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# Efficacy of peripheral nerve blocks for pain management in patients with rib fractures: A systematic review and meta-analysis

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**Abstract. – OBJECTIVE: The aim of the study was to assess the efficacy of different peripheral nerve blocks, compared to conventional methods (analgesics and epidural block), for pain relief in rib fracture patients.**

**MATERIALS AND METHODS: PubMed, Embase, Scopus and Cochrane Central Register of Controlled Trials (CENTRAL) databases were systematically searched. The review included studies that were either randomized controlled trials (RCTs) or observational in design with propensity matching. The primary outcome of interest was patient's reported pain scores, both at rest and on coughing/movement. The secondary outcomes were length of hospital stay, length of stay at intensive care unit (ICU), need for rescue analgesic, arterial blood gas values and parameters of lung function test. STATA was used for statistical analysis.**

**RESULTS: The meta-analysis was conducted with 12 studies. Compared to conventional methods, peripheral nerve block was associated with better pain control at rest 12 hours (SMD -4.89, 95% CI: -5.91, -3.86) and 24 hours (SMD -2.58, 95% CI: -4.40, -0.76) after institution of block. At 24 hours after block, the pooled findings indicate better pain control on movement/coughing for the peripheral nerve block group (SMD -0.78, 95% CI: -1.48, -0.09). There were no significant differences in the patient's reported pain scores at rest and on movement/coughing at 24 hours post-block. There were no differences in the overall risk of any complications (RR 0.48, 95% CI: 0.20, 1.18), pulmonary complication (RR 0.71, 95% CI: 0.35, 1.41) and in-hospital mortality (RR 0.62, 95% CI: 0.20, 1.90) between the two groups. Peripheral nerve block was also associated with a relatively lower need for rescue analgesic (SMD -0.31, 95% CI: -0.54, -0.07). There were no differences in the length of ICU and hospital stay, risk of complications, arterial blood gas values or functional lung parameters, i.e., $PaO_2$ and forced vital capacity between the two management strategies.**

**CONCLUSIONS: Peripheral nerve blocks may be better than conventional pain management strategies for immediate pain control (within 24 hours of initiation of block) in patients with fractured ribs. This method also reduces the need for rescue analgesic. The skills and experience of the health personnel, facilities for care available and the cost involved should guide the decision on which management strategy to utilize.**

*Key Words:*
Rib fracture, Peripheral nerve block, Epidural block, Intercostal nerve block, Paravertebral block, Pain score, Functional outcome, Meta-analysis.

## Introduction

A common consequence of significant impact injury to the chest wall is rib fracture[1,2]. Recent epidemiological data[2-4] suggests that rib fractures are present in ~10% of the patients with physical trauma and in nearly a third of the in-patient admissions due to chest trauma. The mortality rate is 10% and increases with each additional fracture of a rib[1,3,5]. Rib fracture is often accompanied by concomitant injuries and the ensuing complications could vary from pain to pneumonia, atelectasis, pulmonary infection, acute respiratory distress syndrome, and death[1,4]. Particularly, pneumonia has been found to be present in 10-30% of the patients with multiple rib fractures and is a strong risk factor for mortality[6,7].

Studies[4,8-10] have shown that in patients with rib fractures, early and effective pain management often leads to a decrease in the number of days required for mechanical ventilation and the overall cost expenditure is substantially lower. Pain management is critical as sub-optimal pain control leads to decreased patient mobility, atelecta-

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sis and inadequate clearance of secretions; all of these leading to pulmonary infection, alteration of pulmonary functioning and in severe cases, mortality[11,12]. On the other hand, adequate pain control is known to alleviate the risk of pulmonary complications by assisting the patient to take deeper breaths, cough and through early mobilization[11,12]. Conventional methods such as epidural block and other pharmacological modes such as use of opioid analgesics or NSAIDs (non-steroidal anti-inflammatory agents) have been the main stay for pain management in patients with rib fracture[10,13,14]. There has been no clear consensus regarding the methods of pain control that is most efficacious in management of pain in patients with rib fracture. The current recommendation, by Eastern Association for the Surgery of Trauma and Trauma Anesthesiology society, for use of epidural analgesia for management of pain for rib fractures is influenced by the lack of good quality studies comparing epidural analgesia with other modalities[12].

Recently, peripheral nerve blocks have been used to provide pain relief for rib fracture patients. There are some obvious advantages with the use of peripheral nerve blocks, such as easier administration, lower risk of complications such as bleeding, hypotension, nausea and vomiting which are commonly seen in intravenous patient-controlled analgesia and thoracic epidural block[4,15]. However, there has been no systematic effort to summarize evidence comparing the efficacy of peripheral nerve blocks in pain control, compared to conventional methods of pain management. The aim of this meta-analysis is therefore to assess the efficacy of different peripheral nerve blocks for pain relief in rib fracture patients.

## Materials and Methods

### Search Strategy

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines were adhered to during the conduct of this meta-analysis[16]. The protocol was registered in the International Prospective Registry of Systematic Reviews (PROSPERO; registration number: CRD42022302721). PubMed, Embase, Scopus and Cochrane Central Register of Controlled Trials (CENTRAL) databases were used for a thorough systematic search of English language papers published until 15th January 2022. The search strategy included the use of medical subject heading (MeSH) terminology as well as free text words. The search strategy incorporated the following: (peripheral nerve block OR nerve block OR epidural OR analgesic OR paravertebral block OR intravenous analgesia OR erector spinae block OR serratus anterior block) AND (pain score OR complication OR functional outcomes OR clinical outcome OR rescue analgesic OR analgesic consumption) AND (rib fracture OR multiple rib fracture). The literature search aimed at identifying studies that compared pain scores and other outcomes of interest among patients with fractures of rib based on whether peripheral nerve block or conventional pain control measures were adopted. The conventional pain control measures included intravenous analgesics, patient-controlled analgesia and epidural block. The primary outcome of interest was patient's reported pain scores, both at rest and on coughing/movement. The secondary outcomes were length of hospital stay, length of stay at intensive care unit (ICU), need for rescue analgesic, arterial blood gas values and parameters of lung function test.

### Selection Criteria and Methods

Upon identification of studies following the literature search and removal of duplicates, two subject experts from the team reviewed the studies, and screened the titles and abstracts as the initial step. The full text of possible studies was subsequently reviewed. Any disagreements in the inclusion of the studies were resolved through discussions between the study authors. In order to identify additional literature, the reference list of the included studies was also reviewed.

### Inclusion Criteria

Studies that were either randomized controlled trials (RCTs) or observational in design were considered for inclusion. Particularly for observational studies, only those studies were included that had considered propensity score matching in order to reduce the selection bias arising out of differential characteristics among the subjects in the two groups. Studies of interest were those that were done in subjects with rib fractures and had compared relevant outcomes of interest based on the type of pain management method used, i.e., peripheral nerve block and conventional pain control methods (analgesics or epidural block).

### Exclusion Criteria

Case-reports or review articles were excluded. Studies that did not provide comparative findings between peripheral nerve block and conventional pain management methods were excluded. Observational studies that did not involve propensity score matching were also excluded.

### Data Extraction and Quality Assessment

A pretested data extraction sheet was used to extract data from the included studies, two authors completed this independently. Data extracted mainly included the study identifier i.e., the name of the first author along with the year of publication, study setting and design, participant characteristics, sample size and the key findings. The quality assessment of the included studies was done independently by two authors using the Cochrane risk of bias tool for RCTs and the Newcastle-Ottawa Quality Assessment Scale for observational studies[17,18].

### Statistical Analysis

Meta-analysis was performed using STATA software version 16.0 and reported effect sizes as either relative risk (RR) for binary outcomes, weighted mean difference (WMD) or standardized mean differences (SMD) for continuous outcomes. WMD was used for continuous outcomes using the same units and SMD for continuous outcomes with different units. The pooled effect sizes were reported along with 95% confidence intervals (CI). $I^2$ denoted heterogeneity, and where $I^2$ exceeded 50%, a random effects model was used[19]. $p$-value under 0.05 was considered statistically significant. A subgroup analysis was undertaken based on the different types of peripheral and conventional pain control methods compared by the included studies. It included comparison between (a) thoracic paravertebral block and standard analgesics (b) thoracic paravertebral block and epidural block (c) intercostal block and standard analgesics (d) intercostal block and epidural block and (e) serratus anterior or erector spinae block and standard analgesics.

## Results

### Selection of Articles, Study Characteristics and Quality of Included Studies

A total of 924 citations were identified using the search strategy. After removal of the duplicates, 688 relevant citations were obtained (Figure 1). Screening of the titles and abstracts led to

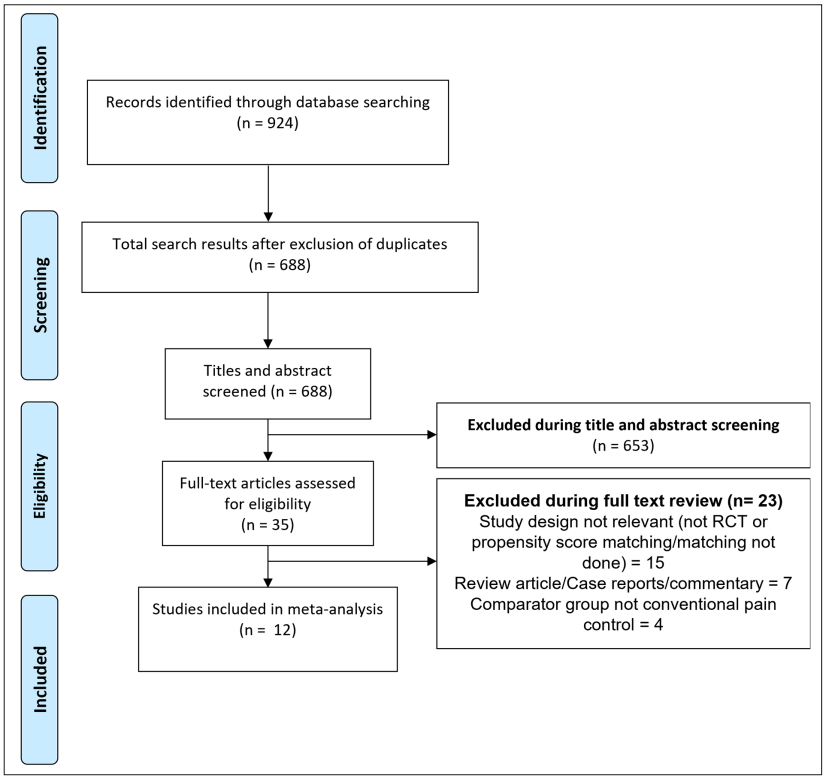


**Figure 1.** Selection process of the studies included in the review.

the removal of 653 citations. Out of the remaining studies, 35 were excluded after reading the full text. Finally, a total of 12 studies were considered for inclusion[20-31]. **Supplementary Table I** presents the details of the studies included in the review. Six of the included studies were RCTs and the remaining studies were retrospective in design and had considered propensity score matching. The majority of the studies were conducted in the USA (n=4) followed by Turkey (n=2). One study each was done in India, China, Iran, South Korea, United Kingdom and Australia. There were two studies[21,26] that compared thoracic paravertebral block with intravenous analgesics; two studies[25,27] compared thoracic paravertebral block with epidural; three studies[23,24,30] compared intercostal nerve block with intravenous analgesics and another three studies[22,29,31] compared intercostal nerve block with epidural. The remaining two studies[20,28] compared plane block (serratus anterior or erector spinae) with intravenous analgesics. The results of the quality evaluation of the included studies are provided in **Supplementary Tables II** and **Supplementary III**. The included studies were of modest to good quality.

### Findings Related to Pain Management

#### Pain on rest

Compared to conventional pain control methods, peripheral nerve block was associated with better pain control at rest within the first 24 hours of institution of block: 1 hour (SMD -2.61, 95% CI: -4.55, -0.67; N=4), 6 hours (SMD -5.42, 95% CI: -6.53, -4.31; N=1), 12 hours (SMD -4.89, 95% CI: -5.91, -3.86; N=1) and 24 hours (SMD -2.58, 95% CI: -4.40, -0.76; N=4) (Figure 2). There were no significant differences in the patient reporting pain scores at rest from the period beyond 24 hours after the application of block (Figure 2).

The findings of the subgroup analysis also suggest better pain control at rest in the first 24 hours in the patients receiving peripheral nerve block (Table I). In the period beyond 24 hours, there were no differences in the pain scores between the groups compared, except for increased pain scores at 72 hours after application of block in those receiving intercostal nerve block, compared with epidural. However, this was based on only one study[22] (Table I).

#### Pain on coughing or movement

No difference in the pain score on coughing and/or movement was noted between conventional pain control and peripheral nerve block after 1 hour of application of block (SMD 0.86, 95% CI: -2.19, 3.91; N=2). After 24 hours the pooled findings indicate better pain control for the peripheral nerve block group (SMD -0.78, 95% CI: -1.48, -0.09; N=2) (Figure 3). There were no significant differences in the patient's reported pain scores during movement after 24 hours from the block (Figure 3).

The findings of the subgroup analysis indicate better pain control at movement at 24 hours post-block in the patients receiving paravertebral block, compared to either standard analgesics or epidural (Table I). At 24 hours, there were no differences in the pain scores between the groups compared. However, increased pain scores on movement were observed after 72 hours in those receiving intercostal nerve block, compared with an epidural (Table I). These findings should be interpreted cautiously as the number of studies included in the subgroup analysis were low.

### Risk of Complications, Need for Rescue Analgesic and Arterial Blood Gas Values

The overall risk of any complications (RR 0.48, 95% CI: 0.20, 1.18; N=3), pulmonary complication (RR 0.71, 95% CI: 0.35, 1.41; N=5) and in-hospital mortality (RR 0.62, 95% CI: 0.20, 1.90; N=4) was similar in the conventional pain control and peripheral nerve block groups (Figure 4). Compared to conventional pain control methods, such as analgesics and epidural anesthesia, peripheral nerve block was associated with a relatively lower need for rescue analgesic (SMD -0.31, 95% CI: -0.54, -0.07; N=4) (Figure 5). No group differences of clinical or statistical significance were noted for $PaO_2$ (in mm Hg) and forced vital capacity (FVC, in Litres) (Figure 6). For parameters, such as respiratory rate, $PaCo_2$, peak expiratory flow rate (PEFR) or $PaO_2/FiO_2$ values, there were not enough studies reporting the relevant findings, so a pooled analysis could not be done. However, the individual that reported on these parameters did not note any significant differences between conventional pain control methods and peripheral nerve block[21,22,25].

### Length of Hospital and Intensive Care Unit (ICU) Stay

There were no significant differences for length of hospital stay (days) (WMD -0.72, 95% CI: -1.98, 0.54; N=8) and length of ICU admission (days) (WMD -0.30, 95% CI: -1.02, 0.41; N=6) between conventional pain control methods and peripheral nerve block (Figure 7).

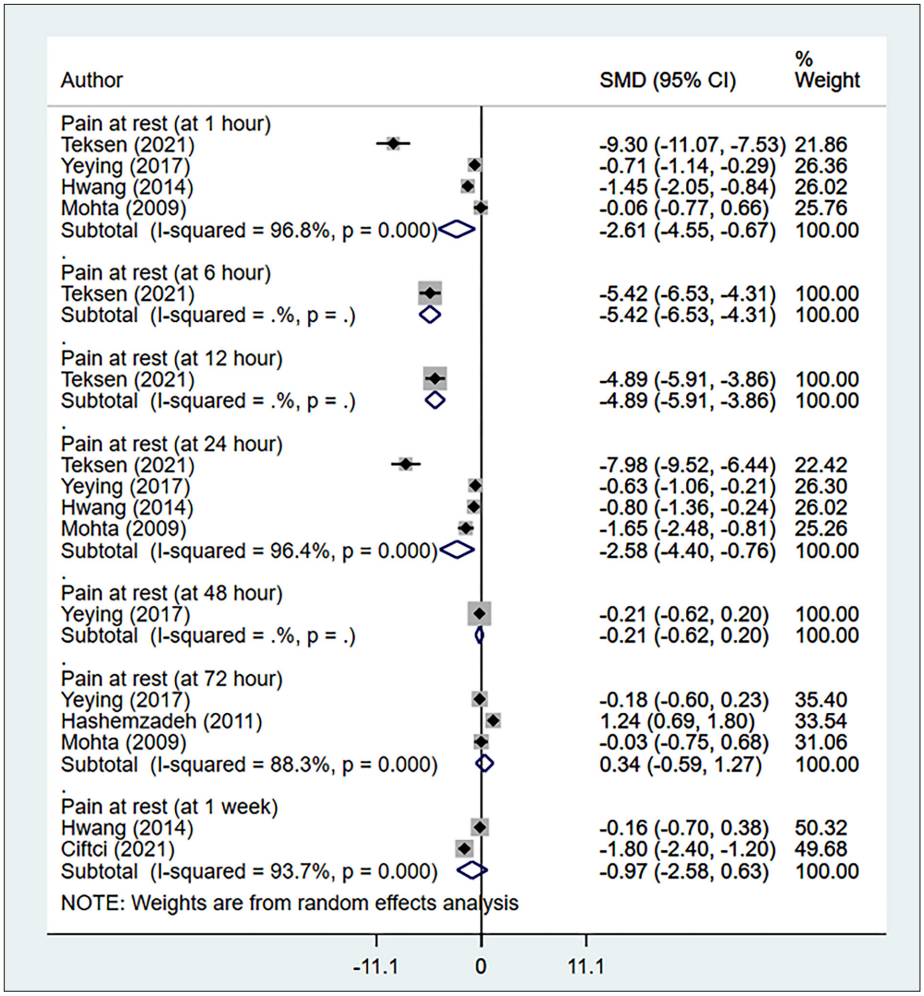


**Figure 2.** Comparison of pooled pain scores at rest between peripheral nerve block and conventional pain control methods (analgesics and epidural block).

## Discussion

The current meta-analysis was conducted with the aim to summarize existing evidence on the efficacy of peripheral nerve blocks in pain control, compared to conventional methods of pain management. Compared to conventional pain control methods, peripheral nerve block was associated with better pain control at rest and on coughing/movement within the first 24 hours of the application of the block. However, there were no significant differences in the pain scores beyond 24 hours after the application of block. The peripheral nerve block was associated with a relatively lower need for rescue analgesic. There were no differences in the length of ICU and hospital stay, risk of complications, arterial blood gas values and functional lung parameters, i.e., $PaO_2$ and forced vital capacity between the two pain control strategies.

The overall findings from this meta-analysis suggest that peripheral nerve block may offer better immediate pain alleviation while other factors are similar to the conventional methods of pain management for rib fracture. The advantage of peripheral nerve block, particularly the intercostal nerve block, is the application with relative ease using the medical imaging technique and administering the anesthetic to target a particular nerve based on the location of the pain[10,23,32]. There are minimal associated complications, such as nausea and vomiting, bleeding and nerve injury, which can be seen in intravenous patient-controlled analgesia or on thoracic epidural

**Table I.** Finding of the subgroup analysis.

| Outcomes | Pooled effect sizes with 95% confidence intervals | | | | |
|---|---|---|---|---|---|
| | Thoracic paravertebral block *vs.* standard analgesics | Thoracic paravertebral block *vs.* epidural | Intercostal block *vs.* standard analgesics | Intercostal block *vs.* epidural | Plane block (serratus anterior/ erector spinae) *vs.* standard analgesics |
| Pain at rest (1 hr) | SMD -0.71 (95% CI: -1.14, -0.29)* (N = 1) | SMD -0.06 (95% CI: -0.77, 0.66) (N = 1) | SMD -1.45 (95% CI: -2.05, -0.84)* (N = 1) | ---- | SMD -9.30 (95% CI: -11.07, -7.53)* (N = 1) |
| Pain at rest (24 hr) | SMD -0.63 (95% CI: -1.06, -0.21)* (N = 1) | SMD -1.65 (95% CI: -2.48, -0.81)* (N = 1) | SMD -0.80 (95% CI: -1.35, -0.24)* (N = 1) | ---- (95% CI: -9.52, -6.44)* (N = 1) | SMD -7.98 |
| Pain at rest (48 hr) | SMD -0.21 (95% CI: -0.62, 0.20) (N = 1) | ---- | ---- | ---- | ---- |
| Pain at rest (72 hr) | SMD -0.18 (95% CI: -0.60, 0.23) (N = 1) | SMD -0.03 (95% CI: -0.75, 0.68) (N = 1) | ---- | SMD 1.24 (95% CI: 0.69, 1.80)* (N = 1) | ---- |
| Pain at rest (1 week) | ---- | ---- | SMD -0.97 (95% CI: -2.58, 0.63) (N = 2; $I^2$ = 93.7%) | ---- | ---- |
| Pain on movement (1 hr) | SMD -0.67 (95% CI: -1.07, -0.24)* (N = 1) | SMD 2.45 (95% CI: 1.49, 3.41)* (N = 1) | ---- | ---- | ---- |
| Pain on movement (24 hr) | SMD -0.50 (95% CI: -0.92, -0.08)* (N = 1) | SMD -1.23 (95% CI: -2.01, -0.44)* (N = 1) | ---- | ---- | ---- |
| Pain on movement (48 hr) | SMD -0.23 (95% CI: -0.65, 0.18) (N = 1) | ---- | ---- | ---- | ---- |
| Pain on movement (72 hr) | SMD -0.15 (95% CI: -0.57, 0.26) (N = 1) | SMD -0.40 (95% CI: -1.12, 0.33) (N = 1) | ---- | SMD 2.03 (95% CI: 1.40, 2.65)* (N = 1) | ---- |

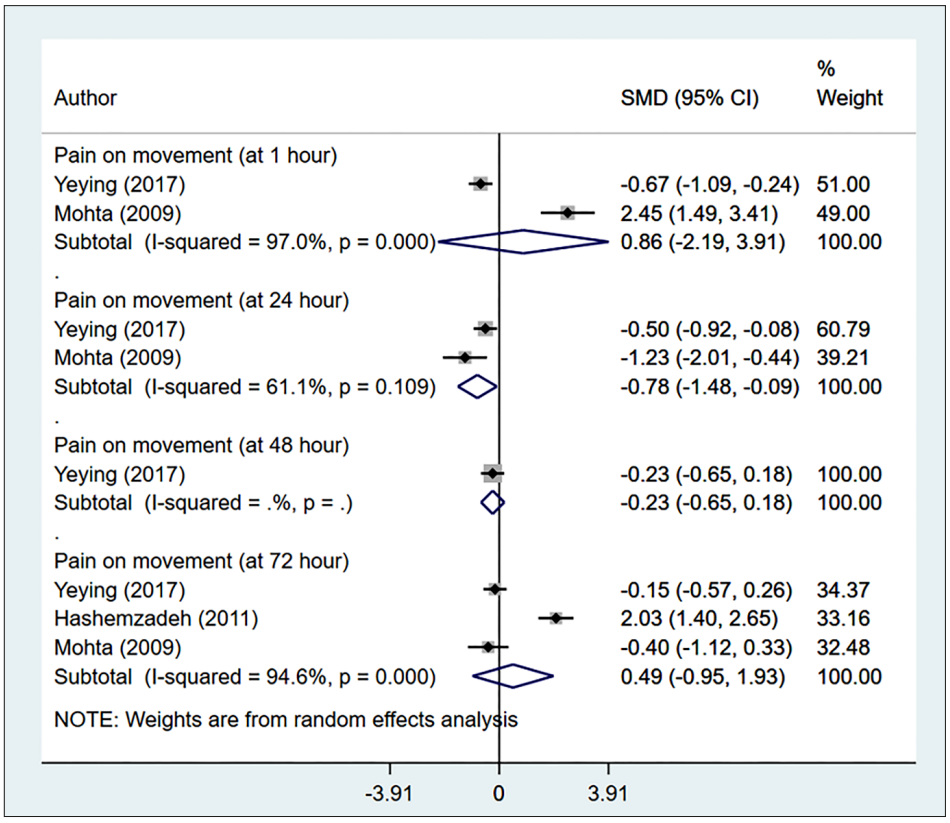


**Figure 3.** Comparison of pooled pain scores at movement/coughing between peripheral nerve block and conventional pain control methods (analgesics and epidural block).

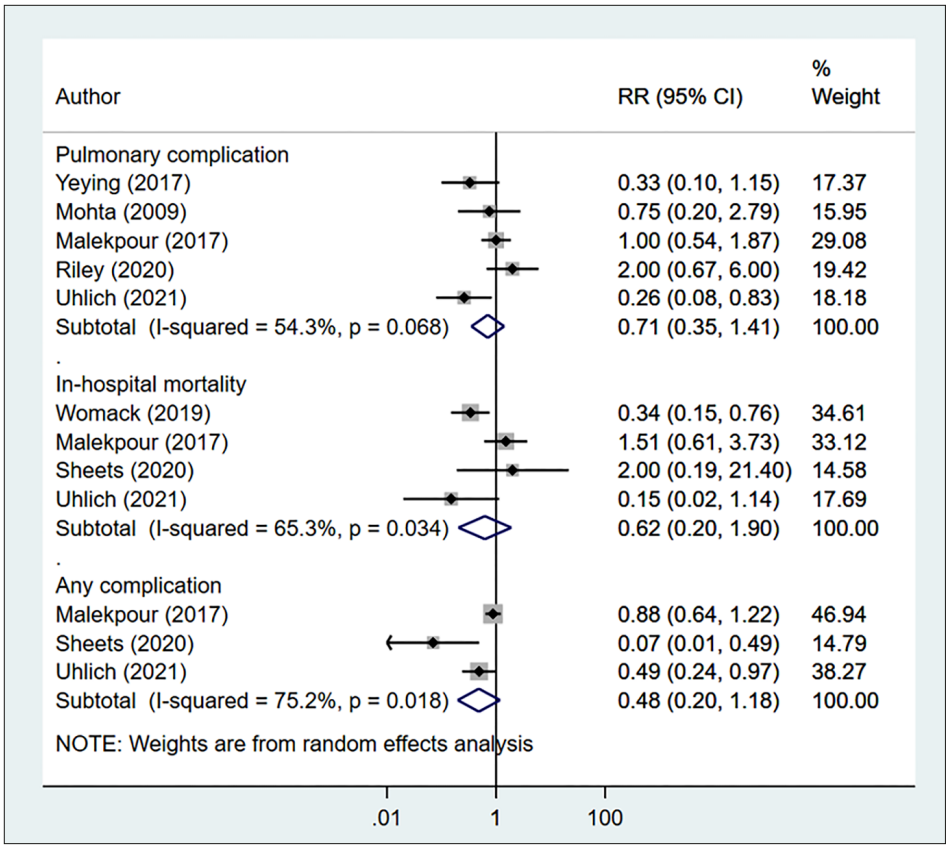


**Figure 4.** Risk of complications between peripheral nerve block and conventional pain control methods (analgesics and epidural block).

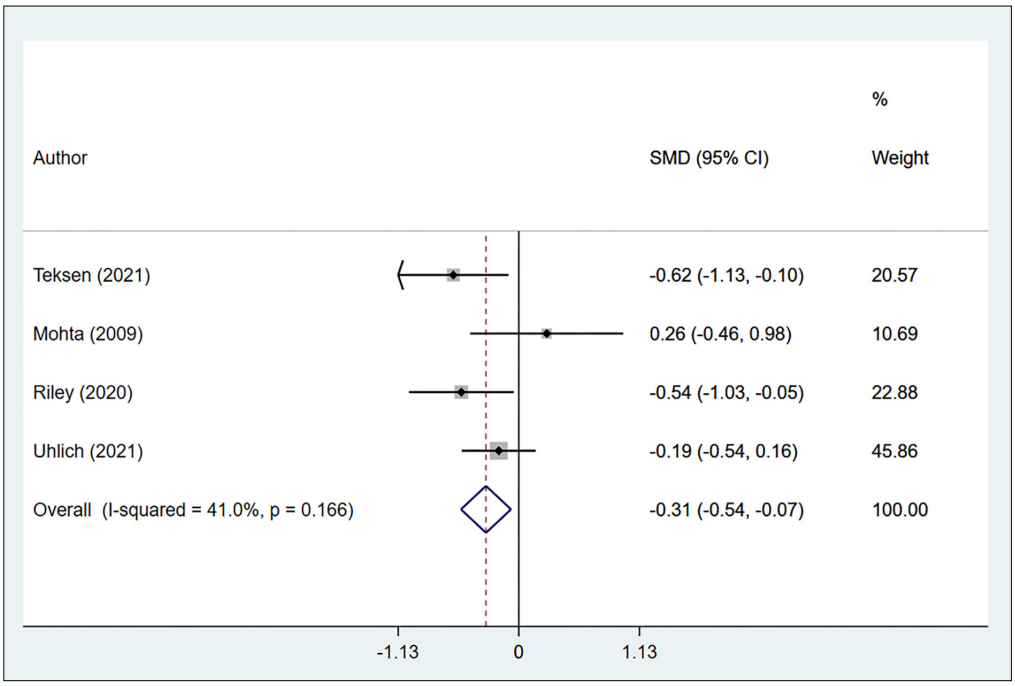


**Figure 5.** Comparison of requirement of rescue analgesic between peripheral nerve block and conventional pain control methods (analgesics and epidural block).

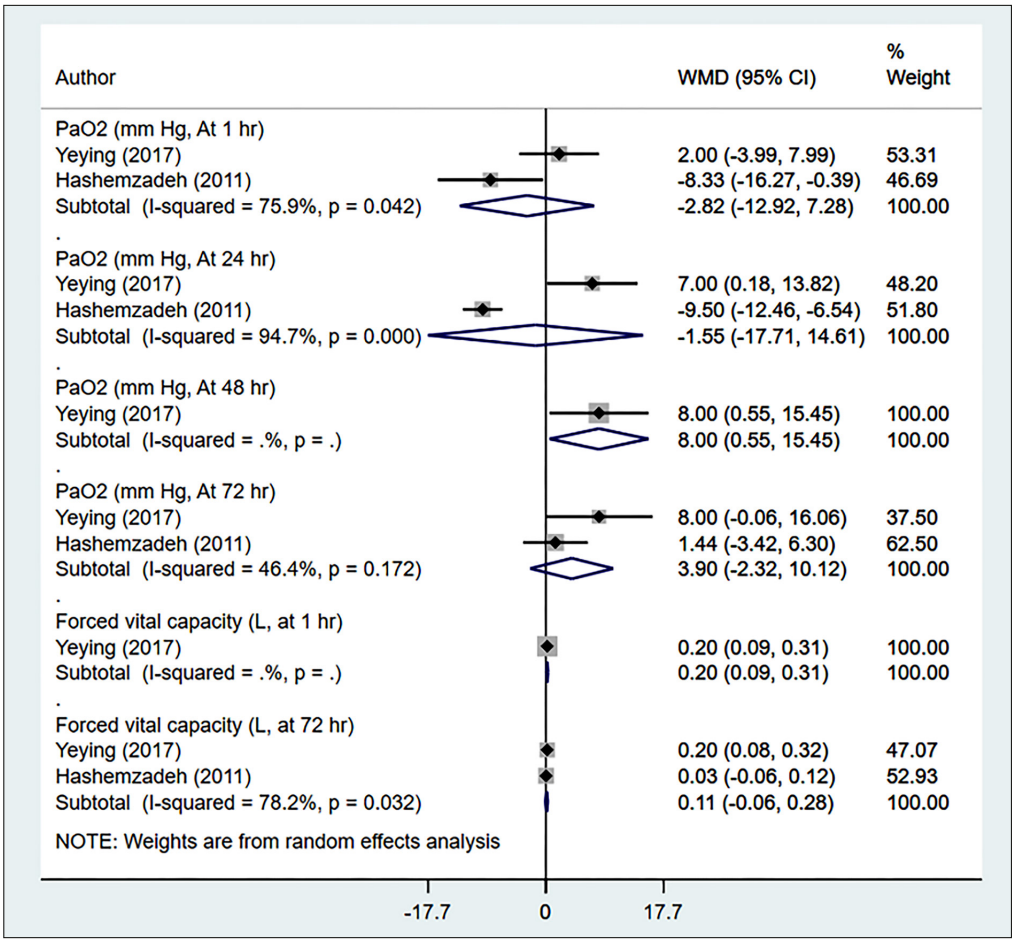


**Figure 6.** Comparison of partial pressure of oxygen ($PaO_2$) and forced vital capacity (FVC) between peripheral nerve block and conventional pain control methods (analgesics and epidural block).

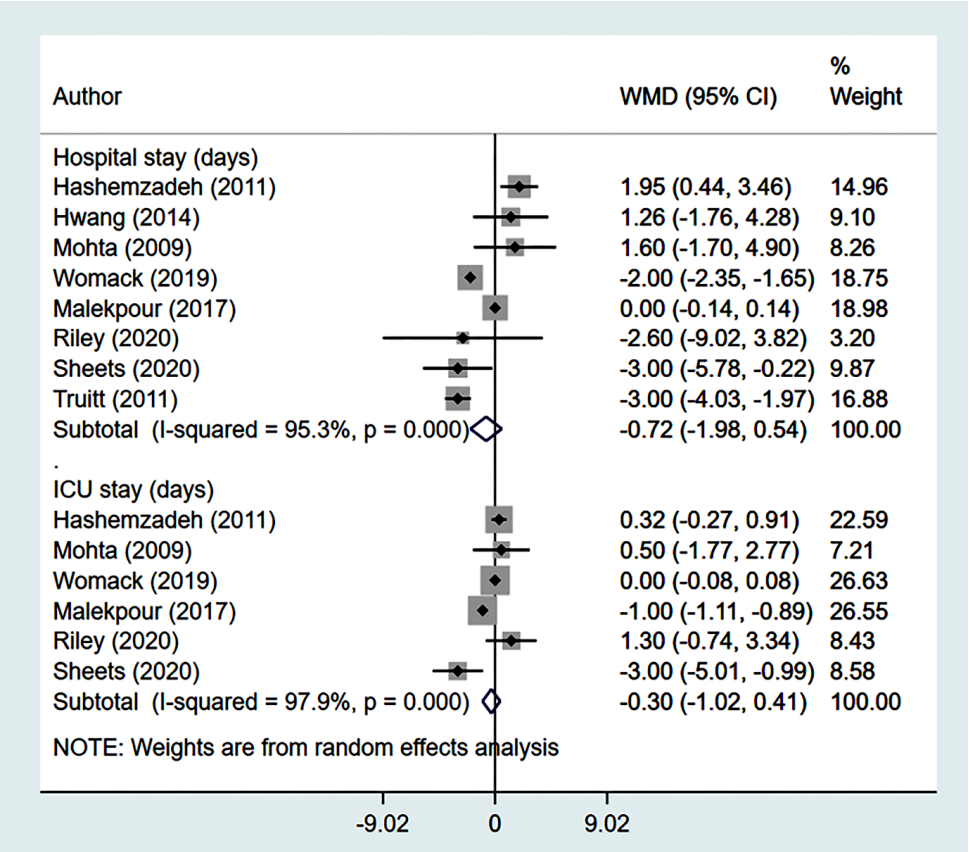


**Figure 7.** Comparison of length of hospital and intensive care unit (ICU) stay between peripheral nerve block and conventional pain control methods (analgesics and epidural block).

injection[4,15]. Therefore, this could make it the preferred choice in patients with trauma and in the elderly. The relative disadvantage is the short duration of action which requires the procedure to be repeated every 6 to 8 hours and consequently, the toxicity of the local anaesthetics could be a concern[4,15,32]. There were no differences in the length of ICU and hospital stay or risk of complications between the two methods and this provides assurance that either of the two modalities could be used to alleviate the risk of pulmonary complications of traumatic rib fractures.

The findings have special consideration for the elderly. These patients are at increased risk of fall and injuries, including rib fracture[33]. The management of pain in elderly subjects is challenging as there are multiple co-morbidities such as diabetes, hypertension, dyslipidemia, chronic obstructive pulmonary disease etc. The conventional method of using analgesics and narcotics may lead to serious complications. The results presented here show that peripheral nerve blocks may be as effective as conventional methods (epidural analgesia and/or use of analgesics) without the added risk of complications. The current review did not focus on patient mobility and quality of life, but a recent study suggested that intercostal nerve blockage is more effective than management using oral analgesia on quality of life, time to return to work, and grip strength in patients with isolated rib fractures[24]. Our review highlights that peripheral nerve blocks reduced the consumption of rescue analgesics which are usually opioids. Opioids, particularly morphine, are known to affect both cellular and humoral immunity negatively and, in this sense, peripheral nerve blocks will have minimal adverse impact on local and systemic immunity[34,35].

One of the strengths of the analysis is the comprehensive search of studies and inclusion of RCTs and observational studies that had adopted propensity score matching. In this way, the se-

lection bias and bias arising from non-adjusted potential confounders was minimized.

### Limitations

There are certain limitations of the analysis which should be considered while interpretating the findings. First, the included studies compared different pain management strategies and therefore, for most of the outcomes there were not enough studies to pool. Consequently, for the outcomes considered, pooling of findings was done considering two broad categories i.e., peripheral block and conventional block and not on the specific types of blocks. This was similar within the subgroup analysis where for most of the outcomes, only one study was available. Secondly, for most of the outcomes, there was high heterogeneity. This could be due to differences in the study methodology such as difference in the groups studied, different types and doses of anesthetics used and the variation in the skills and experience of the health care professional involved in these studies. Finally, the meta-analysis did not explore long-term chronic pain as an outcome. Chronic pain is one of the most important sequalae of chest trauma and future studies should document the efficacy of peripheral nerve blocks and conventional methods in alleviating chronic pain.

## Conclusions

The current meta-analysis, through pooling of findings from 12 studies, suggests that peripheral nerve blocks may be better than conventional pain management strategies, such as analgesics and epidural blocks for immediate pain control (within 24 hours of initiation of block) in patients with rib fractures. The two methods of pain management are similar with respect to pain management beyond 24 hours of block initiation, risk of complications, arterial blood gas values and functional lung parameters. The choice of method for pain control should depend on the skills and experience of the health personnel, facilities for care available, and the cost involved.

### Conflict of Interest

The Authors declare that they have no conflict of interests.

### Acknowledgements

NA.

### Informed Consent

NA.

### Authors' Contribution

DX conceived and designed the study, DX and JX collected data and performed data analysis. DX wrote the draft of this manuscript. JX edited the manuscript.

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