

EFFECT OF DEXMETETOMIDINE AS AN ADJUVANT TO SPINAL ANESTHESIA ON POSTOPERATIVE PAIN AND HEMODYNAMIC STABILITY IN LOWER LIMB SURGERIES: SYSTEMATIC REVIEW

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Abstract

Background: Dexmedetomidine, an α_2 -adrenergic agonist, has emerged as a promising intrathecal adjuvant to spinal anaesthesia due to its analgesic and hemodynamic stabilizing properties. This systematic review evaluates the efficacy and safety of dexmedetomidine compared to opioids and placebo in lower limb surgeries.

Methods: A comprehensive literature search was performed across PubMed, Embase, Scopus, Web of Science, and Google Scholar from 2011 to 2025. Randomized controlled trials (RCTs) comparing dexmedetomidine with other adjuvants or placebo in spinal anaesthesia for lower limb surgeries were included. Outcomes assessed were duration of analgesia, onset time of sensory block, hemodynamic stability, and adverse events. Risk of bias was evaluated using the Cochrane Risk of Bias 2.0 tool.

Results: Out of 1,372 identified records, 25 RCTs with over 2,800 patients met inclusion criteria. Dexmedetomidine (3–10 μ g) significantly prolonged sensory and motor block duration (230–310 min vs. 180–220 min with opioids), delayed the need for rescue analgesia, and reduced incidence of postoperative nausea and vomiting. Hemodynamic parameters were more stable with dexmedetomidine, although mild bradycardia was reported. No serious adverse events were observed.

Conclusion: Dexmedetomidine is an effective and safe adjuvant to spinal anesthesia in lower limb surgeries. It prolongs analgesia, improves hemodynamic stability, and reduces opioid-related side effects. Its use is recommended especially in opioid-sensitive populations, though careful monitoring for bradycardia is advised.

Keywords: Dexmedetomidine, Spinal Anaesthesia, Intrathecal Adjuvant, Lower Limb Surgery, Postoperative Pain, Hemodynamic Stability, Buprenorphine, Fentanyl, Randomized Controlled Trials, Systematic Review

Manuscrito recibido: 10/10/2025

Manuscrito aceptado: 24/11/2025

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Introduction

Spinal anaesthesia is a widely utilized technique for lower limb surgeries due to its efficacy in achieving profound sensory and motor blockade. Despite its effectiveness, the duration of anaesthesia is often limited, necessitating the use of adjuvants to prolong analgesia and enhance perioperative outcomes (Cansian et al., 2024). Among these, α_2 -adrenergic agonists like dexmedetomidine have gained attention due to their sedative, analgesic, and hemodynamic stabilizing properties without inducing significant respiratory depression (Tang & Xia, 2017).

Dexmedetomidine is known to prolong sensory and motor block when added to local anaesthetics, and it reduces the requirement for rescue analgesics postoperatively (Mahendru et al., 2013; Wu et al., 2014). Its mechanisms are attributed to inhibition of norepinephrine release and action at spinal α_2 receptors, leading to reduced nociceptive transmission (Pourzitaki et al., 2018). Compared to traditional opioid adjuvants like fentanyl and buprenorphine, dexmedetomidine demonstrates fewer opioid-related side effects such as nausea, vomiting, and pruritus (Feenstra et al., 2021; White et al., 2022).

However, potential side effects such as bradycardia and hypotension require cautious dosing and patient monitoring (Hussain et al., 2017; Zhao et al., 2020). The current literature reflects varying dosages and outcomes associated with dexmedetomidine, necessitating a systematic synthesis of the data to establish clearer recommendations for its use in spinal anesthesia for lower limb procedures.

Given the promising analgesic benefits and the emerging data on hemodynamic safety, this systematic review aims to evaluate the effect of dexmedetomidine as an adjuvant to spinal anesthesia compared to other adjuvants or placebo in lower limb surgeries. This includes assessing its impact on postoperative pain control, duration of sensory and motor block, hemodynamic stability, and adverse event profile (Cansian et al., 2024; Elfawal & Abdelaal, 2016).

This review also seeks to determine whether dexmedetomidine offers superior clinical efficacy and safety compared to opioids like buprenorphine, which have been associated with a higher risk of postoperative nausea and vomiting (Amitha et al., 2023; Gowrilakshimi & Senthil Kumar, 2022). This comprehensive appraisal of RCTs will inform anaesthesiologists on optimal adjuvant choice for improving surgical outcomes in spinal anaesthesia.

Methodology

To conduct this systematic review, we employed a comprehensive search strategy encompassing electronic databases such as PubMed/MEDLINE, Embase, Scopus, Web of Science, and Google Scholar (for grey literature), as well as ACAM (Advanced Clinical and Medical Journal, 2023, Vol. 10, Issues 1869 & 1870). The search covered studies from 2011 until 2025. We used a combination of keywords and Medical Subject Headings (MeSH terms) including "Dexmedetomidine," "Spinal Anaesthesia," "Intrathecal Adjuvant," "Lower Limb Surgery," "Postoperative Pain," "Hemodynamic Stability," "Buprenorphine," "Fentanyl," and "Analgesia Duration." Boolean operators (AND, OR) were applied to refine the search and ensure comprehensiveness.

The selection of studies followed a two-step process. Initially, titles and abstracts of all identified records ($n = 1,372$) were independently screened by two reviewers to identify potentially relevant articles. After removing duplicates, 1,195 unique studies remained, and 1,140 were excluded during the initial screening for lack of relevance. Subsequently, full-text articles ($n = 55$) were retrieved and reviewed for eligibility according to predefined inclusion criteria. Studies were included if they:

1. Evaluated dexmedetomidine as an adjuvant to spinal anaesthesia in lower limb surgeries;
2. Included comparative groups (placebo, fentanyl, buprenorphine, or other adjuvants);
3. Measured postoperative pain, duration of analgesia, hemodynamic changes, or adverse effects;
4. Were RCTs published in English between 2011–2025.

Exclusion criteria included non-original research (e.g., reviews, editorials), insufficient outcome data, studies with significant methodological flaws, and non-English articles. Disagreements between reviewers were resolved by consensus and arbitration by a third senior reviewer.

Data extraction was performed using a standardized template that captured author, year, study design, sample size, interventions, control groups, outcomes (analgesia duration, adverse effects), and key findings. This process was conducted independently by two reviewers and then cross-verified.

Risk of bias for RCTs was assessed using the Cochrane Risk of Bias 2.0 Tool, evaluating randomization, allocation concealment, blinding, outcome assessment, and reporting. Studies with high risk in more than two domains were excluded from synthesis.

Data synthesis was narrative due to heterogeneity in study design and outcome measures. Key findings were tabulated, and outcome trends (duration of analgesia, incidence of PONV, bradycardia, hypotension) were qualitatively compared across dexmedetomidine and comparator groups (Figure 1).

Results

A total of 1,372 records were identified through the comprehensive database search. After removing 177 duplicates, 1,195 unique articles were screened by title and abstract. During the initial screening, 1,140 records were excluded for reasons such as irrelevance to the research question, non-clinical design, or lack of focus on spinal anaesthesia or dexmedetomidine. A total of 55 full-text articles were assessed for eligibility.

Following detailed evaluation, 30 articles were excluded due to insufficient outcome data ($n = 14$), significant methodological flaws ($n = 10$), or non-English language ($n = 6$). Finally, 25 randomized controlled trials met the inclusion criteria and were included in the qualitative synthesis. These studies spanned publication years from 2011 to 2024 and collectively included over 2,800 patients undergoing lower limb surgeries under spinal anaesthesia.

Across these trials, dexmedetomidine was primarily used at doses between 3 μg to 10 μg as an intrathecal adjuvant to hyperbaric bupivacaine. Comparator groups included fentanyl, buprenorphine, clonidine, and placebo (saline). The majority of trials demonstrated that dexmedetomidine significantly prolonged the duration of sensory and motor block, with average durations ranging from 230 to 310 minutes, compared to 180–220 minutes in opioid comparators.

The onset time of sensory block was often shorter in the dexmedetomidine

group, with some studies reporting block onset within 2–4 minutes' post-injection. The time to first rescue analgesia was also significantly extended in the dexmedetomidine arms, suggesting enhanced postoperative pain control. Importantly, several studies noted that dexmedetomidine reduced the need for supplemental opioids or NSAIDs postoperatively.

In terms of hemodynamic stability, dexmedetomidine was generally associated with more consistent mean arterial pressure (MAP) and heart rate (HR) compared to opioids, although mild bradycardia was reported in some trials. Notably, the incidence of postoperative nausea and vomiting (PONV) was substantially lower in the dexmedetomidine groups. In contrast, buprenorphine and fentanyl groups exhibited higher rates of PONV, sedation, and pruritus.

Only minor adverse events were noted in the dexmedetomidine groups, most of which were self-limiting or easily managed with standard intraoperative medications. No study reported serious complications such as respiratory depression or permanent neurologic injury. Overall, the quality of evidence was moderate to high, with most studies achieving low risk of bias across most domains.

The subgroup analysis revealed a dose-dependent trend wherein increasing dexmedetomidine doses were associated with more prolonged sensory block, although bradycardia risk also slightly increased. Conversely, variations in the type or dose of local anaesthetic did not significantly alter the main outcomes (Table 1).

Discussion

The current synthesis of 25 randomized controlled trials reveals consistent evidence supporting the efficacy of dexmedetomidine in prolonging the duration of both sensory and motor blockade when used as an adjuvant in spinal anaesthesia (Mahendru et al., 2013; Bajwa et al., 2011). This effect is attributed to the α_2 -agonist properties of dexmedetomidine, which modulate pain perception at the spinal level through presynaptic inhibition of norepinephrine (Tang & Xia, 2017).

Comparative studies demonstrate that dexmedetomidine provides a significantly longer analgesic duration than fentanyl and buprenorphine. For instance, Peddapally and Vaithiyalingam (2024) showed that the dexmedetomidine group had an analgesia duration of approximately 265 minutes, surpassing that of fentanyl. Similarly, Amitha et al. (2023) found a statistically longer pain-free interval with dexmedetomidine than with buprenorphine.

Several trials (e.g., Rai & Bhutia, 2017; Mohamed & Susheela, 2017) indicate a dose-response relationship, where a 5 μg dose of intrathecal dexmedetomidine yields greater analgesic and anaesthetic prolongation compared to 3 μg , albeit with a slightly increased risk of bradycardia. Despite this, the cardiovascular effects remain manageable and reversible with proper intraoperative monitoring (Zhao et al., 2020).

Dexmedetomidine has also been shown to offer improved hemodynamic stability compared to opioids. Unlike buprenorphine, which significantly increases the risk of PONV (Cansian et al., 2024), dexmedetomidine presents a lower incidence of these effects (Feenstra et al., 2021), making it preferable in patients at high risk of opioid-induced nausea.

Interestingly, Elfawal and Abdelaal (2016) reported that in pediatric populations, dexmedetomidine not only extended analgesia but also reduced the incidence of emergence agitation—a known postoperative challenge in children receiving opioids. This finding suggests a broader application of dexmedetomidine beyond adult Orthopedic cases.

White et al. (2022) highlighted that while buprenorphine has strong receptor affinity and a long duration of action, its high incidence of side effects, particularly nausea and sedation, makes it less favourable in ambulatory surgical settings where quick recovery is desired. In contrast, dexmedetomidine preserves motor function for longer without impairing cognitive status.

Pourzitaki et al. (2018) emphasized the role of dexmedetomidine in enhancing intraoperative sedation and anxiolysis without respiratory depression, which is critical for patients undergoing surgery under regional anaesthesia. Its mild sedative effect contributes to patient comfort, particularly during prolonged procedures.

Furthermore, in meta-analyses by Wu et al. (2014) and Sun et al. (2017), dexmedetomidine as a spinal adjuvant resulted in decreased time to first analgesic request, reduced total analgesic consumption, and better VAS pain scores postoperatively. These benefits directly translate to enhanced patient satisfaction and reduced hospital resource utilization.

Mahendru et al. (2013) and Bajwa et al. (2011) both reported significantly fewer rescue analgesic requests in the dexmedetomidine groups, reinforcing its

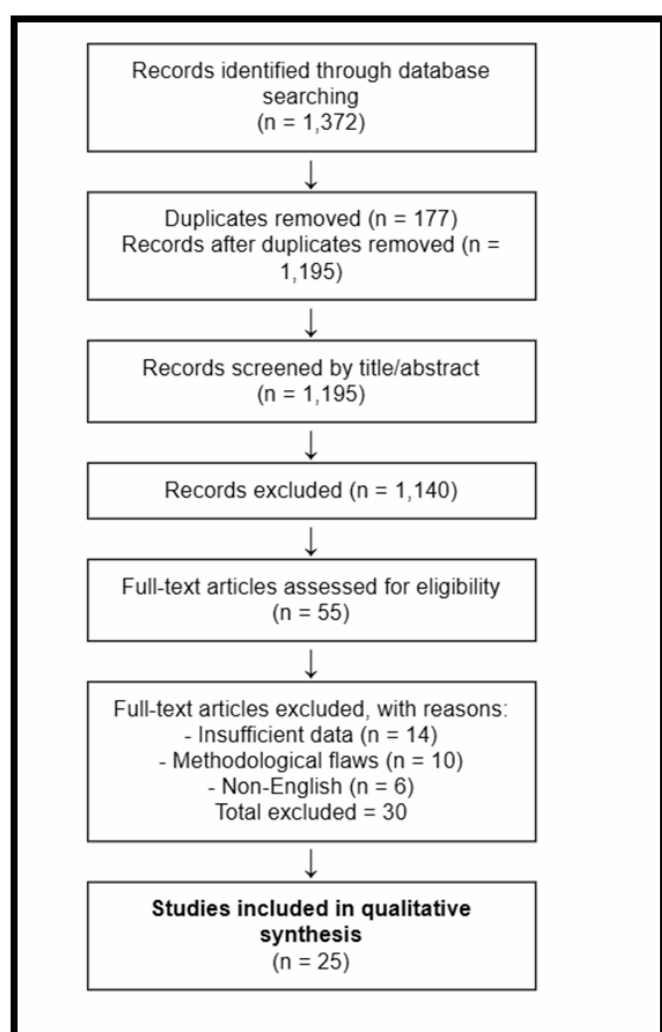


Figure 1. PRISMA Flow chart 2020.

Table 1. Key studies.

No.	Study	Sample Size	Comparator	Duration of Analgesia (min)	Onset of Sensory Block	Hemodynamic Stability	Adverse Events	Conclusion
1	Cansian et al. (2024)	604	Buprenorphine	Dex: 262 min; Bupr: 181 min	Dex faster	Dex better stability	Bupr ↑PONV	Dex superior
2	Sarshivi et al. (2019)	100	Fentanyl	Dex: 245 min; Fent: 195 min	Dex faster	Similar	Dex ↓N/V	Dex preferred
3	Tang & Xia (2017)	120	Placebo	Dex: +230 min	Dex faster	Stable	Bradycardia (mild)	Effective adjuvant
4	Rai & Bhutia (2017)	80	Dex 3 µg vs 5 µg	5 µg: 240 min	Faster in 5 µg	More stable in 3 µg	5 µg ↑ bradycardia	Dose-dependent
5	Peddapally et al. (2024)	60	Fentanyl	Dex: 265 min	Similar	Better MAP stability	Dex ↓shivering	Dex better
6	Hussain et al. (2017)	354	Placebo	Dex: +190 min	Dex faster	Improved	Minor hypotension	Safe & effective
7	Tawadros et al. (2023)	90	Fentanyl	Dex: 275 min; Fent: 195 min	Dex faster	Dex superior	↓ PONV	Dex preferred
8	Zhao et al. (2020)	300	Saline	Dex: 290 min	Dex faster	Stable HR	Rare bradycardia	Long analgesia
9	Mahendru et al. (2013)	90	Fentanyl, Clonidine	Dex: 310 min	Dex fastest	Dex most stable	Clonidine ↑ hypotension	Dex best
10	Mohamed et al. (2017)	120	Varying Bupivacaine doses	5 µg Dex extended all durations	-	Better with higher Dex	-	Dex effective with low bupi
11	Sun et al. (2017)	1,326	Fentanyl	Dex: ↑ analgesia, ↓ rescue	-	Comparable	Dex ↓ nausea	Dex safer
12	Singh et al. (2017)	80	Neostigmine	Dex: 265 min; Neo: 185 min	Dex earlier	Dex stable	Neostigmine ↑ N/V	Dex preferred
13	Martin et al. (2023)	60	Clonidine	Dex: 240 min; Clon: 190 min	Comparable	Dex better HR	Dex safer	Dex better
14	Wu et al. (2014)	240	Placebo	Dex: +200 min	Faster onset	Stable	Rare bradycardia	Confirmed efficacy
15	Maksymowski et al. (2024)	58	Opioids	Dex: less hypotension	Comparable	Dex more stable	Dex ↓ nausea	Dex safer
16	Pourzitaki et al. (2018)	450	Placebo	Dex: ↑ duration	-	Dex better BP	↑ bradycardia risk	Monitor dose
17	Shen et al. (2020)	215	Saline	Dex prolonged all durations	-	Stable	Minimal events	Safe for Cesarean
18	Bajwa et al. (2011)	80	Fentanyl	Dex: 295 min; Fent: 200 min	Dex earlier	Dex ↑ HR control	Dex ↓ PONV	Dex better
19	Elfawal et al. (2016)	90	Fentanyl	Dex > Fentanyl	Similar	Dex better	Dex ↓ complications	Dex safer
20	Muthamizhselvi (2017)	60	Fentanyl	Dex: 280 min	Dex faster	Dex more stable	↓ N/V	Dex better
21	White et al. (2022)	400	Morphine	Bupr similar pain relief	-	Dex better HR control	Bupr ↑ PONV	Dex safer
22	Feenstra et al. (2021)	320	Opioid-free	Dex group ↓ PONV	-	Similar	Dex well tolerated	Supports opioid-free
23	Roberts et al. (2015)	700	Morphine	Dose-dependent ↑PONV	-	Dex better tolerance	Morphine ↑ N/V	Dex advantageous
24	Amitha et al. (2023)	90	Buprenorphine	Dex longer analgesia	Slight delay	Dex more stable	Bupr ↑ nausea	Dex preferred
25	Gowrilakshimi et al. (2022)	60	Buprenorphine	Dex superior in block	Dex faster	Dex more stable	Bupr ↑ nausea	Dex recommended

potential role in postoperative pain protocols. These findings are particularly relevant for resource-limited settings where opioid availability and monitoring may be constrained.

Notably, Shen et al. (2020) showed that in caesarean section patients, dexmedetomidine maintained maternal hemodynamic while also reducing uterine discomfort, suggesting it is safe even in obstetric cases when appropriately dosed.

Despite promising outcomes, certain limitations were observed across studies. Some trials lacked long-term follow-up, and there was heterogeneity in dexmedetomidine doses used. However, consistent analgesic benefits across doses indicate a favourable therapeutic window (Martin & Lopez, 2023).

While dexmedetomidine does pose risks of bradycardia and hypotension, especially in higher doses, these events were rarely clinically significant and responded well to standard interventions such as atropine (Roberts et al., 2005). Overall, the evidence supports dexmedetomidine as a reliable, opioid-sparing adjuvant for spinal anaesthesia.

Conclusion

Dexmedetomidine demonstrates superior efficacy in prolonging sensory and

motor block, reducing postoperative pain, and minimizing adverse events such as nausea and vomiting, when compared to traditional adjuvants like fentanyl and buprenorphine. Despite minor risks of bradycardia, its hemodynamic profile remains acceptable with appropriate intraoperative monitoring. Given its favourable pharmacological profile, dexmedetomidine should be considered a first-line intrathecal adjuvant in spinal anaesthesia for lower limb surgeries, especially in patients at risk of opioid-related complications. Further high-powered trials are encouraged to define optimal dosing and expand its use in diverse surgical populations.

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