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Research Article

Regional Anaesthesia Techniques for Orthopaedic Surgery: A Systematic Review

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ABSTRACT
Background: Regional anaesthesia has increasingly replaced general anaesthesia as the preferred technique for orthopaedic surgical procedures due to its superior postoperative analgesia, reduced opioid consumption, and favourable safety profile. This systematic review evaluates the efficacy, safety, and clinical outcomes of various regional anaesthesia techniques in orthopaedic surgery during the period 2016–2018.
Methods: A systematic search of PubMed, Cochrane Library, MEDLINE, and EMBASE databases was conducted. A total of 65 studies meeting inclusion criteria were reviewed. Patients undergoing lower limb, upper limb, and spinal orthopaedic procedures under various regional anaesthesia modalities were included. Outcomes assessed included postoperative pain scores, opioid consumption, block duration, onset time, complications, and patient satisfaction.
Results: Among 65 included studies (n = 4,280 patients), ultrasound-guided nerve blocks demonstrated superior block success rates (94.6%) compared to landmark-based techniques (81.2%). Spinal anaesthesia remained the gold standard for lower limb surgeries with a complication rate of 3.1%. Peripheral nerve blocks showed significantly reduced opioid consumption (mean reduction 58.4%) and shorter hospital stays. Complications were predominantly minor and included transient neurological symptoms (2.3%) and hypotension (5.8%).
Conclusion: Regional anaesthesia techniques, particularly ultrasound-guided peripheral nerve blocks and neuraxial anaesthesia, offer significant advantages in orthopaedic surgery with excellent efficacy and acceptable safety profiles. Multimodal analgesia incorporating regional techniques should be considered as first-line anaesthetic management for orthopaedic procedures.

Keywords: Regional Anaesthesia, Nerve Block, Orthopaedic Surgery, Spinal Anaesthesia, Epidural Anaesthesia, Ultrasound-Guided, Postoperative Analgesia, Peripheral Nerve Block.

INTRODUCTION

Orthopaedic surgical procedures encompass a wide spectrum of interventions ranging from arthroplasty and fracture fixation to spinal surgeries and soft tissue repairs. Adequate anaesthesia and postoperative analgesia are critical determinants of surgical outcomes and patient recovery. Over the past decade, regional anaesthesia has emerged as a cornerstone in the anaesthetic management of orthopaedic patients, offering targeted pain relief with minimal systemic side effects [1].

General anaesthesia, while effective, carries risks including postoperative nausea and vomiting (PONV), respiratory depression, and prolonged sedation complications that can substantially impede early mobilisation and rehabilitation. Regional anaesthesia, encompassing neuraxial techniques (spinal and epidural) and peripheral nerve blocks, has demonstrated compelling advantages in reducing postoperative pain, opioid requirements, and associated adverse effects [2,3].

The advent of ultrasound guidance has revolutionised peripheral nerve block administration, enabling real-time visualisation of neural structures and improving block accuracy, onset time, and safety. Studies have consistently demonstrated that ultrasound-guided techniques are associated with higher block success rates, reduced local anaesthetic volumes, and fewer vascular punctures compared to traditional landmark or nerve stimulator-guided approaches [4,5].

Orthopaedic procedures of the lower extremity including total knee arthroplasty (TKA), total hip arthroplasty (THA), and femoral neck fracture repairs have particularly benefited from advances in regional anaesthesia, with femoral nerve blocks, adductor canal blocks, sciatic nerve blocks, and neuraxial techniques forming the backbone of perioperative pain management [6]. Similarly, upper extremity surgeries have increasingly utilised brachial

plexus blocks via interscalene, supraclavicular, infraclavicular, and axillary approaches [7].

Despite the growing body of literature supporting regional anaesthesia in orthopaedic surgery, there remains considerable variability in clinical practice regarding technique selection, local anaesthetic choice, adjuvant use, and continuous versus single-shot techniques. This systematic review aims to critically appraise and synthesise the available evidence on regional anaesthesia modalities for orthopaedic surgery, with a focus on studies published between 2016 and 2018, to provide an evidence-based framework for clinical decision-making.

MATERIALS AND METHODS

Study Design

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review protocol was registered prospectively.

Search Strategy

A comprehensive electronic search was performed across PubMed/MEDLINE, Cochrane Central Register of Controlled Trials (CENTRAL), EMBASE, and Google Scholar databases from January 2016 to December 2018. The following Medical Subject Headings (MeSH) terms and keywords were used in combination: "regional anaesthesia," "nerve block," "orthopaedic surgery," "spinal anaesthesia," "epidural anaesthesia," "peripheral nerve block," "femoral nerve block," "brachial plexus," "adductor canal block," "sciatic nerve block," "interscalene block," "ultrasound-guided," "postoperative analgesia," and "total knee arthroplasty."

Inclusion and Exclusion Criteria

Studies were included if they: (i) were randomised controlled trials (RCTs), prospective cohort studies, or well-designed retrospective comparative studies; (ii) enrolled adult patients (≥18 years) undergoing orthopaedic surgical procedures; (iii) evaluated one or more regional anaesthesia techniques; (iv) reported at least one primary outcome of interest; and (v) were published in peer-reviewed journals in the English language. Studies were excluded if they involved paediatric populations, were case reports or case series with fewer than 10 patients, lacked a control or comparator group, or were conference abstracts without full-text data.

Study Selection and Data Extraction

Two independent reviewers screened titles and abstracts, followed by full-text assessment of eligible studies. Disagreements were resolved by consensus or a third reviewer. Data were extracted using a standardised extraction form including: study design, patient demographics, surgical procedure, anaesthetic technique, local anaesthetic agent and dosage, adjuvants used, primary and secondary outcomes, and adverse events. The risk of bias of RCTs was assessed using the Cochrane Risk of Bias Tool (RoB 2.0).

Study Population

A total of 65 studies with a cumulative patient population of 4,280 individuals were included in this systematic review. The mean age of patients across studies ranged from 34 to 72 years. Male patients constituted 54.3% and female patients 45.7% of the study population. The duration of the study period extended from January 2016 to December 2018.

Outcome Measures

Primary outcomes included: postoperative pain scores at 2, 6, 12, and 24 hours (Visual Analogue Scale, 0–10); total opioid consumption in the first 24 hours postoperatively; and block success rate. Secondary outcomes included: time to first analgesic request, duration of sensory and motor block, intraoperative haemodynamic stability, incidence of complications (neurological, vascular, systemic toxicity), PONV rates, patient satisfaction scores, and hospital length of stay.

RESULTS

Study Selection

The initial database search yielded 834 records. After removal of duplicates (n=187), 647 titles and abstracts were screened. Following full-text assessment of 124 potentially eligible articles, 65 studies met the inclusion criteria and were included in this systematic review. The most common reasons for exclusion were: paediatric population (n=18), insufficient outcome data (n=22), case series without control group (n=14), and non-English language (n=5).

Characteristics of Included Studies

The 65 included studies comprised 42 randomised controlled trials (64.6%), 14 prospective cohort studies (21.5%), and 9 retrospective comparative studies (13.8%).

Studies were conducted predominantly in India, Europe, and North America. Sample sizes ranged from 30 to 240 patients per study.

Table 1. Distribution of Study Types and Surgical Procedures

Category	Number of Studies	Total Patients (n)	Percentage (%)
Lower Limb Surgeries	28	1,842	43.0
Upper Limb Surgeries	19	1,254	29.3
Spinal/Vertebral Surgeries	11	726	17.0
Mixed/Combined Procedures	7	458	10.7
Total	**65**	**4,280**	**100.0**

Regional Anaesthesia Techniques and Efficacy

Across all included studies, four principal categories of regional anaesthesia were identified: (1) neuraxial techniques (spinal and epidural anaesthesia), (2) ultrasound-guided peripheral nerve blocks, (3) nerve stimulator-guided peripheral nerve blocks, and (4) combined neuraxial-peripheral techniques.

Neuraxial Techniques

Spinal anaesthesia was evaluated in 22 studies and represented the most frequently utilised technique for lower limb orthopaedic procedures. Heavy bupivacaine 0.5% (doses ranging from 10–15 mg) was the most commonly used local anaesthetic. Intrathecal adjuvants included fentanyl (10–25 mcg), morphine (0.1–0.3 mg), and dexmedetomidine (5–10 mcg). The mean onset time of spinal anaesthesia was 4.2 ± 1.3 minutes, with a mean block duration of 3.8 ± 0.9 hours. Haemodynamic stability was maintained in 91.7% of patients, with hypotension (defined as >20% decrease from baseline) occurring in 8.3% of cases, effectively managed with vasopressors and fluid administration [8].

Epidural anaesthesia was utilised in 11 studies, predominantly for spinal orthopaedic procedures and as continuous postoperative analgesia following arthroplasty. Patient-controlled epidural analgesia (PCEA) with ropivacaine 0.2% and fentanyl 2 mcg/mL demonstrated superior pain control compared to intravenous PCA (mean VAS 2.1 vs 4.8 at 24 hours; $p<0.001$) [9].

Ultrasound-Guided Peripheral Nerve Blocks

Ultrasound-guided blocks were evaluated in 31 studies and showed consistently superior outcomes compared to non-ultrasound-guided approaches. The overall block success rate with ultrasound guidance was 94.6% compared to 81.2% with nerve stimulator guidance ($p<0.001$). Local anaesthetic volumes were significantly lower with ultrasound guidance (mean reduction of 27.3%), without compromising block quality [4].

For lower limb surgeries, the femoral nerve block (FNB) in combination with sciatic nerve block was evaluated in 14 studies for knee and femur procedures. The adductor canal block (ACB) emerged as a preferred alternative to FNB for TKA, as it provided equivalent analgesia with significantly preserved quadriceps motor strength (92.4% vs 34.1% preservation at 6 hours; $p<0.001$), facilitating early rehabilitation [10].

For upper limb surgeries, the interscalene brachial plexus block was most frequently employed for shoulder procedures (16 studies), with ropivacaine 0.5% (20–30 mL) being the local anaesthetic of choice. Phrenic nerve palsy occurred in 81-100% of interscalene blocks, an important consideration in patients with compromised respiratory function [7]. Supraclavicular blocks were preferred for elbow and forearm surgeries, with high success rates (96.2%) and rapid onset (mean 12.4 minutes) [11].

Effect on Postoperative Pain and Opioid Consumption

Table 2. Comparison of Postoperative Pain Scores (VAS) Across Anaesthetic Techniques

Technique	VAS at 2 h	VAS at 6 h	VAS at 12 h	VAS at 24 h
Spinal Anaesthesia	1.8 ± 0.6	2.9 ± 0.8	3.4 ± 0.9	3.9 ± 1.1
Epidural Anaesthesia	1.4 ± 0.5	2.1 ± 0.7	2.3 ± 0.6	2.8 ± 0.8
US-Guided Peripheral NB	2.1 ± 0.7	2.6 ± 0.8	3.1 ± 0.9	3.6 ± 1.0
Nerve Stimulator-Guided NB	3.2 ± 1.0	3.8 ± 1.1	4.2 ± 1.2	4.8 ± 1.3
General Anaesthesia (control)	5.4 ± 1.4	5.9 ± 1.3	5.6 ± 1.4	5.1 ± 1.5

Values expressed as Mean ± SD. NB = Nerve Block; US = Ultrasound; VAS = Visual Analogue Scale (0–10)

Regional anaesthesia techniques demonstrated statistically significant reductions in postoperative pain scores at all time points compared to general anaesthesia ($p<0.001$). Epidural anaesthesia provided the most sustained analgesia over 24 hours, particularly for major joint replacements. Ultrasound-guided peripheral nerve blocks offered superior analgesia compared to nerve stimulator-guided techniques at all time points. Total opioid consumption in the first 24 hours was reduced by a mean of 58.4% (range: 42.1%–74.8%) in regional anaesthesia groups versus general anaesthesia controls [12].

Complications and Adverse Events

Table 3. Incidence of Complications Across Regional Anaesthesia Techniques

Complication	Incidence (%)	Management
Hypotension	5.8	IV fluids, vasopressors
Transient Neurological Symptoms	2.3	Conservative, resolved in 24–72 h
PONV	8.2	Antiemetics
Urinary Retention	4.6	Catheterisation
Vascular Puncture	1.9 (US-guided: 0.7)	Compression, observation
LAST (Local Anaesthetic Systemic Toxicity)	0.3	Intralipid 20%, supportive care
Pneumothorax (interscalene)	0.8	Conservative/chest drain
Post-Dural Puncture Headache	1.4	Hydration, analgesics, blood patch
Persistent Neurological Deficit	0.1	Neurology referral, physiotherapy

PONV = Postoperative Nausea and Vomiting; LAST = Local Anaesthetic Systemic Toxicity; US = Ultrasound

Local Anaesthetic Agents and Adjuvants

Ropivacaine (0.2%–0.75%) and bupivacaine (0.25%–0.5%) were the most commonly employed local anaesthetics across included studies. Ropivacaine demonstrated a superior safety profile with lower cardiotoxicity, making it preferable for high-volume peripheral nerve blocks. Levobupivacaine was used in 8 studies and showed comparable efficacy with reduced systemic toxicity compared to racemic bupivacaine [13].

Adjuvants significantly enhanced block characteristics across studies. Dexamethasone (4–8 mg perineural) was the most studied adjuvant, consistently prolonging peripheral nerve block duration by a mean of 6.8 hours (range: 4.2–9.4 hours) without significant adverse effects [14]. Dexmedetomidine (0.5–1 mcg/kg) added to bupivacaine for spinal anaesthesia extended sensory block duration by 42.6% and provided superior postoperative analgesia. Clonidine and fentanyl were used as intrathecal adjuvants in multiple studies, with fentanyl (25 mcg) demonstrating significant improvement in block quality and perioperative analgesia [15].

Patient Satisfaction and Hospital Length of Stay

Patient satisfaction was assessed in 38 of 65 included studies using validated scales (numeric rating scales, Likert scales). Overall patient satisfaction was significantly higher in the regional anaesthesia groups compared to general anaesthesia controls (mean satisfaction score: 8.4/10 vs 6.9/10; $p<0.001$). Factors contributing to higher satisfaction included reduced pain intensity, lower PONV rates, and earlier mobilisation. Hospital length of stay was significantly reduced in regional anaesthesia groups by a mean of 1.6 days ($p<0.01$) compared to general anaesthesia, with particular benefit observed in TKA and THA patients receiving continuous peripheral nerve block catheters [16].

DISCUSSION

This systematic review of 65 studies provides comprehensive evidence supporting the superiority of regional anaesthesia over general anaesthesia for orthopaedic surgical procedures across multiple outcome domains. Our findings are concordant with, and extend, the conclusions of recent meta-analyses and systematic reviews in this field [17,18].

The most clinically significant finding of this review is the consistent reduction in postoperative opioid consumption across all regional anaesthesia modalities, with a mean reduction of 58.4% compared to general anaesthesia. This opioid-sparing effect has

profound implications for patient outcomes, as opioid-related adverse effects including respiratory depression, excessive sedation, ileus, and PONV represent major barriers to early recovery and rehabilitation following orthopaedic surgery. The Enhanced Recovery After Surgery (ERAS) protocols, which have been increasingly adopted in orthopaedic practice, explicitly incorporate regional anaesthesia as a cornerstone of multimodal analgesia [19].

Ultrasound guidance has become the standard of care for peripheral nerve block administration, as demonstrated by the significantly higher success rates (94.6% vs 81.2%) and lower complication rates compared to nerve stimulator techniques observed in this review. The ability to visualise the needle, nerve, and spread of local anaesthetic in real time has fundamentally transformed the safety and efficacy of regional anaesthesia, enabling reduced local anaesthetic volumes and more precise deposition [4,20].

The emergence of the adductor canal block as an alternative to femoral nerve block for TKA deserves particular attention. While both techniques provide equivalent postoperative analgesia, the adductor canal block's selective sensory blockade of the saphenous nerve with preservation of quadriceps motor function represents a critical advantage in facilitating early postoperative physiotherapy and reducing fall risk. Studies in this review demonstrated >90% preservation of quadriceps strength with ACB compared to <35% with FNB [10,21].

Neuraxial techniques, particularly spinal anaesthesia, continue to hold a prominent position in lower limb orthopaedic surgery due to their reliability, cost-effectiveness, and well-established safety record. The addition of intrathecal adjuvants particularly lipophilic opioids such as fentanyl and long-acting alpha-2 agonists such as dexmedetomidine has further enhanced the quality and duration of spinal anaesthesia, reducing the analgesic gap during the transition period when spinal anaesthesia resolves [15].

Local anaesthetic systemic toxicity (LAST), although rare (0.3% in this review), represents the most serious complication of peripheral nerve block techniques. The widespread adoption of ultrasound guidance, use of fractionated injection, careful aspiration before injection, and adherence to maximum safe dose guidelines have contributed to the low incidence observed in contemporary practice. The availability of intravenous intralipid emulsion as a rescue therapy for LAST has further improved management outcomes [22].

This review has several limitations. The inherent heterogeneity of included studies encompassing different surgical procedures, anaesthetic techniques, local anaesthetic agents, outcome measures, and patient populations precludes formal meta-analysis and limits the generalisability of pooled estimates. Additionally, the rapid evolution of ultrasound technology and block techniques during the study period may have introduced temporal bias. Not all studies reported all outcomes of interest, potentially introducing reporting bias.

CONCLUSION

This systematic review provides robust evidence that regional anaesthesia techniques including neuraxial anaesthesia and ultrasound-guided peripheral nerve blocks offer significant advantages over general anaesthesia for orthopaedic surgical procedures. Key benefits include superior postoperative analgesia, substantial opioid-sparing effects, reduced PONV, maintained haemodynamic stability, and shorter hospital stays. Ultrasound guidance has become the preferred approach for peripheral nerve blocks, offering higher success rates and improved safety. Multimodal analgesia incorporating regional anaesthesia should be considered the standard of care in orthopaedic surgery to optimise patient outcomes and facilitate early recovery.

Future research should focus on the optimal selection of local anaesthetic agents and adjuvants for specific procedures, the role of continuous peripheral nerve block catheters in ambulatory orthopaedic surgery, and the integration of regional anaesthesia within comprehensive ERAS pathways. Standardisation of outcome reporting in regional anaesthesia trials will facilitate future evidence synthesis and meta-analyses.

Conflict of Interest & Funding

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