ($P = 0.230$, CI; - 2.55; 10.42). After initiation of the allocated block, the PaO_2/FIO_2 ratio was significantly increased as compared to the pre-block value of the same group ($P < 0.05$) without significant difference between both groups ($P > 0.05$). Table 3

The incidence of hypotension was significantly higher in the TEA group than the ESPB group ($P = 0.01$). The incidence of bradycardia, pneumonia and nausea and vomiting was insignificantly different between both groups ($P = 0.237$, > 0.99, 0.353 respectively). Table 2

No patients needed mechanical ventilation during the study period.

Discussion

The results of our study revealed that the ESPB effectively reduced pain associated with the unilateral traumatic flail

Table 2: Rescue analgesic consumption, length of hospital stay and complications in the studied groups

		TEA group	ESPB group	Mean difference	95% CI	*P*
Rescue pethidine consumption (mg)		188±29.1	200.7±30.4	12.67	-2.71; 28.04	0.104
Length of hospital stay (days)		8.3±1.78	8.9±1.88	0.6	- 0.34; 1.55	0.21
Complications	Bradycardia	5 (16.7%)	0			0.237
	hypotension	7 (23.3%)	0			0.01
	Nausea and vomiting	4 (13.3%)	1 (3.3%)			0.353
	Pneumonia	2 (6.7%)	1 (3.3%)			>0.99

Data presented as mean±SD or patient number (%)

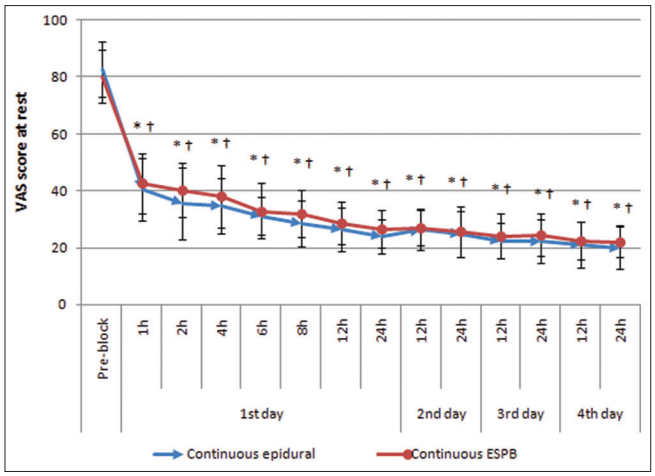

Figure 2: VAS scores at rest in both groups. *indicates significant difference as compared to pre-block value of the TEA group. †indicates significant difference as compared to pre-block value of the ESPB group

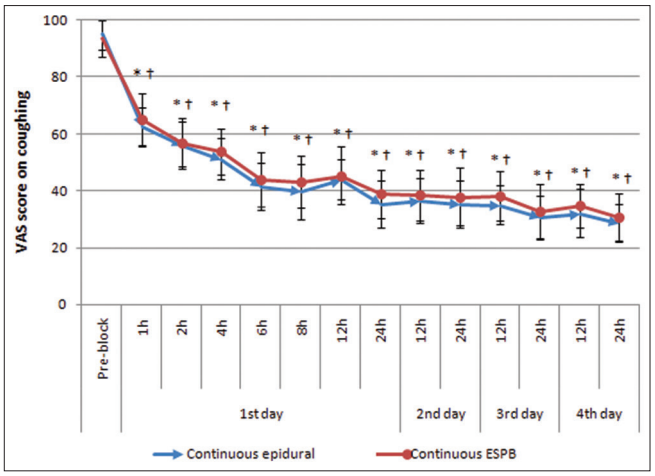

Figure 3: VAS scores on coughing in both groups. *indicates significant difference as compared to pre-block value of the TEA group. †indicates significant difference as compared to pre-block value of the ESPB group

chest and improved the arterial oxygenation and pulmonary functions as those provided by the TEA. Moreover, the ESPB was associated with better hemodynamic stability and without serious side effects.

Pain is a contributing factor to unfavorable outcomes following traumatic fracture ribs due to inadequate respiratory efforts leading to subsequent atelectasis, inability to clear secretions and an increased risk of pneumonia.[4,10,17] Adequate analgesia is therefore crucial in the managing those patients.[6]

Epidural analgesia (EA) using either local anesthetics, opioids or a combination of both has been successfully employed in managing pain in patients with rib fractures. EA increases functional residual capacity (FRC), dynamic lung compliance and vital capacity; by decreasing the airway resistance; and by significantly increasing PaO_2.[10-13,17]

Though the guidelines braced by the Eastern Association for the Surgery of Trauma (EAST) recommends EA or a multimodal approach over opioids alone in patients with blunt chest trauma,[6] there is growing evidence questioning its advantages over other less invasive analgesic modalities in the management of severely injured trauma patients.[7,10,11,18,19] So, the recommendation the EAST for the use of epidurals is conditional and is based on "very low-quality evidence".[6]

McKendy *et al.*[20] suggested that TEA may actually worsen hospital complications and increase the length of hospital stay. Moreover, Carrier *et al.*[21] reported that EA had no effect on improving mortality, length of hospital and ICU stay when compared with other analgesic regimens. In a trial to assess the pros and cons of continuous EA compared with other analgesic interventions in cases of traumatic fracture ribs, systematic reviews and meta-analyses performed by Duch *et al.*[22] reported no significant difference in pain, duration of mechanical ventilation, pneumonia, and mortality. Well-powered RCTs investigating clinically relevant patient-centered outcome measures are highly needed.

ESPB is a myofascial plane block successfully utilized in the management of pain after both rib fractures and thoracic surgery, as well as in chronic thoracic pain.[14,23-29] Adhikary *et al.*[23] in a retrospective cohort study concluded that ESPB can improve inspiratory capacity following rib fracture, and reported modest reduction in pain scores and opioid consumption, as well as hemodynamic stability. The ESPB is therefore a feasible alternative to many regional analgesic

Table 3: Pulmonary functions, PaO_2/FIO_2 and $PaCO_2$

		TEA group	ESPB group	Mean difference	95% CI	*P*
PaO_2/FIO_2	pre	210.0±12.6	213.9±12.5	3.93	-2.55; 10.42	0.230
	24 h	266.8*±11.9	261.6*±18.3	5.11	-2.87; 13.11	0.205
	48 h	275.7*±11.7	269.7*±16.8	6.0	-1.46; 13.46	0.205
	72 h	276.1*±10.2	270.8*±17.8	5.25	-2.24; 12.73	0.166
	96 h	282.4*±16.8	278.4*±17.3	3.98	-4.84; 12.80	0.370
$PaCO_2$	pre	40.17±3.63	40.07±3.90	0.1	-1.84; 2.05	0.919
	24 h	38.63±2.76	38.77±3.00	0.13	-1.36; 1.62	0.859
	48 h	37.87*±1.89	38.03*±2.13	0.17	-0.87;1.21	0.749
	72 h	37.30*±2.32	37.70*±1.91	0.4	-0.7;1.5	0.470
	96 h	37.27*±1.89	37.43*±1.89	0.17	-0.81;1.14	0.734
RR	pre	23.27±3.47	22.97±3.17	0.3	-1.42; 2.02	0.728
	24 h	20.00*±2.45	21.03*±1.90	1.03	-0.1; 2.17	0.073
	48 h	19.13*±2.5	20.1*±2.11	0.97	-0.23; 2.16	0.111
	72 h	18.1*±1.86	18.7*±1.95	0.6	-0.39; 1.59	0.228
	96 h	17.3*±1.58	18.07*±2.3	0.77	-0.25; 1.79	0.138
FVC	pre	1.96±0.21	1.99±0.20	0.03	-0.08; 0.13	0.581
	24 h	2.86*±0.25	2.81*±0.20	0.05	-0.07; 0.16	0.406
	48 h	3.15*±0.26	3.08*±0.21	0.07	-0.05; 0.19	0.264
	72 h	3.19*±0.23	3.11*±0.22	0.08	-0.04; 0.2	0.190
	96 h	3.28*±0.24	3.26*±0.22	0.02	-0.1; 0.14	0.708
FEV1	pre	1.48±0.14	1.53±0.13	0.05	-0.03; 0.12	0.209
	24 h	2.29*±0.25	2.27*±0.27	0.03	-0.11; 0.16	0.706
	48 h	2.63*±0.27	2.56*±0.27	0.07	-0.07; 0.21	0.294
	72 h	2.62*±0.25	2.65*±0.25	0.04	-0.09; 0.17	0.572
	96 h	2.72*±0.27	2.68*±0.28	0.03	-0.11; 0.17	0.626

*Data presented as mean±SD. * Indicates significant difference as compared to the pre-block value of the same group*

techniques. Hamilton and Manickam[25] as well as Kumar *et al.*[26] reported effective analgesic effect of continuous ESPB in patients with multiple rib fractures.

The ESPB can achieve analgesia to both anterior and posterior hemithorax, thus potentially effective in the management of pain following extensive thoracic surgery or trauma. Innervation of the ribs and adjoining tissue occur primarily through thoracic spinal nerves. After emerging from the spinal cord, traversing through the intervertebral foramina, the thoracic spinal nerves split into ventral and dorsal rami. Ventral rami continue as intercostal nerves innervating the lateral and anterior chest wall, whereas the dorsal rami innervate the posterior chest wall after exiting the paravertebral space.[30]

The ESP block is directed at the erector spinae myofascial plane, which is located on the posterior chest wall between the anterior surface of the erector spinae muscle and oriented cephalocaudally to the posterior surface of the spinal transverse process.[27] Local anesthetic in this plane can block the dorsal rami producing anesthesia to the posterior hemithorax as well as ventral rami and intercostal nerves that can be blocked by anterior spread, providing analgesia to ribs and periosteum as well as large cutaneous areas of the lateral and anterior chest wall (by blockade of lateral and anterior branches of the intercostal nerves).[14] A single injection can achieve extensive thoracic anesthesia as local anesthetics exhibit cephalocaudal spread anesthetizing at least three segments above and four segments below the injection site.[14,27]

The incidence of hypotension in our trail was lower in the ESPB than the TEA group. Hypotension induced by the EA is caused by the local anesthetic-induced sympathectomy.[21] EA-induced hypotension was reported in the patients with multiple fracture ribs by Sagiroglu *et al.*[31] and Peek *et al.*[32] ESPB is considered a simpler, safer, and less invasive regional analgesic technique that provides extensive truncal analgesia with smaller risk of pneumothorax or neurovascular injury as there are no vital structures near the site of needle insertion. Using appropriate local anesthetic solutions, the risk of local anesthetic toxicity can be minimized. One of the advantages of an ESPB is that it can be utilized in the presence of either coagulopathy or anticoagulation.[27,33]

On the other hand, the use of TEA is also limited by some adverse effects such as hypotension, possibility of lower limb weakness and urinary retention and the need for intensive monitoring and nursing care.[23] Moreover, bradycardia, respiratory depression, and catheter-related complications

such as epidural hematoma or abscess can also complicate TEA.[32,34] A matched-cohort study by McKendy *et al*.[20] reported higher incidence of respiratory complications and longer hospital stay in cases with fractured ribs who received EA compared to other analgesic interventions. They attributed that to the possibility of failed application of EA due to lack of experience as well as delayed mobilization. Epidural analgesia may not be the first choice in unilateral rib fracture management.[33]

Our study has some limitations. In addition to the relatively small sample size, we did not perform assessment of dermatomal sensory block. Another limitation is that we did not assess the long-term outcomes of continuous ESPB or the continuous TEA. In addition, we did not assess the ease and time taken to insert ESPB or TEA catheters.

Conclusion

ESPB can be considered as a safe and effective alternative to the thoracic epidural analgesia in patients with unilateral traumatic flail chest. ESPB is effective in reducing the pain scores and improving the arterial oxygenation and pulmonary functions without increased adverse effects.

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Conflicts of interest
There are no conflicts of interest.

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