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Systematic Review

A Meta-Analysis of Ultrasound Guided Nerve Blocks for Enhanced Recovery in Adult Cardiac Surgery Patients

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Abstract

Background: Ultrasound-guided nerve blocks can both reduce intraoperative opioid use and pain scores. However, its role in enhancing postoperative recovery for adult cardiac patients requires further investigation. This study examines the impact of ultrasound-guided nerve block on adult cardiac patients' recovery. **Methods**: We conducted a systematic search for randomized controlled trials (RCTs) published between 2018 to 2022, focusing ultrasound-guided nerve block in adult cardiac surgery. The search included Pubmed, Embase, and Cochrane databases, targeting studies on elective thoracotomy. The outcomes analyzed included postoperative extubation time, intensive care unit (ICU) stay time, and length of hospital stay (LOS), using Review Manager software (Review Manager 5.4, The Cochrane Collaboration, 2020, Beijing, China) for data synthesis and analysis. **Results**: Out of 26 RCTs, eight studies involving including 424 subjects were included in this meta-analysis. The results showed that ultrasound-guided nerve block significantly reduced postoperative extubation time (odds ratio [OR] = –2.16, 95% confidence interval [CI]: –3.05 to –1.26), ICU stay (OR = –1.17, 95% CI: –1.40 to –0.94), and overall hospitalization duration (OR = –0.96, 95% CI: –1.64 to –0.29). **Conclusion**: Ultrasound-guided nerve block significantly reduces the postoperative extubation time, ICU stay, and LOS, in adult cardiovascular surgery. These benefits contribute substantially to enhanced recovery after cardiac procedures. **Registration**: PROSPERO (CRD42023470545).

Keywords

ultrasound guided nerve block; cardiac surgery; enhanced recovery after surgery

Introduction

An ultrasound-guided nerve block is an anesthetic technique that achieves precise localized analgesia through real-time or visual-guided delivery of the anesthetic agent. This method not only facilitates targeted analgesia but also minimizes local tissue trauma—an essential consideration in surgeries where maintaining tissue integrity is crucial. The utilization of ultrasound guidance increases the accuracy of the nerve block, potentially leading to improved patient outcomes by reducing postoperative pain and accelerating recovery [1]. Given these benefits, this technique has gained widespread adoption in various medical settings, with particularly significant uptake in cardiac surgery [1–3].

In cardiac surgery, ultrasound-guided nerve block techniques play a pivotal role in perioperative pain management [4]. Common methods include paravertebral nerve block, erector spinae plane block, intercostal nerve block, parasternal chest wall block, and parasternal intercostal space muscle block [4]. Ultrasound-guided nerve blocks have been successfully applied in various cardiac procedures, including coronary artery bypass grafting (CABG), valve surgeries, and minimally invasive cardiac interventions [4,5]. These methods have proven to be instrumental in reducing the reliance on opioids, thereby diminishing the risks associated with opioid consumption, as well as improving patient satisfaction, and expiditing recovery times [5].

Studies have demonstrated the efficacy of ultrasound-guided nerve blocks in reducing postoperative pain and curtailing opioid-related side effects [4–6]. These techniques, when applied correctly, are linked to a lower incidence of complications, such as bleeding and infection, which are significant concerns in cardiac surgery [6]. Furthermore, the reduction in intraoperative use of analgesic drugs facilitated by these blocks can lower the incidence of adverse reactions such as postoperative nausea and vomiting caused by opioids, which is critical for accelerating the postoperative recovery of cardiac surgery patients [7,8]. While these blocks are generally regarded as safe, there are inherent risks, including nerve injury, local anesthetic toxicity, and pneumothorax [9,10]. However, the precision afforded by ultrasound guidance substantially mitigates these risks [9,10].

Despite these advantages, the widespread adoption of ultrasound-guided nerve blocks in cardiac surgery has yet to be fully realized. In recent years, an increasing number

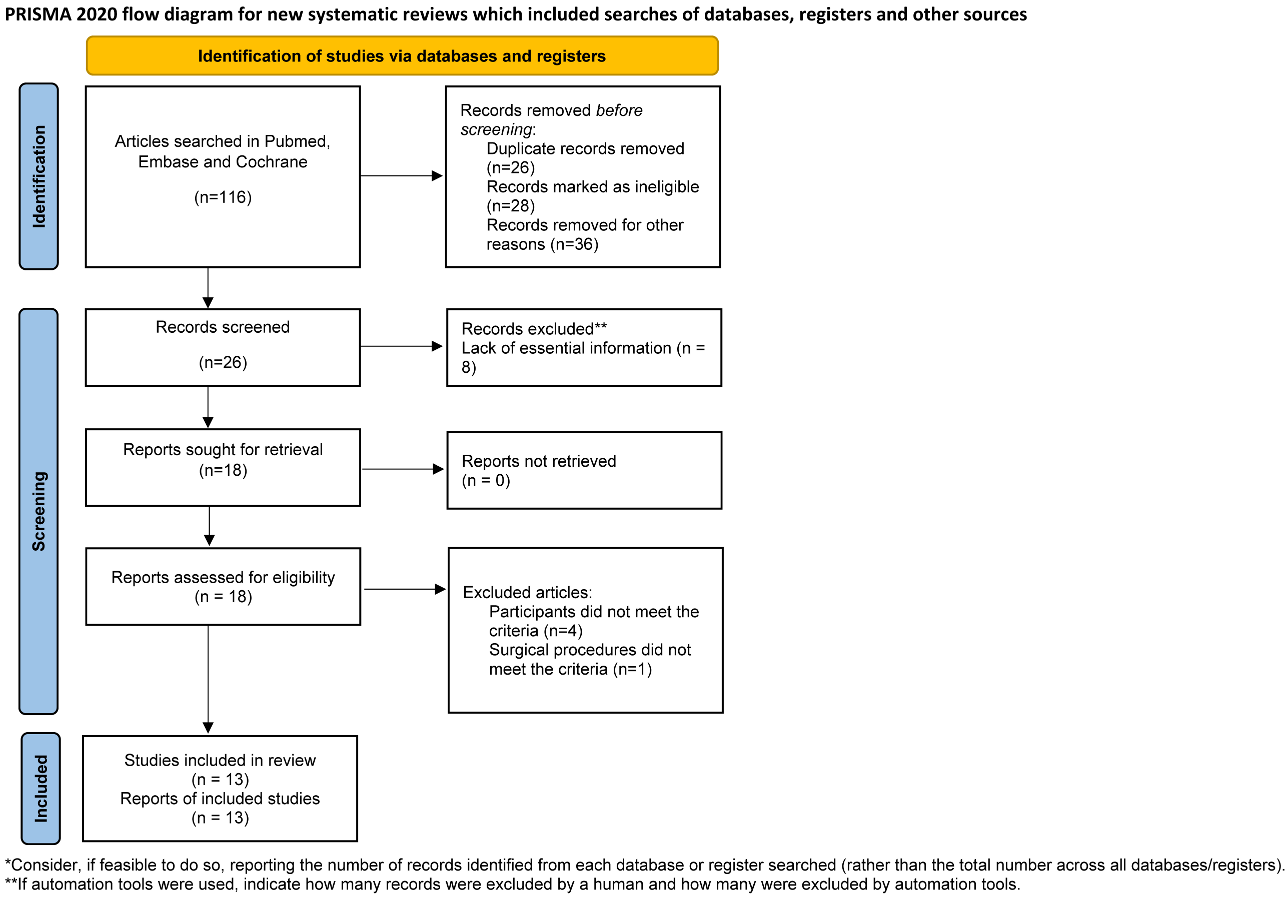

Fig. 1. Meta-analysis literature selection process. This flowchart delineates the literature selection process for the meta-analysis. Initially, 116 records were identified through database searches. After removing 26 duplicates and further screening of 90 articles, 26 were assessed for eligibility. Ultimately, 13 studies met the inclusion criteria and were incorporated into the meta-analysis.

of randomized controlled clinical trials have begun to illuminate their potential, providing a stronger evidence base for their use [9,10]. Current guidelines acknowledge the efficacy of ultrasound-guided nerve blocks in reducing the intraoperative use of opioid medications thereby reducing time to extubation and shortening stays in the intensive care unit (ICU) time, among other clinical benefits [7,8]. However, these guidelines also highlight that the evidence supporting their use remains underdeveloped, primarily due to the limited number of studies and sample sizes [7,8]. Therefore, this meta-analysis aims to systematically consolidate and evaluate the existing evidence regarding the effectiveness of ultrasound-guided nerve blocks in enhancing recovery outcomes in adult cardiac surgery patients.

Materials and Methods

Literature Search, Screening and Data Extraction

We searched Pubmed, Embase, and Cochrane databases for studies conducted between January 2018 to December 2022. Searches were performed using English terms related to nerve block techniques—including nerve block, paravertebral block, spinal erector block, anterior serratus block, parasternal block, and transverse thoracic block. We also searched for a comprehensive range of cardiac surgery procedures, encompassing cardiac surgery, cardiovascular surgery, heart surgery, thoracic surgery, open surgery, thoracotomy, valve surgery, vascular surgery, coronary surgery, coronary artery bypass graft surgery, CABG, aortic surgery, valvulotomy, valve replacement, valve repair, valve reconstruction, valve arterioplasty, valve prosthesis, pulmonary surgery, cardiopulmonary bypass, on-pump, off-pump surgeries.

The inclusion criteria were as follows: (1) studies conducted between January 2018 and December 2022, (2) Randomized Controlled Trials (RCTs), (3) surgical procedures involving elective cardiac major vascular surgery, (4) the intervention studied was ultrasound-guided nerve block, (5) studies must include at least one of the following outcomes: time to extubation post-surgery, ICU length of stay, length of hospital stay, and the incidence of postoperative nausea and vomiting, (6) the most recent duplicate publications with comprehensive source of data were considered. The exclusion criteria were as follows: (1) participants aged be-

Table 1. Basic characteristics of included studies.

Reference	Country	Surgery	Age	Sex	N	Group 1		Group 2
Venkataswamy Manjunath 2018 [11]	India	CABG	>21 years old	Male and Female	60	PVB	bupivacaine	C NS
Kumar KN 2018 [12]	India	CABG	25–65 years old	Male and Female	40	Pecs	bupivacaine	C None
Lixin Sun 2019 [13]	China	CABG	50–75 years old	Male and Female	60	PVB	ropivacaine	C NS
Satoru Fujii 2019 [14]	Canada	cardiac and valve surgery	18–90 years old	Male and Female	17	TTPB	rocuronium	C None
Manazir Athar 2021 [15]	India	cardiac surgery	18–60 years old	Male and Female	30	ESP	bupivacaine	C NS
Hoda Shokri 2021 [16]	Egypt	cardiac surgery	55–74 years old	Male and Female	60	TTPB	bupivacaine	C NS
Yang Zhang 2021 (1) [17]	China	valve surgery	20–70 years old	Male and Female	98	PIFB	ropivacaine	C NS
Yang Zhang 2021 (2) [18]	China	cardiac surgery	18–70 years old	Male and Female	60	TTPB	ropivacaine	C NS

ESP, erector spinae block; Pecs, pectoralis nerve (Pecs) block; PIFB, parasternal intercostal fascial block; PVB, paravertebral nerve block; TTPB, transversus thoracic muscle plane block; CABG, coronary artery bypass grafting; C, control; NS, normal saline.

low 18 years, (2) emergency surgeries, (3) surgeries without midline incision, (4) conference abstracts, abstract-only publications, and articles that cannot be accessed in full.

Two researchers independently screened the retrieved literature strictly with the inclusion and exclusion criteria. In cases of disagreement, a third researcher adjudicated the discrepancies or facilitated a consensus. The data extracted from each study included general information (first author, publication date, conducting country, and sample size), intervention details (grouping, nerve block technique, and details including anatomical location and medications used), outcomes (extubation time, ICU length of stay, and total hospital length of stay), and key information related to the risk of bias assessment.

Risk of Bias Assessment for Included Studies

The risk of bias for the included studies was assessed using Review Manager 5.4 (The Cochrane Collaboration, 2020, Beijing, China). The assessment process involved two researchers independently evaluating the literature. In case of disagreements, a third researcher was consulted for adjudication. The assessment covered the following aspects: randomization process, blinding, allocation concealment, and reporting bias. The risk for each included study was graded accordingly.

Statistical Analysis

A meta-analysis of the outcomes was conducted using Review Manager software. For continuous variables, data was recorded as means and standard deviations. For dichotomous variables, the number of events and the total sample size were recorded. A random-effects model was used to assess the standard mean difference and 95% confidence interval (95% CI), and the I^2 test was applied to assess heterogeneity in study results. If $I^2 < 50\%$, it suggested no significant heterogeneity among the studies. The significance level was set at $\alpha = 0.05$, and $p < 0.05$ was considered to indicate a significant difference between groups.

Results

Literature Selection and Inclusion Criteria

The initial search yielded 116 articles from databases including PubMed, Embase, and Cochrane. After the removal of 26 duplicate articles, 90 articles underwent a detailed screening process. Of these, 28 were excluded for being ineligible and an additional 36 were removed for other reasons not meeting the study criteria. The remaining 26 articles were assessed in depth. A total of 8 studies were ultimately included, comprising 424 participants [11–18]. The literature screening process is illustrated in Fig. 1. This study was conducted and reported in strict accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (**Supplementary Table 1**).

Basic Characteristics and Risk of Bias Assessment Results

The basic characteristics of the studies ncluded in this meta-analysis encompass a diverse range of demographic and clinical settings, as detailed in Table 1 (Ref. [11–18]). The studies originate from multiple countries and include varied cardiac surgical procedures such as CABG and valve surgery, reflecting a broad applicability of the findings. Participants' age ranges—from 18 to 90 years—and sex distributions are also noted, providing insights into the demographic variability across the studies. This variability enhances the generalizability of the meta-analysis results.

The risk assessment revealed a generally low risk of reporting bias, indicating robustness in the reporting practices across the included literature. Such low reporting bias contributes to the reliability of the synthesized evidence from these studies, underscoring the effectiveness of ultrasound-guided nerve blocks in different populations and surgical contexts.

The risk of bias assessment for the eight original studies included in the meta-analysis revealed varied levels of potential biases. Three studies [11,14,16] exhibited an unknown risk of selection and implementation bias. Specifically, one study [14] was classified as having a high risk, while two studies [11,13] were noted for their unknown risk of implementation bias due to the lack of blinding of the operator. Additionally, two studies [11,15] displayed an unknown risk of selection bias because the results of randomization were not adequately concealed. Moreover, three studies [11,15,16] were assessed as having measurement bias due to the non-reporting of blinding of outcome assessors. These biases are visually summarized in Fig. 2.

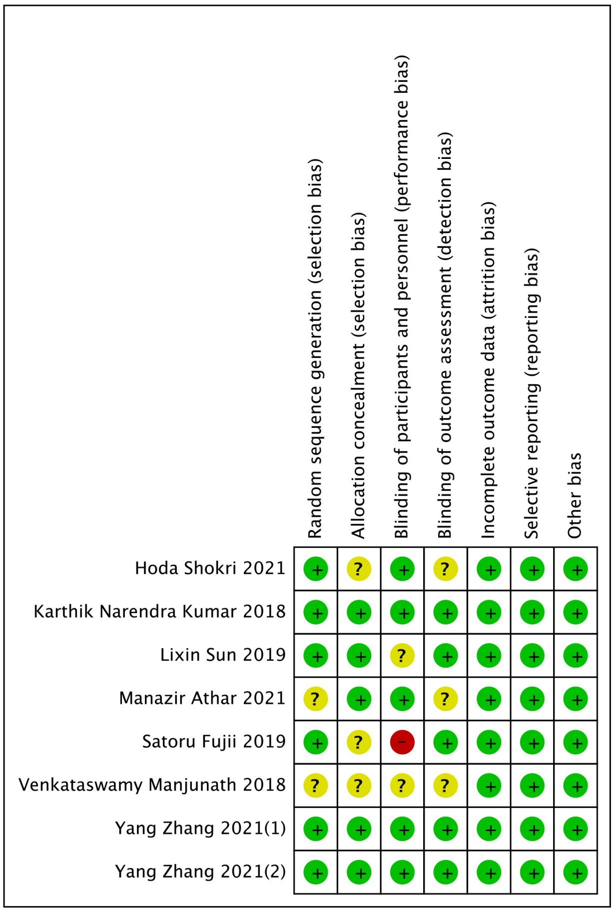

Fig. 2. Summary of the risk of bias for studies included in the meta-analysis. This figure illustrates the various risks of bias identified in the studies included in the meta-analysis. It categorizes the studies according to the presence of selection, implementation, and measurement biases, highlighting areas of potential concern that could affect the reliability of the study outcomes. Biases are depicted by color: green being negligible risk, yellow being unknown risk, and red being high risk.

Meta-Analysis Results

Extubation Time

The effect of ultrasound-guided nerve block on extubation times was evaluated across eight studies [11–18] which together included a total of 212 participants. The findings reveal that in the group receiving ultrasound-guided nerve blocks, extubation times varied between 1.81 to 7.5 hours. In contrast, the control group, which did not receive nerve blocks, experienced longer extubation times ranging from 3.44 to 11.07 hours. Statistical analysis confirms that the use of ultrasound-guided nerve blocks significantly reduced extubation times in postoperative patients ($p < 0.05$). These results are visually depicted in Fig. 3.

ICU Length of Stay

The impact of ultrasound-guided nerve block on the intensive care unit (ICU) length of stay was analyzed through five studies [11,13,16–18] which collectively included 168 participants. The meta-analysis revealed that patients who received ultrasound-guided nerve block had a significantly shorter length of stay in the ICU compared to the control group ($p < 0.05$). These findings underscore the potential of ultrasound-guided nerve blocks to enhance postoperative recovery by reducing ICU stay times. The detailed results are illustrated in Fig. 4.

Length of Hospital Stay

The effect of ultrasound-guided nerve block on the length of hospital stay was assessed across four randomized controlled trials (RCTs) [11,13,17,18] including a total of 138 participants. The results indicated that patients who received ultrasound-guided nerve block had an average postoperative hospital stay of approximately one week. In comparison, the control group experienced a longer average hospital stay of more than 8 days. The meta-analysis

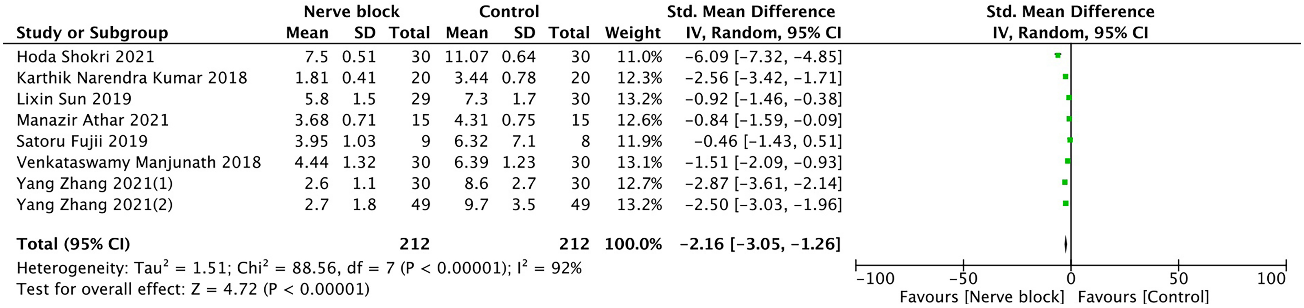

Fig. 3. Comparative analysis of extubation times. This forest plot displays the extubation times for postoperative patients, comparing those who received ultrasound-guided nerve blocks against the control group. The plot highlights the reduced extubation times associated with the intervention, demonstrating statistical significance. SD, standard deviation; Std, standard; IV, independent variable; CI, confidence interval.

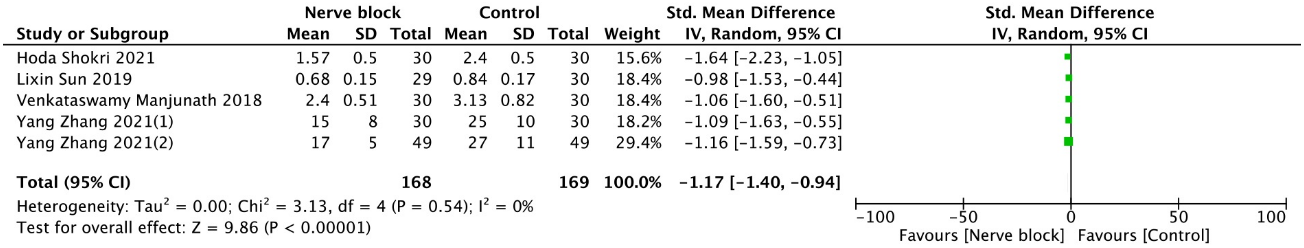

Fig. 4. Impact of ultrasound-guided nerve blocks on intensive care unit (ICU) length of stay. This forest plot compares the ICU length of stay between patients who received ultrasound-guided nerve blocks and those in the control group. The plot clearly demonstrates a significant reduction in ICU stay for the intervention group, indicating the effectiveness of the nerve block approach.

clearly demonstrates that ultrasound-guided nerve blocks significantly reduce the duration of hospital stay in patients ($p < 0.05$) , as depicted in Fig. 5.

Discussion

This meta-analysis, which synthesized data from eight RCTs, showed that ultrasound-guided nerve block can decrease the extubation time, ICU stay, and overall hospitalization time in patients recovering from cardiac surgery [11–18]. These findings suggest that ultrasound-guided nerve blocks play a vital role in enhancing recovery processes, thus potentially improving patient outcomes and reducing the burden on healthcare facilities. Despite these promising results, further studies are needed to fully understand the scope and mechanisms by which ultrasound-guided nerve blocks influence recovery after cardiac surgery.

Ultrasound-guided nerve block is a versatile anesthetic technique widely used for perioperative pain management across multiple surgical disciplines, including orthopedic, thoracic, general, and gynecological surgeries, showing effective decreases in pain scores [1–3]. In recent years, several studies have been conducted to investigate the application of ultrasound-guided nerve block in cardiac surgeries. The results showed that ultrasound-guided nerve blocks significantly decreased pain scores [19–21]. Reflecting this evidence, the 2019 Enhanced Recovery After Surgery (ERAS) guidelines for adults, published in JAMA Surgery, advocate for the integration of ultrasound-guided nerve blocks into cardiac surgery protocols to optimize recovery [7,8].

While ultrasound-guided nerve blocks offer significant benefits, they are not without associated risks. In cardioivascular surgery, common complications such as hematoma and other adverse events related to the puncture procedure can occur [7]. The risk of developing a hematoma is notably heightened in cardiac surgery patients due to the preoperative administration of anticoagulant medications, which increase bleeding tendencies [22].

Postoperative pain following cardiac surgery arises from multiple factors, including thoracotomy and damage to the intercostal nerves [19]. Ultrasound-guided nerve block can effectively manage this pain by targeting the affected nerves, offering an alternative to high-dose opioids, which are traditionally used but associated with significant adverse events [23]. While opioids are often chosen for their ability to maintain hemodynamic stability and manage pain, their high doses can lead to severe side effects including respiratory depression, postoperative nausea, and vomitting [24–26]. Respiratory depression may extend the need for mechanical ventilation and complicate the process of extubation [25,26]. In severe cases, it leads to respiratory de-

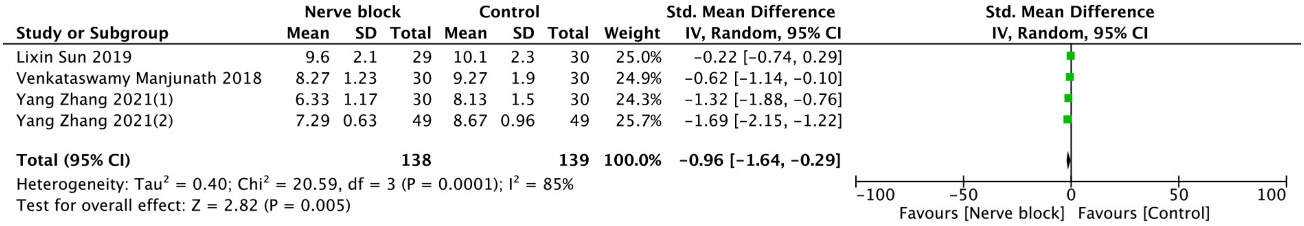

Fig. 5. Effect of ultrasound-guided nerve blocks on hospital stay duration. This forest plot visualizes the comparative lengths of hospital stay between patients who received ultrasound-guided nerve blocks and those in the control group. It highlights the statistically significant reduction in hospital stay duration for patients undergoing the nerve block intervention.

pression and ventilator-associated pneumonia [25,26]. Additionally, patients experiencing opioid-induced respiratory depression often struggle with coughing and breathing, increasing their risk of developing lung infections. Furthermore, the sedative effects of opioids can contribute to oversedation and respiratory suppression, further complicating recovery [25–27].

Patients with compromised renal or liver function stand to benefit from ultrasound-guided nerve blocks by alleviating the cumulative usage and elimination time of opioid drugs [25]. This meta-analysis reinforces the advantages of employing ultrasound-guided nerve blocks in cardiac surgery: significantly shorter extubation times, reduced ICU stays, and decreased length of hospital stay (LOS). Furthermore, the efficacy of ultrasound-guided nerve blocks in enhancing postoperative pain management and overall recovery while minimizing opioid drugs usage aligns with findings from prior studies [7,8,24–26]. This consistency underscores the reliability and potential of nerve blocks as a critical component of postoperative care in cardiac surgery patients.

This study has several limitations that warrant consideration. Firstly, this meta-analysis included limited studies and participants, leading to high heterogeneity ($I^2 > 50\%$) among the included studies. This heterogeneity might derive from the broad range of patient ages, the diversity in nerve block techniques, and the different anesthetic drugs used. Future studies should aim to include larger and more homogenous samples. Additionally, employing subgroup and sensitivity analysis could further refine the results based on larger sample sizes, providing more nuanced insights into the effectiveness of ultrasound-guided nerve blocks. Further assessment of study bias using methods such as the Egger test is also recommended to strengthen future meta-analyses. Secondly, the patients examined were exclusively adults undergoing elective cardiac surgery, limiting the applicability of the findings to this demographic. The efficacy and safety of ultrasound-guided nerve blocks in pediatric patients remain unexplored and require dedicated studies to determine their viability in younger age groups. Thirdly, this study did not include a comparison of adverse events associated with ultrasound-guided nerve blocks, such as hematoma, which are particularly relevant in cardiac surgery due to the use of anticoagulants. Future research should focus on these adverse events to provide a more comprehensive understanding of the risks associated with this anesthetic technique in cardiac surgery settings.

Conclusion

In conclusion, this meta-analysis demonstrates that ultrasound-guided nerve blocks significantly reduce extubation time, ICU stay, and overall hospitalization duration, thereby facilitating postoperative recovery. These findings support the effective incorporation of ultrasound-guided nerve blocks into Enhanced Recovery After Surgery (ERAS) protocols for cardiac surgery. This evidence suggests that ultrasound-guided nerve blocks are a viable option for improving outcomes and expediting recovery in patients undergoing cardiac procedures.

Availability of Data and Materials

The datasets used and/or analyzed during the currentstudy were available from the corresponding author on reasonable request.

Author Contributions

DD conceived of the study and participated in the design of the study. LW participated in the design of the study and drafted the manuscript. DD, YZ, LY, and ZL performed the statistical analysis, data interpretation and helped draft the manuscript. FY participated in the design of the study. All authors have read and approved the final manuscript. All authors contributed to editorial changes in the manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.59958/hsf.7657.

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