Original Article

Ultrasound-guided deep versus superficial continuous serratus anterior plane block for pain management in patients with multiple rib fractures: A prospective randomized double-blind clinical trial

ABSTRACT

Background: Efficient analgesia is the cornerstone in multiple rib fractures (MRFs) management. The serratus anterior plane block (SAPB) shows promising outcomes. However, it is still provocative whether the superficial or deep approach is more effective in the SAPB procedure. We hypothesized that the deep approach of ultrasound (US)–guided continuous SAPB could be superior for MRFs pain management.

Methods: Sixty-two adult patients having unilateral MRFs, were randomized into two groups to receive continuous superficial SAPB (group S, n = 31) or continuous deep SAPB (group D, n = 31). As a primary outcome, we compared pain numeric rating scale (NRS), while total analgesic consumption, incentive spirometer volume (IS-V), lung ultrasound score (LUSS), basal and 24-h serum beta-endorphin (BE) levels, and any adverse events were secondary outcomes.

Results: There was a significant reduction in NRS in favor of group D when compared to group S at 30 minutes ($P = 0.001$) until 12 hours ($P = 0.029$); total analgesic consumption was significantly lower in group D ($P = 0.005$). A significant increase in the median IS-V in group D compared to group S at 90 minutes ($P = 0.02$) and 12h postblock ($P = 0.004$) LUSS was significantly lower in D group at 90 min, 12 h, and 24 h ($P = 0.04, 0.001, 0.031$). No significant differences as regards serum BE levels. No adverse events were noted.

Conclusion: Either superficial or deep continuous SAPB can be used safely and effectively in managing pain related to MRFs. Notably, the deep approach offered superior analgesia and improved deep breathing compared to the superficial.

Key words: Multiple rib fractures, pain management, serratus anterior plane block

Introduction

Blunt chest trauma poses a significant management challenge, particularly when it is compounded by multiple rib fractures (MRFs). This condition is correlated to considerable morbidity, primarily due to the intense pain it causes.[1]

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Such pain can severely restrict breathing, coughing, movement, and puts them in a higher jeopardy of developing atelectasis and pneumonia, making effective pain management crucial to promote the expansion of lung volume. It is also vital to mitigate the negative impact of opioids on both airway patency and respiratory drive.[2]

Thoracic epidural analgesia and paravertebral nerve blockade have been recommended for rib fracture analgesia. Nonetheless, their usage is hampered by technical challenges, complications, contraindications (specially coagulopathy), and conflicting research on their benefits for trauma patients with MRFs,[3] besides patient positioning for such procedures may be impractical.[4]

The ultrasound-guided (USG) serratus anterior plane block (SAPB) is known for its ease of performance, safety, and lack of major contraindications. There are two potential injection planes: either deeper or superficial to the serratus muscle (SAM).[5] SAPB has proven to be efficient in analgesic management for numerous conditions, such as rib fractures, thoracotomies, thoracoscopies, breast surgeries, and postmastectomy pain syndrome.[5-7]

Yet, it is questioned whether superficial or deep SAPB is superior. Although some studies have evaluated the two planes,[7-10] the distinction among them has not been extensively researched in traumatic MRFs analgesia.

Using incentive spirometry provides, a reliable evaluation of pulmonary function and displays a sound correlation with inspiratory reserve volume and vital capacity.[11]

Incentive spirometer volume (IS-V) has been suggested as a potential metric for assessing respiratory function after rib fractures.[12,13]

The lung ultrasound score (LUSS) is granted as a consistent semiquantifiable practice for evaluating the magnitude of lung aeration loss. This scoring system has shown its efficacy in the diagnosis of many lung conditions.[14]

Our hypothesis for this study was to compare the effect of US-guided deep versus superficial continuous SAPB for analgesic management in patients with MRFs.

Materials and Methods

Eligibility of the study

This prospective interventional double-blinded clinical trial was done at Assiut University Hospitals, Assiut, Egypt, from August 3, 2021, to December 10, 2023, after approval by the medical Ethical Committee of the Faculty of Medicine, Assiut University, on December 28, 2020, under the number (IRB17200526) and ClinicalTrials.gov registration (ID: NCT04575272). All participants signed a written informed consent before inclusion. The study followed the ethics and guidelines of the Declaration of Helsinki.

Inclusion criteria

Inclusion criteria include adult patients aged between 18 and 60 years, from both genders, who had unilateral traumatic rib fractures, specifically three or more anterolateral, lateral, or posterolateral fractures confirmed by a CT chest scan, a pain score ≥ 4, and were admitted to the AUH trauma department.

Exclusion criteria

Exclusion criteria include patients who declined the intervention, infection at the injection site, a body mass index (BMI) of 35 or higher, those with significant head injuries leading to unconsciousness, severe pain related to another injury, or a known allergy to local anesthetics.

Study design and randomization

The current study was a prospective randomized double-blind study. On providing written informed consent after thorough discussion about the study design, interventions, outcomes, and possible adverse events, the participants were randomly allocated to one of the two study groups (within 12 h of their admission), using a computer-created randomization table. Details of the group assignments were sealed within opaque envelopes. The principal researcher opened the envelope and administered the designated block.

The groups were as follows: group S (31 patients) received continuous superficial SAPB and group (D) (31 patients) received continuous deep SAPB. Both the assessing physicians and the patients were blinded to the type of block performed.

Preparation

Monitoring of the patients was carried out through peripheral pulse oximetry, electrocardiogram, and noninvasive blood pressure tracking. Intravenous lines were placed and secured, oxygen therapy was individualized and titrated according to patient condition, drugs for local anesthetic systemic toxicity were on hand, and each patient was administered 1 gram of intravenous paracetamol every 6 hours. They were briefed on the procedure, NRS pain assessment, and how to use the incentive spirometer.

SAPB technique

To reduce the discomfort caused by the pressure of the ultrasound probe and the needling process in the SAPB

technique, preprocedural sedation was administered using intravenous (IV) midazolam (0.03 mg/kg). The patient was gently placed flat with an abducted arm to reveal his midaxillary area. In a sterile environment, a linear ultrasound transducer (GE Healthcare-Logiq F6) was used to scan the injured hemithorax and identify the fifth rib at the midclavicular line.

Subsequently, the probe was shifted laterally to locate the SAM and the fifth rib underneath it at the midaxillary region. 2 mL of 2% lidocaine was used to numb the skin; then, we inserted an 18-gauge Touhy needle (in-plane), just above (for the S group) or below (for the D group) the SAM.

Following a negative aspiration test, 36 mL of 0.25% bupivacaine was injected, followed by insertion of a 20-gauge catheter into the identified space. After removing the needle, the catheter was fixed in place with adhesive. Then, an infusion of 5 ml/h of 0.125% bupivacaine was initiated using an Infusion Syringe Pump, with continuous close monitoring of the patient.

LUSS technique

An experienced investigator, unaware of the patients' group assignments, conducted lung ultrasounds using a GE Healthcare-Logiq F6 ultrasound device and a convex probe, with the patient lying supine. The study used a globally recognized technique for point-of-care lung ultrasound, which involves a thorough eight-zone examination of the lung.[14–16] Each hemithorax was segmented into four zones by the anterior axillary and nipple lines. This eight-zone method was chosen for its clinical practicability.

Each zone received a score depending on the findings from the lung ultrasound. 0 score was given for a normal lung and pleura pattern (A-lines or 0:2 separated B-lines). For numerous discrete B-lines, a score of 1 was given. In addition, a score of 2 indicated multiple fused B-lines, while a score of 3 was associated with specific lung tissue patterns showing dynamic air bronchograms, indicative of lung consolidation. The highest score detected in each zone was noted, and the cumulative score was calculated, with the maximum possible score being 24.

Lab work: Two venous blood samples (3 ml) were drawn from each patient before and 24 h after SAPB, after centrifugation plasma samples were stored at -70°C; finally, we used Human Beta-Endorphin ELISA Kit (Catalog No: SG-00355) for the assay.

Outcome measures: Primary outcome was to compare the pain numeric rating scale (NRS) between superficial and deep approaches of continuous USG-SAPB at 24 h.

Comparing both groups regarding: total analgesic use over 72 hours, IS-V, LUSS, serum beta-endorphin levels at 24 hours, need for mechanical ventilation, pneumonia development, hospital stay length, and any adverse events were secondry outcomes.

Data collection

Data collection include demographic and baseline data (age, body mass index (BMI), gender, medical diseases, number of rib fractures, existence of intercostal drains, and lung contusions).

NRS score: "0 implies no pain, and 10 indicates the most terrible imaginable pain" basal, at 30 min, 2 h, 4 h, 6 h, 12 h, 24 h, 36 h, 48 h, and 72 h post-SAPB.

Total analgesic consumption: when NRS score equal or exceed 4 IV 30 mg ketorolac was given and the total dose throughout the 72 h was recorded.

IS-V: basal and at 90 min and then every 12 h until 72 h post-SAPB.

LUSS: basal then at 90 min and then every 24 h until 72 h after SAPB.

Vital signs including heart rate (HR), respiratory rate (RR), mean arterial pressure (MAP), and partial saturation of oxygen (SpO2) were recorded for 3 days.

Stress response: (basal and 24 h after SAPB) serum BE levels.

Need for mechanical ventilation (MV), development of pneumonia, length of hospital stay, and any adverse events were also recorded.

Statistical analysis

Sample size: We used G*Power 3 software to calculate our sample size. The NRS pain score was our primary outcome variable. Based on a previous study,[17] 27 participants were required to detect a significant difference of 2.5 in NRS with a standard deviation of 3.2 at 80% power of the study and α error of 0.05 on a two-tailed test. Subsequently, we included 31 patients per group for potential dropouts.

We used SPSS (Statistical Package for the Social Sciences, version 27) for data collection and analysis. The Shapiro–Wilk test was used to evaluate data distribution normality. For quantitative data with a normal distribution, the mean and standard deviation (SD) were computed and analyzed via the independent *t*-test to compare two distinct group means. In contrast, quantitative data with an abnormal distribution were

denoted as median and interquartile range (IQR or range) and analyzed with the Mann–Whitney test for comparing two distinct group medians and the Wilcoxon signed-rank test for medians at different time points within the same group. Nominal data were stated as counts (n) and percentages, and with the Chi-squared test applied for analysis, a 95% confidence level was maintained, deeming a *P* value lower than 0.05 as significant for the primary outcome. Findings of statistical significance in secondary outcomes are considered indicative, warranting further validation in subsequent trials to be deemed conclusive.

Results

Seventy-six patients were presented with MRFs, fourteen of them did not meet our inclusion criteria and were excluded. Figure 1 shows the CONSORT flow diagram with the 62 patients who completed the study.

Both groups had nonsignificant differences regarding demographic and baseline clinical data (age, BMI, gender, medical diseases, number of rib fractures, existence of intercostal drains, and lung contusions) [Table 1].

Numeric rating scale

The D group had significantly lower median (IQR) NRS scores than the S group at 30 min [2 (1) versus 4 (1); $P = 0.001$], 2 h [3 (2) versus 3 (2); $P = 0.025$], 4 h [2 (2) versus 3 (2); $P = 0.002$], 6 h [2 (2) versus 3 (2); $P = 0.049$], and 12 h [2 (2) versus 3 (2); $P = 0.029$] after block but not at 24 h and afterward (at 36 h, 48 h, and 72 h) [Figure 2].

In each group, there was a significant decrease in the NRS score following the SAPB when compared to baseline values up to 72 h ($P < 0.001$ for all).

The median (range) total analgesic consumption throughout 72 hours was significantly lower in the group D (30 (150-0)) when compared to the group S (30 (150-0)) $P = 0.005$ [Table 2].

Incentive spirometer volume

The median (IQR) IS-V was significantly higher in the group D as compared to the group S at 90 min [1200 (500) versus 1000 (400); $P = 0.02$] and 12 h [1300 (400) versus 1200 (400); $P = 0.004$] after the block. The groups were comparable at 24 h and afterward (at 36 h, 48 h, and 72 h), and both groups showed a significant increase in IS-V when compared to baseline values ($P < 0.001$) [Table 3].

Lung ultrasound score

LUSS was significantly lower in the group D than the group S at 90 min [3 (4) versus 5 (4) $P = 0.04$], 12 h [2 (3) versus 5 (4) $P = 0.001$], and 24 h [1 (3) versus 3 (4) $P = 0.031$] after the block, but not afterward (at 36 h, 48 h, and 72 h) [Figure 3].

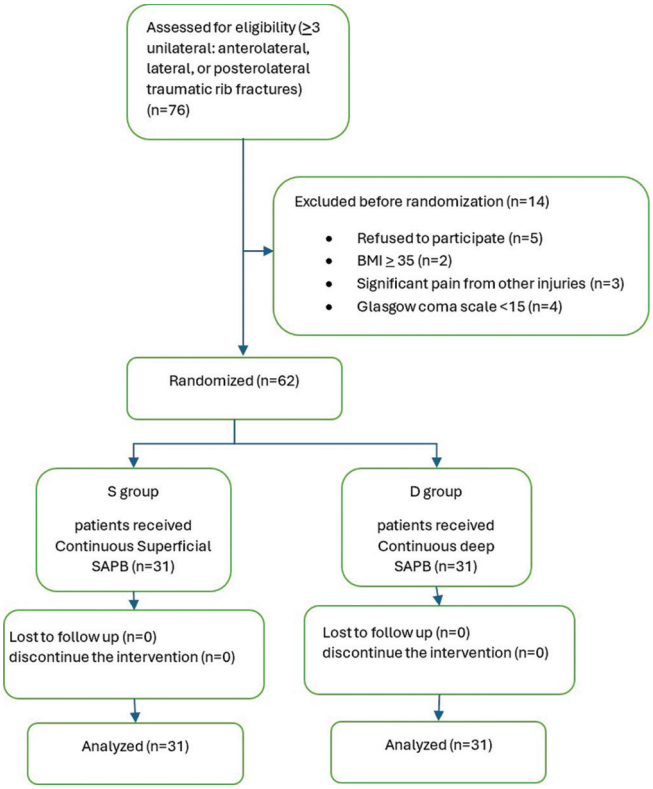

Figure 1: Figure 26 CONSORT Flowchart of the two studied groups

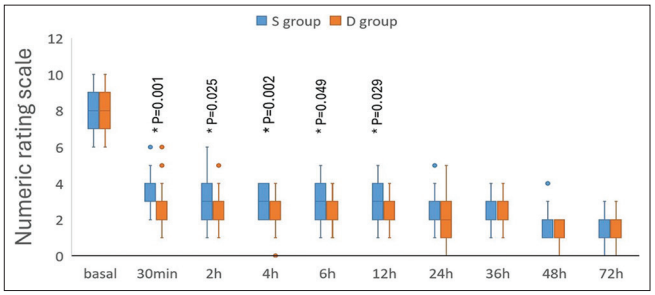

Figure 2: Numerical rating scale among the studied groups. Data are denoted as medians (ranges). Asterisk (*) denotes a statistically significant difference (*P* < .05)

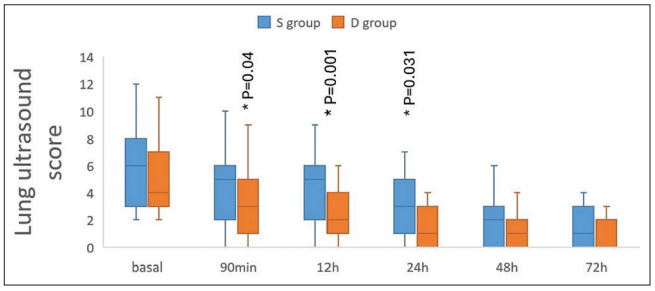

Figure 3: Lung ultrasound score (LUSS) among the studied groups. Data presented as median (range). * Represents statistically significant difference (*P* < .05)

Table 1: Demographic and Baseline clinical data

Variable	S group ($n=31$)	D group ($n=31$)	*P*
Age (years)	41.9±13.1	42.8±13.6	0.813
Body mass index (kg/m^2)	28.75±3.69	29.29±3.92	0.581
Gender (male/female)	22/9	20/11	0.786
Number of rib fractures	5 (2)	5 (3)	0.971
Chest drain	5 (16.1%)	7 (22.6%)	0.749
Lung contusions	9 (29.0%)	6 (19.4%)	0.554
Medical disease			
HTN	5 (16.13%)	3 (9.68%)	0.749
DM	1 (3.2%)	1 (3.2%)	

Data are denoted as numbers and percentages, mean±SD, and median (IQR). $P<0.05$ implies a statistically significant difference among the study groups. HTN: Hypertension, DM: Diabetes mellitus

Table 2: other secondary outcomes among the studied groups

Variable	S Group	D Group	*P*
baseline-BE level (pg/ml)	5.7 (2.9)	5.2 (2)	0.26
24 h-BE level (pg/ml)	4 (2.9) *	3.5 (1.7) *	0.237
Total analgesic consumption (mg)	30 (150-0)	0 (120-0)	0.005
Non-invasive ventilation (n)	5 (16.12%)	3 (9.7%)	0.749
Hospital length of stay (days)	6 (16-3)	4 (10-3)	0.184

Data are shown as numbers, and (percentages), median (IQR or Range). $P<0.05$ implies statistical significance among the study groups. *denotes a significant intragroup reduction of BE from baseline values

Table 3: Incentive spirometer volume (IS-V) (ml) among the studied groups

Variable	S group	D group	*P*
Pre (IS-V)	700 (400)	600 (400)	0.419
90 min (IS-V)	1000 (400)*	1200 (500)*	0.02
12 h (IS-V)	1200 (400)*	1300 (400)*	0.004
24 h (IS-V)	1500 (400)*	1500 (500)*	0.707
36 h (IS-V)	1700 (600)*	1600 (500)*	0.848
48 h (IS-V)	1900 (400)*	1800 (500)*	0.51
72 h (IS-V)	2000 (400)*	2000 (400)*	0.949

Data are represented as median (IQR). *Denotes intragroup significant increase in median IS-V compared to baseline. $P<0.05$ represents statistical significance connecting the study groups

Other secondary outcomes

As shown in Table 2, both groups had nonsignificant differences regarding basal, 24 h postblock serum BE level (pg/ml) and length of hospital stay.

In each group, there was a significant reduction in serum BE (pg/ml) at 24 h after SAPB when compared to baseline levels ($P < 0.001$).

No patient required invasive MV; only five patients in S group and three patients in D group needed NIV. There was no clinically significant difference among both groups in terms of MAP, HR, SpO2, and RR.

Neither group developed procedure-related complications such as pneumothorax, hematoma, and LAST. None developed pneumonia or mortality during hospitalization.

Discussion

SAPB have become popular as a safer and simpler option for MFRs pain relief.[18–20] However, there remains controversy over whether superficial or deep SAPB technique is more effective.[21]

In this prospective randomized trial, USG continuous deep was compared to superficial SAPB for analgesic management in patients with MRFs. Both groups demonstrated a significant reduction in NRS scores up to 72 h after the block.

Specifically, the D group showed a significant reduction in NRS pain scores compared to the S group at 30 minutes ($P = 0.001$) and up to 12 hours ($P = 0.029$). However, beyond 12 h until 72 h postblock, both groups were comparable.

Total analgesic consumption throughout 72 hours was significantly lower in the group D when compared to the group S ($P = 0.005$).

In line with this study, Edwards *et al*.[21] studied the analgesic effects of SAPB in mastectomy patients. Patients who took deep SAPB had significantly lower pain scores at 12 h, but not at subsequent time periods (until 24 h). The study concluded that both deep and superficial SAPB can be effective for pain control in mastectomy patients. Notably, deep SAPB demonstrated greater analgesic benefits, resulting in a 30% reduction in opioid utilization during the following 24 h.

Jayadeep *et al*.[22] in their randomized clinical trial compared the effectiveness of USG deep and superficial SAPB in pain management for modified radical mastectomy surgery. Notably, NRS scores were significantly lower in deep SAPB group during rest at 12 h and 16 h, alongside during cough at eight, 12, and 16 hours. However, after 16 hours, NRS scores became comparable between the two groups.

In a case series by Paul *et al*.,[23] both approaches of SAPB were successfully used in ten patients with MRFs, regardless of the specific rib fracture site. There were no instances of block failure, and none of the patients needed rescue analgesics.

In contrast, in a study by Lan Qiu *et al*.,[9] the analgesic effect of deep versus superficial SAPB was investigated in patients undergoing thoracoscopic lobectomy. Notably, there was no significant difference in median VAS scores among groups at 6 hours (1 vs. 1) and 12 hours (1 vs. 1). However, at 24 hours, the

deep group exhibited higher VAS scores (3 vs. 1, $P < 0.001$). The superior effect observed in the Superficial group may be attributed to its ability to block the lateral thoracic nerve (which is the motor supply of the SAM).

Basal and 24-hour postblock serum β-endorphin levels did not vary amongst the two groups.

The deep SAPB may hypothetically block more lateral cutaneous branches of the intercostal nerves before they ramify. In addition, local anesthetic spread with the deep SAPB may occur faster and with a larger volume across the injured intercostal muscles to reach the intercostal nerves.[21,24] This could explain the initial (12 h) improved analgesia observed with the deep technique. Furthermore, we noted a "better" spread with the deep SAPB specially in the company of chest wall emphysema and/or chest drains as the needle tip contacts the rib directly, unlike in the superficial SSPB, which needs a potential space to be created between serratus and latissimus dorsi muscles.[25]

It is important to distinct the original SAPB, which primarily targets the anterolateral chest wall only[26] from the SAPB in the company of rib fractures, which was observed to provide both anterolateral and posterolateral analgesia. The interrupted intercostal muscles with rib fractures could aid the spread of LA to reach the intercostal nerves and permit posterior analgesia.[24,27]

Achieving satisfactory pain relief in patients suffering from MFRs is crucial for enabling deeper breathing and preventing atelectasis.[28]

In the current study, the initial superior pain reduction within 12 h after the block allowed candidates in the deep SAPB group to take deeper breaths. The median (IS-V) significantly increased in the D group (from 600 to 1300 ml) compared to the S group (from 700 to 1200 ml) at 12 h postblock (P value = 0.004). Both groups remained comparable as regards IS-V after 12 h until 72 h. The initial pain reduction and improved deep inspiration in the D group also contributed to a significant reduction in LUSS (decreased atelectasis) compared to the S group at 90 min ($P = 0.04$), 12 h ($P = 0.001$) and 24 h ($P = 0.031$) after the block. Beyond that, both groups were comparable until 72 h.

In line, Fernando *et al*.[29] published a case of a 36-year-old male with eight rib fractures and severe pain. Despite receiving intravenous analgesia (paracetamol, NSAIDs, and IV opioids), the pain remained severe (NRS 8), hindering his movement and adequate breathing. On the fifth day, he received ultrasound-guided continuous deep SAPB with 20 mL of levobupivacaine 0.25%, followed by a levobupivacaine 0.12% infusion at 5 mL/h. His pain significantly improved, could breathe deeply, and after 24 hours, his NRS reduced to 0. Decreased atelectasis was seen on serial chest radiographs.

Beard *et al*.,[30] in a multicenter longitudinal cross-sectional study, assessed the analgesic effects and inspiratory volumes (with incentive spirometry) provided by contentious SAPB versus continuous paravertebral or thoracic epidural for MRFs analgesia. Overall, there was an average improvement in inspiratory volume of 789.4 mL (SD 479.7) following all blocks. Unfortunately, the specific plane of SAPB was not mentioned in their study.

Adhikary *et al*.[17] reported similar results in a retrospective cohort study of seventy-nine patients suffering MRFs. They used erector spinae plane block. They observed a mean increase in IS-V from 784 (SD 694) to 1375 (SD 667) mL ($P < 0.01$) throughout the first day.

Pneumothorax, local anesthetic systemic toxicity, infection at the injection site, and vascular or nerve injury are possible SAPB complications; we did not encounter any of these complications.

Limitations

The limitations of the current study included not assessing dynamic pain scores, a small sample size, lack of specific recording of rib fracture levels and locations, and the absence of postblock dermatome mapping.

Conclusion

Either superficial or deep continuous SAPB can be used safely and effectively in managing pain related to MRFs. Notably, the deep approach offered superior analgesia and improved deep breathing compared to the superficial.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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