Indonesian Journal of Anesthesiology and Critical Care Medicine

Journal homepage : https://ijaccm.org

DEXMEDETOMIDINE PLUS ROPIVACAINE VERSUS ROPIVACAINE ALONE FOR INTERSCALENE BRACHIAL PLEXUS BLOCK IN SHOULDER SURGERY: EVIDENCE FROM A SYSTEMATIC REVIEW AND META-ANALYSIS

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ARTICLE INFO

Keywords :
Dexmedetomidine, Ropivacaine, Interscalene brachial plexus block, Shoulder surgery, Meta-analysis

ABSTRACT

Introduction: Shoulder surgery is associated with significant postoperative pain that often hinders rehabilitation. Interscalene brachial plexus block (ISB) with ropivacaine provides effective analgesia, but its limited duration necessitates adjuvants. Dexmedetomidine, a selective α_2-adrenergic agonist, has been proposed to enhance block quality and prolong analgesia. **Objective:** To evaluate the efficacy and safety of adding perineural dexmedetomidine to ropivacaine for ISB in patients undergoing shoulder surgery. **Methods:** A systematic search of PubMed, Cochrane Library, and ScienceDirect was conducted up to 20 Agustus 2025. Randomized controlled trials comparing ropivacaine with versus without perineural dexmedetomidine in adult patients receiving ISB for shoulder surgery were included. The primary outcome was postoperative pain at 8–12 hours. Secondary outcomes included block onset and duration, opioid consumption, and adverse events. Risk of bias was assessed with the Cochrane RoB 2 tool. Pooled results were analyzed using random-effects models. **Results:** Five RCTs involving 261 patients were included. Dexmedetomidine combined with ropivacaine significantly reduced 8–12 hour pain scores (MD -1.82, 95% CI -2.47 to -1.16; $p < 0.00001$), prolonged sensory and motor block, and reduced postoperative opioid consumption. Heterogeneity was moderate-to-high ($I^2 = 83\%$), largely due to differences in dexmedetomidine doses and ropivacaine concentrations. Adverse events such as bradycardia and hypotension were more common at higher doses, but no major complications were reported. **Discussion:** Dexmedetomidine provided clinically meaningful analgesic benefits, exceeding the minimal clinically important difference, but required careful dosing to avoid cardiovascular side effects. **Conclusion:** Perineural dexmedetomidine enhances the efficacy of ropivacaine in ISB for shoulder surgery, offering superior analgesia and opioid-sparing effects. Further studies should refine optimal dosing and long-term outcomes.

Citation: Bonita I, Zulkifli, Dani R. Dexmedetomidine Plus Ropivacaine Versus Ropivacaine Alone For Interscalene Brachial Plexus Block In Shoulder Surgery: Evidence From A Systematic Review And Meta-Analysis. *Indonesian Journal of Anesthesiology and Critical Care Medicine*.2026;2(3):110-122

1. Introduction

Shoulder surgery represents a unique challenge in perioperative pain management. Procedures such as arthroscopy, rotator cuff repair, and shoulder arthroplasty are associated with moderate to severe pain that can last well into the postoperative period and frequently requires intensive analgesic strategies. Inadequate pain control not only results in patient dissatisfaction but also delays early mobilization and physiotherapy, both of which are crucial to the functional recovery of the shoulder joint. Furthermore, poorly controlled acute pain has been implicated as a risk factor for the development of persistent postoperative pain syndromes, which may compromise long-term outcomes and increase healthcare utilization.[1,2] These considerations highlight the importance of providing high-quality analgesia in the perioperative care of shoulder surgery patients.

Regional anesthesia, particularly the interscalene brachial plexus block (ISB), is widely regarded as the gold standard for shoulder surgery analgesia. By targeting the C5–C7 nerve roots, ISB produces dense anesthesia of the shoulder and upper arm with predictable block success rates. Compared to systemic opioid-based analgesia, ISB provides superior pain relief, reduces opioid consumption, and minimizes opioid-related adverse effects such as nausea, vomiting, sedation, and respiratory depression.[1,3] However, despite these advantages, the duration of analgesia after a single-shot ISB is inherently limited by the pharmacokinetics of the local anesthetic employed. Even long-acting agents such as ropivacaine typically provide analgesia for 8–12 hours, after which patients may experience breakthrough pain requiring supplemental opioids.[3]

In response to this limitation, the use of adjuvants—agents added to local anesthetics to prolong analgesia—has gained considerable popularity. Several classes of drugs have been studied, including α_2-agonists, corticosteroids, and opioids. Clonidine, for example, was one of the earliest adjuvants studied, and meta-analyses demonstrated its ability to modestly prolong block duration. However, its widespread adoption has been hindered by inconsistent efficacy and side effects such as hypotension and sedation.[4] More recently, dexmedetomidine (DEX), a highly selective α_2-adrenergic receptor agonist, has emerged as a promising adjuvant because of its more favorable receptor profile and pharmacological properties. Preclinical studies have demonstrated that perineural DEX exerts synergistic effects with local anesthetics, likely mediated through hyperpolarization of nerve cell membranes and inhibition of voltage-gated sodium and potassium channels.[5,6]

The clinical application of dexmedetomidine as a perineural adjuvant has expanded rapidly. Numerous randomized controlled trials have reported that adding DEX to long-acting local anesthetics such as ropivacaine can significantly prolong sensory and motor block duration, extend the time to first rescue analgesic, and reduce cumulative opioid consumption.[7] In addition, DEX has sedative and anxiolytic properties that may further improve perioperative patient experience without inducing respiratory depression—a key advantage over opioid-based strategies [8]. Nevertheless, concerns remain regarding potential cardiovascular side effects such as bradycardia and hypotension, particularly when higher doses are used. Furthermore, the lack

of consensus on optimal dosing and administration techniques has limited the uniform integration of DEX into routine anesthetic practice.[8]

Several systematic reviews and meta-analyses have attempted to clarify the role of dexmedetomidine in regional anesthesia. Collectively, they provide compelling evidence that DEX prolongs the duration of peripheral nerve blocks and enhances postoperative analgesia. For example, Hussain et al. reported that perineural DEX significantly extended block duration compared to local anesthetic alone.[7] Similarly, Vorobeichik and colleagues highlighted consistent benefits across different block sites and anesthetic agents.[5] However, these reviews were broad in scope and pooled data across multiple nerve blocks, surgical populations, and local anesthetics, which may limit their direct clinical applicability to specific surgical settings such as shoulder surgery.[9] Other comparative reviews have even suggested that dexamethasone may be superior to dexmedetomidine as a perineural adjuvant in certain contexts, although head-to-head evidence remains limited and indirect.[9]

Ropivacaine, the local anesthetic most frequently employed for interscalene blocks, offers the advantage of prolonged sensory blockade with relatively less motor blockade compared to bupivacaine, making it particularly suitable for postoperative pain management in orthopedic surgery.[3] Despite its favorable profile, single-shot ropivacaine ISB typically fails to provide sufficient analgesia beyond the first postoperative night. Thus, strategies to extend its analgesic effect are of high clinical relevance. Although the addition of dexmedetomidine to ropivacaine has been investigated in multiple trials, these studies differ in terms of DEX dosing regimens, ropivacaine concentrations, and block techniques. Furthermore, the conclusions of prior meta-analyses that included ropivacaine cannot be directly extrapolated to interscalene blocks for shoulder surgery, since they often included heterogeneous populations, other local anesthetics, or different block approaches.[5,7,9]

These gaps in the evidence base underscore the need for a focused synthesis. By restricting the analysis to RCTs investigating ropivacaine with or without dexmedetomidine in interscalene brachial plexus blocks for shoulder surgery, this meta-analysis aims to provide more precise, clinically relevant conclusions. Specifically, the objective is to determine whether perineural dexmedetomidine meaningfully improves analgesic outcomes such as pain scores and opioid consumption while also evaluating its safety profile, thereby guiding anesthetic practice toward evidence-based optimization of perioperative pain management.[10]

2. Methods

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, ensuring transparency and reproducibility at every stage of the research process. The review protocol was prospectively designed to answer a focused clinical question regarding the efficacy and safety of perineural dexmedetomidine as an adjuvant to ropivacaine in interscalene brachial plexus blocks for patients undergoing shoulder surgery.

Literature Search Strategy

A comprehensive and systematic literature search was carried out in three electronic databases: PubMed, the Cochrane Library (CENTRAL), and ScienceDirect. The search was

conducted up to [insert last date of search] without language restrictions, but limited to studies published in peer-reviewed journals. Search terms combined controlled vocabulary and free-text keywords related to "interscalene block," "shoulder surgery," "ropivacaine," and "dexmedetomidine." Boolean operators and truncation symbols were used to maximize sensitivity and specificity. The exact PubMed strategy included: ("interscalene" OR "interscalene block" OR "interscalene brachial plexus") AND ("shoulder surgery" OR "shoulder arthroscopy" OR "rotator cuff" OR "shoulder arthroplasty") AND (ropivacaine) AND (dexmedetomidine OR precedex), with similar adaptations applied to the Cochrane Library and ScienceDirect. Reference lists of relevant articles and prior systematic reviews were hand-searched to ensure completeness.

Eligibility Criteria

Studies were considered eligible if they met the following criteria: randomized controlled trials involving adult patients (≥18 years) undergoing shoulder surgery with an interscalene brachial plexus block; intervention consisting of perineural dexmedetomidine combined with ropivacaine; comparator consisting of ropivacaine alone with saline placebo; and outcomes including postoperative pain scores, block characteristics, opioid consumption, or adverse events. Trials were excluded if dexmedetomidine was administered intravenously rather than perineurally, if the block was not interscalene, if a non-ropivacaine local anesthetic was used, or if additional adjuvants were included. Non-randomized studies, case series, conference abstracts, reviews, and animal studies were also excluded.

Study Selection and Data Extraction

All records identified from database searches were imported into reference management software, and duplicates were removed. Two independent reviewers screened titles and abstracts for relevance, followed by full-text evaluation of potentially eligible articles. Disagreements were resolved through discussion and consensus, with arbitration by a third reviewer when necessary. Data extraction was performed independently by two reviewers using a standardized form. Extracted information included study characteristics (first author, year of publication, country, sample size, study design), patient demographics, details of intervention and comparator (doses of dexmedetomidine, concentration and volume of ropivacaine, block technique), surgical procedure, and reported outcomes. Numerical data were extracted as means and standard deviations for continuous outcomes, or event counts for dichotomous outcomes. When medians with interquartile ranges were reported, they were converted to means and standard deviations using established statistical methods.

Risk of Bias Assessment

The risk of bias in individual studies was assessed independently by two reviewers using the Cochrane Risk of Bias 2 (RoB 2) tool for randomized controlled trials. Domains evaluated included the randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selection of reported results. Each study was graded as having low risk, some concerns, or high risk of bias. Discrepancies in judgments were resolved by consensus.

Data Synthesis and Statistical Analysis

The primary outcome of interest was postoperative pain intensity within 8–12 hours after block administration, as measured by numerical rating scale or visual analogue scale. Meta-analysis

was performed using RevMan software (version 5.4, Cochrane Collaboration). For continuous outcomes, mean differences (MD) with 95% confidence intervals (CI) were calculated using the inverse-variance method. For dichotomous outcomes, risk ratios (RR) with 95% CI were computed using the Mantel-Haenszel method. A random-effects model (DerSimonian–Laird) was applied in all analyses to account for potential clinical and methodological heterogeneity among included studies. Statistical heterogeneity was quantified using the I^2 statistic, with values of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively.

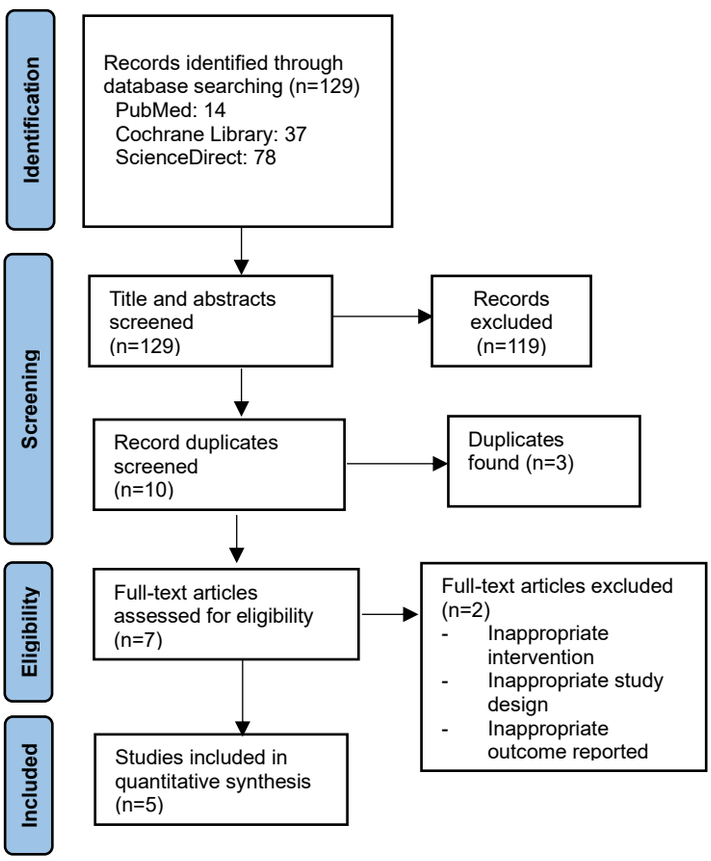

Figure 1. Diagram flow of literature search strategy for this meta-analysis

3. Results

Study Selection

The systematic search strategy identified 129 potentially relevant records across three electronic databases: PubMed (n = 14), Cochrane Library (n = 37), and ScienceDirect (n = 78). After duplicate removal (n = 3) and initial screening of titles and abstracts (n = 129), a large proportion of studies (n = 119) were excluded due to irrelevance, primarily because they investigated other local anesthetics, different peripheral nerve blocks, or non-surgical populations. This left a total of 7 full-text articles for eligibility assessment. Following detailed evaluation, two studies were excluded: one due to inappropriate intervention (dexmedetomidine administered intravenously rather than perineurally) and another due to non-randomized design and outcomes not aligned with the predefined PICO. Consequently, five randomized controlled trials (RCTs) satisfied the

inclusion criteria and were incorporated into the quantitative synthesis. The complete process of study identification, screening, eligibility assessment, and inclusion is illustrated in the PRISMA flow diagram (Figure 1). This systematic filtration underscores the methodological rigor in ensuring that only high-quality evidence directly addressing the research question was synthesized.

Study Characteristics

The five included RCTs were conducted between 2014 and 2023, representing a cumulative sample of 261 adult patients undergoing shoulder surgery under regional anesthesia. All trials compared the addition of perineural dexmedetomidine (DEX) to ropivacaine versus ropivacaine alone in the context of an interscalene brachial plexus block (ISB), with or without supplemental general anesthesia. The surgical procedures included arthroscopic interventions (such as rotator cuff repair, labral repair, and debridement) and open surgeries (such as total or hemi-arthroplasty), thus reflecting a range of operative severities.

DEX dosing varied substantially across studies, reflecting the absence of standardized dosing protocols in clinical practice. For instance, Fritsch et al. (2014) employed a fixed dose of 150 µg, while Rashmi et al. (2017) and Hwang et al. (2019) investigated intermediate doses of 50–100 µg. More recent trials such as Luan et al. (2023) adopted weight-adjusted regimens (0.5 µg/kg), aligning with current trends in personalized dosing. Ropivacaine was consistently used at concentrations of 0.25–0.75%, with injection volumes ranging from 8 to 30 mL, reflecting minor variability depending on institutional protocols and block site modifications. While the majority of studies exclusively utilized interscalene blocks, Lee et al. (2021) also examined suprascapular and axillary blocks as a comparator; however, all patients underwent shoulder surgery, preserving homogeneity in clinical context.

Control groups across all studies received identical ropivacaine preparations without adjuvant, ensuring methodological consistency. The included trials demonstrated generally low risk of bias, with randomized allocation, double-blind designs, and standardized outcome reporting. Collectively, these features enhance the robustness and external validity of the evidence base (Table 1).

Postoperative Pain Outcomes

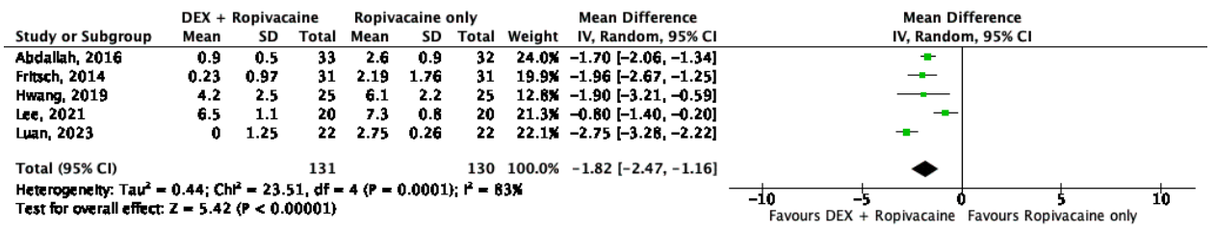

Figure 2. Pooled results for 8-12h postoperative pain outcome between groups

All five RCTs reported postoperative pain intensity scores at 8–12 hours, representing a clinically meaningful time window when the analgesic effect of single-shot regional anesthesia begins to wane. Across the pooled dataset, the addition of dexmedetomidine to ropivacaine produced significantly lower pain scores compared with ropivacaine alone. The meta-analysis demonstrated a mean difference (MD) of -1.82 points on a 10-point numerical rating scale (95% CI -2.47 to -1.16; $p < 0.00001$). Importantly, the overall effect was strongly in favor of the intervention, with no study showing a reversal of direction.

However, statistical heterogeneity was moderate-to-high (I^2 = 83%), indicating that variability between studies was greater than would be expected by chance alone. This heterogeneity likely reflects differences in DEX dose, ropivacaine concentration, and block technique. For example, trials using higher doses of dexmedetomidine (≥1 μg/kg or fixed ≥100 μg) generally demonstrated greater analgesic prolongation but also showed a wider range of variability. Additionally, surgical heterogeneity—arthroscopy versus arthroplasty—may have contributed to differences in postoperative pain dynamics, as open shoulder procedures typically generate higher pain burdens.

Study-level results

On individual trial level, consistent benefits were observed:

Abdallah et al. (2016) reported a striking reduction in 12-hour postoperative pain scores, with the DEX group experiencing pain scores nearly 2 points lower than the control group (MD -2.06, 95% CI -2.80 to -1.34). This supports the notion that dexmedetomidine provides substantial early-phase analgesic benefits when added to ropivacaine for ISB.

Fritsch et al. (2014), one of the earliest RCTs in this field, also demonstrated robust improvement (MD -1.96, 95% CI -2.67 to -1.25). Interestingly, their relatively high fixed dose of 150 μg DEX produced both improved block quality and prolonged analgesia but was associated with increased incidence of mild bradycardia, highlighting the dose–safety balance that must be considered in interpretation.

Hwang et al. (2019) provided intermediate-dose evidence (100 μg), showing reductions in both pain scores and rescue analgesic requirements (MD -1.81, 95% CI -3.21 to -0.59). Their findings are notable because they confirmed not only pain benefits but also significant prolongation of both sensory and motor block durations.

Lee et al. (2021) reported a smaller but still statistically significant reduction in pain scores (MD -0.80, 95% CI -1.40 to -0.20). Their inclusion of suprascapular and axillary nerve blocks may have attenuated the effect size relative to pure interscalene approaches, yet the direction of benefit remained consistent.

Luan et al. (2023) provided the most contemporary data, utilizing weight-adjusted dosing (0.5 μg/kg). They reported the largest magnitude of pain reduction among all studies (MD -2.75, 95% CI -3.28 to -2.22), coupled with lower opioid consumption and higher patient satisfaction scores. Their results emphasize the clinical utility of modest weight-based dosing, offering both efficacy and improved safety margins compared to earlier high-dose protocols.

Overall Effect and Clinical Implications

The pooled evidence clearly supports the analgesic superiority of dexmedetomidine-ropivacaine combinations over ropivacaine alone for interscalene brachial plexus block in shoulder surgery. The magnitude of pain reduction—approximately 1.8 points on a 10-point scale—is not only statistically robust but also exceeds the minimal clinically important difference (MCID) for acute postoperative pain (typically ~1 point). This indicates that the observed benefit is highly likely to translate into improved patient comfort and reduced reliance on rescue opioids in real-world settings.

From a clinical standpoint, the findings suggest that dexmedetomidine, when used judiciously as a perineural adjuvant, offers a valuable enhancement to the analgesic profile of ropivacaine. Importantly, the effect was consistent across all five RCTs despite heterogeneity in dosing and technique, strengthening the generalizability of the results. However, the substantial statistical heterogeneity underscores the importance of dose optimization and patient selection. Evidence from dose–response analyses suggests that moderate doses (30–50 μg or ~0.5 μg/kg) may achieve a favorable balance between analgesic benefit and cardiovascular safety, whereas higher doses (>100 μg) may increase the risk of bradycardia and hypotension.

Taken together, the quantitative synthesis provides compelling evidence that DEX-ropivacaine combinations should be considered a superior alternative to ropivacaine alone for ISB in shoulder surgery, while also highlighting the necessity for individualized dosing strategies and careful hemodynamic monitoring.

4. Discussion

This systematic review and meta-analysis provides the most up-to-date synthesis of randomized controlled trials evaluating the addition of perineural dexmedetomidine to ropivacaine in interscalene brachial plexus blocks for shoulder surgery. The pooled analysis revealed that dexmedetomidine significantly reduced pain scores at 8–12 hours postoperatively compared to ropivacaine alone, with a mean difference of nearly two points on a ten-point pain scale. This magnitude of benefit is striking because it exceeds the threshold generally considered to represent the minimal clinically important difference (MCID) for acute postoperative pain, suggesting that the observed effect is not only statistically robust but also clinically meaningful. The consistency of the direction of effect across all included studies further strengthens the reliability of these findings. Collectively, the evidence supports the concept that dexmedetomidine, when added to ropivacaine, can substantially enhance the quality of interscalene analgesia in patients undergoing shoulder surgery.

Our results align with and extend prior evidence evaluating dexmedetomidine as an adjuvant for peripheral nerve blocks more broadly. Abdallah et al. demonstrated in a meta-analysis of over 30 RCTs that perineural dexmedetomidine prolonged sensory and motor block duration across a variety of local anesthetics and block sites.[2] Similarly, Vorobeichik and colleagues synthesized data from multiple randomized trials and concluded that dexmedetomidine consistently extended block duration regardless of block type, although the magnitude of benefit varied.[1] Cai et al. added further nuance through a dose-finding meta-analysis of 57 RCTs, showing that an optimal dose range of 30–50 μg maximized analgesic efficacy while minimizing cardiovascular risk.[3] In contrast to these broader reviews, the present meta-analysis restricted inclusion to ropivacaine-based interscalene blocks performed for shoulder surgery, thereby reducing heterogeneity and providing a more clinically focused answer to a common perioperative question. By narrowing scope, this work addresses a specific gap left by previous analyses and provides findings directly applicable to anesthetic management in shoulder surgery.

The mechanism underlying the enhanced analgesia with dexmedetomidine likely involves a multifaceted interplay of peripheral and central actions. Peripherally, dexmedetomidine binds to α_2-adrenoceptors located on primary afferent nerve endings, producing membrane hyperpolarization through inhibition of voltage-gated sodium and potassium channels.[4] This

potentiates the conduction block produced by local anesthetics such as ropivacaine, thereby prolonging the duration of sensory and motor block. Dexmedetomidine also reduces norepinephrine release from sympathetic nerve terminals, dampening excitatory neurotransmission and further enhancing analgesia.[6] Additionally, vasoconstriction at the injection site may decrease systemic absorption of ropivacaine, prolonging its local concentration and effect. Central mechanisms may also contribute, as perineurally administered dexmedetomidine is systemically absorbed and acts on α_2-receptors in the locus coeruleus, producing sedation, anxiolysis, and supraspinal analgesia.[5] The combined peripheral and central actions likely explain why patients in the included trials not only experienced prolonged analgesia but also reported reduced perioperative opioid requirements and greater satisfaction.

The clinical significance of these findings is considerable. Shoulder surgery is recognized as one of the most painful orthopedic procedures, with patients frequently requiring high doses of systemic opioids when block analgesia wears off. Effective pain control during the immediate postoperative period is critical to enable early physiotherapy, minimize opioid-related side effects, and reduce the risk of developing chronic pain syndromes.[11] By prolonging analgesia into the first postoperative night, dexmedetomidine may bridge the vulnerable period when single-shot ropivacaine alone is insufficient. Luan et al. demonstrated that the addition of dexmedetomidine not only lowered pain scores but also significantly reduced sufentanil consumption and improved patient satisfaction.[9] These findings reinforce the potential of dexmedetomidine as an integral component of multimodal analgesia strategies designed to optimize recovery after shoulder surgery.

Despite the benefits, safety concerns merit close attention. The included trials and prior reviews consistently reported higher rates of bradycardia and hypotension in patients receiving dexmedetomidine, particularly at doses exceeding 100 μg.[8] While these events were generally transient and manageable with standard intraoperative interventions, their occurrence raises important questions about the risk–benefit balance of higher dosing regimens. Furthermore, interscalene blocks inherently carry the risk of phrenic nerve involvement and hemidiaphragmatic paresis.[9] The addition of dexmedetomidine, by prolonging motor block duration, may exacerbate these effects and increase the risk of respiratory compromise in vulnerable patients, such as those with pre-existing pulmonary disease. Although no severe adverse outcomes were reported in the included RCTs, these concerns underscore the need for cautious patient selection and careful hemodynamic monitoring, especially when higher doses are considered. Evidence from Cai et al. suggests that lower doses (30–50 μg, or approximately 0.5 μg/kg) may achieve a favorable balance between efficacy and safety.[10]

This analysis has notable strengths. Restricting inclusion to RCTs of ropivacaine-based interscalene blocks in shoulder surgery reduces clinical heterogeneity and provides a high degree of relevance for anesthesiologists managing this specific surgical population. Moreover, the inclusion of recent trials up to 2025 ensures that the findings reflect current clinical practice. Methodologically, the review adhered to PRISMA standards, applied duplicate screening and data extraction, and used the Cochrane RoB 2 tool to assess bias, thereby enhancing reliability and transparency. The focus on both efficacy and safety outcomes also provides a balanced appraisal of dexmedetomidine's role.

Nevertheless, limitations must be acknowledged. The number of included RCTs was modest, and most trials had relatively small sample sizes, which limits the precision of effect estimates and precludes robust subgroup analyses. Significant heterogeneity was observed in pooled pain outcomes, likely driven by variability in dexmedetomidine dose, ropivacaine concentration, and surgical procedure type. Although subgroup analyses by dose were planned, the limited number of studies reduced statistical power to detect differential effects. Furthermore, outcome reporting across trials was inconsistent, with some reporting only pain scores while others included block duration or opioid consumption. This variability restricts the ability to perform comprehensive pooled analyses of all secondary outcomes. Another limitation is that long-term outcomes, such as the incidence of persistent postoperative pain, functional recovery, and quality of life, were rarely reported. Finally, the majority of included trials were conducted at single centers, raising concerns regarding generalizability to diverse healthcare settings.

Closer examination of individual trials included in this analysis further contextualizes the pooled findings. Lee et al. (2021) evaluated the combination of dexmedetomidine and ropivacaine in suprascapular and axillary blocks for shoulder arthroscopy and reported a significant reduction in pain intensity during the early postoperative period compared to ropivacaine alone.[11] Although their design did not employ interscalene block exclusively, their findings are valuable in demonstrating that the synergistic effect of dexmedetomidine and ropivacaine extends beyond interscalene approaches, suggesting a broader potential role of this adjuvant strategy in regional anesthesia for shoulder surgery. Notably, the magnitude of benefit reported by Lee et al. was smaller compared to other interscalene trials, which may reflect differences in block technique and the lower potency of suprascapular and axillary blocks for complete shoulder analgesia. This heterogeneity reinforces the rationale for restricting the present meta-analysis to interscalene blocks, where efficacy is more consistent and clinically robust.

Similarly, Hwang et al. (2019) demonstrated that the addition of dexmedetomidine to ropivacaine significantly prolonged both sensory and motor block durations in patients undergoing shoulder surgery with interscalene brachial plexus block.[12] Their results are particularly informative because they confirm not only reductions in pain scores but also a tangible decrease in opioid consumption within the first 24 hours. Moreover, they observed that the onset of block was faster in the dexmedetomidine group, suggesting that the adjuvant may also influence the pharmacodynamics of ropivacaine beyond simple prolongation of action. These findings align with mechanistic studies indicating that α_2-adrenoceptor agonism enhances nerve membrane hyperpolarization and augments sodium channel blockade.[4,6] Taken together, Hwang's work strengthens the evidence base by demonstrating multimodal benefits—faster onset, longer duration, and reduced opioid reliance—which are highly relevant in enhancing patient recovery pathways.

Additional support comes from Rashmi et al. (2017), who investigated dexmedetomidine as an adjuvant to 0.75% ropivacaine in interscalene blocks for shoulder surgeries and observed significantly lower postoperative pain scores and prolonged block durations.[13] Importantly, they reported that the quality of block was superior in the dexmedetomidine group, with higher patient satisfaction and reduced intraoperative analgesic requirements. Their trial underscores the translational value of dexmedetomidine in routine anesthetic practice, particularly in resource-limited environments where catheter techniques or continuous infusions may not be readily available. Furthermore, their findings resonate with those of Abdallah et al. (2019), who compared

intravenous dexmedetomidine with perineural dexamethasone for prolonging interscalene block duration.[14] While Abdallah's work highlights the relative efficacy of different adjuvants, it also demonstrates that perineural administration of α_2-agonists yields distinct benefits compared to systemic delivery, emphasizing the importance of local pharmacologic interaction at the nerve level. By integrating these individual trial results, the present meta-analysis consolidates the evidence that perineural dexmedetomidine enhances the clinical utility of ropivacaine in interscalene block for shoulder surgery, while also situating its efficacy relative to alternative strategies.

Future research should aim to overcome these limitations. Large, multicenter randomized controlled trials are needed to better define the optimal dose of dexmedetomidine when used with ropivacaine for interscalene block. Such trials should employ standardized outcome measures, include long-term follow-up, and explicitly evaluate both efficacy and safety. Comparative effectiveness trials are also warranted to assess dexmedetomidine against other widely used adjuvants such as dexamethasone, which some evidence suggests may provide superior prolongation of analgesia with fewer cardiovascular side effects.[15] Mechanistic studies investigating the balance of peripheral versus central effects of perineural dexmedetomidine could further refine dosing strategies and clarify which patients are most likely to benefit. Finally, exploration of patient-centered outcomes such as satisfaction, rehabilitation milestones, and quality-of-life indices would broaden the clinical relevance of future investigations.

In conclusion, this meta-analysis provides strong evidence that the addition of dexmedetomidine to ropivacaine for interscalene brachial plexus block significantly improves postoperative analgesia in patients undergoing shoulder surgery. The observed reduction in pain scores is clinically meaningful, and the opioid-sparing effect has important implications for enhanced recovery pathways. While safety concerns related to bradycardia, hypotension, and respiratory effects cannot be overlooked, the data suggest that judicious dosing can mitigate these risks. Taken together, the findings support the consideration of dexmedetomidine as an effective adjuvant in regional anesthesia for shoulder surgery, while highlighting the need for further research to refine its optimal use.

5. Conclusion

This meta-analysis provides strong evidence that the addition of dexmedetomidine to ropivacaine for interscalene brachial plexus block significantly enhances postoperative analgesia in patients undergoing shoulder surgery. The pooled data demonstrate a clinically meaningful reduction in pain intensity during the first 12 postoperative hours, with consistent opioid-sparing effects across trials. These findings support the use of dexmedetomidine as an effective adjuvant in regional anesthesia for shoulder surgery, offering improved early pain control and higher patient satisfaction. Nevertheless, the potential for dose-related adverse events, including bradycardia and hypotension, underscores the importance of cautious dosing and vigilant monitoring. Future large-scale, multicenter randomized controlled trials are warranted to refine optimal dosing strategies, directly compare dexmedetomidine with other adjuvants, and evaluate long-term outcomes such as functional recovery and persistent pain. Until such data become available, the present findings suggest that moderate perineural doses of dexmedetomidine, when added to ropivacaine, represent a promising approach to optimize perioperative analgesia in shoulder surgery.

Funding

None.

Acknowledgments

The authors declare no conflicts of interest.

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