

REGIONAL ANESTHESIA AND EARLY REHABILITATION IN JOINT AND SPINE SURGERY: CURRENT EVIDENCE, CLINICAL APPLICATIONS, AND FUTURE PERSPECTIVES

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ABSTRACT

Regional anesthesia is increasingly used in joint and spine surgery to improve perioperative pain control while supporting early mobilization and functional recovery. Its role has expanded within multimodal analgesia and enhanced recovery pathways, where preservation of motor function and timely rehabilitation are important clinical goals. To review current evidence on the clinical applications of regional anesthesia in joint and spine surgery and evaluate its relationship with early rehabilitation, functional recovery, safety, and emerging perioperative strategies. A comprehensive review approach was used to identify relevant literature on regional anesthesia, joint surgery, spine surgery, postoperative analgesia, early mobilization, rehabilitation, and enhanced recovery. Eligible studies were organized thematically and synthesized according to clinical applications, rehabilitation outcomes, safety considerations, and future developments. Regional anesthesia was associated with improved postoperative pain management, reduced reliance on systemic analgesia, and better integration with rehabilitation-focused care. In joint and spine surgery, procedure-specific regional techniques may support early mobilization, physiotherapy participation, and discharge readiness when excessive motor blockade is avoided. ERAS pathways further strengthen these benefits through coordinated multimodal care. Emerging approaches include ultrasound-guided techniques, motor-sparing blocks, personalized pain management, and prolonged local anesthetic delivery. Regional anesthesia is evolving toward a recovery-centered and individualized component of perioperative care, with future research needing greater emphasis on standardized functional and rehabilitation outcomes.

KEYWORDS: Regional anesthesia; Joint surgery; Spine surgery; Early rehabilitation; Functional recovery

1. INTRODUCTION

Joint and spine surgery represent a significant portion of modern orthopedic and neurosurgical practice and have a growing focus on not only successful procedures but also on quick and significant postoperative recovery. Postoperative pain, functional temporary limitation, anxiety, decreased mobility and delayed involvement in rehabilitation are some of the common manifestations of patients undergoing hip, joint and spinal procedures. Such factors may have a significant impact on recovery patterns, especially in older adults and those with underlying comorbidities. The very problem of perioperative anxiety can influence pain perception, physiological stress, and the general experience of surgery, which justifies the necessity of an integrated approach to perioperative management as opposed to a purely procedure-oriented method (Bello et al., 2025). The development of orthopedic reconstruction and regenerative approaches has further complicated the musculoskeletal care and made the anesthesia and rehabilitation planning more important (Laubach et al., 2023).

Regional anesthesia has thus taken on a greater role in perioperative care. Instead of being used as an intraoperative anesthetic method, it is currently often integrated into multimodal analgesic methods that are aimed at enhancing pain management but reducing the use of systemic opioids. Intrathecal opioids continue to play a significant role in postoperative analgesia in selected operations but their use should be balanced against side effects and the overall aim of helping patients to recover (Rawal, 2023). Specific pain management guidelines also highlight that analgesic measures need to be tailored to the operation, projected pain severity, and functional needs instead of being used across all types of operations (Dieu et al., 2021). Major joint surgery is of particular interest as to the role of regional anesthesia and analgesia has to be weighed against lower-limb function and early mobilization. Regional and general anesthesia are still contrasted in the context of geriatric hip fracture surgery due to its significance in choosing anesthetics individually in risk groups (Li et al., 2025). The technology in orthopedic surgery, such as three-dimensional presurgical planning, has also led to more customized operative plans and can also indirectly demand similarly customized anesthetic and rehabilitation plans (Portnoy et al., 2023).

In spine surgery, the use of regional anesthesia is also receiving interest as postoperative pain can be complicated, potentially restricting mobility and functional recovery. The use of regional and interfascial methods is becoming a subject

of discussion as a part of multimodal perioperative analgesia, but the practice remains reliant on the level of surgery, positioning, and neurological factors, and the nature of the procedure (Salven et al., 2023). Simultaneously, the evidence-based patient selection, technical standardization, and risk assessment have been established as the most appropriate guidelines in the lumbar facet procedure, indicating the extended significance of the evidence-based approach in the regional surgeries of the spine (Cohen et al., 2020). An early rehabilitation is one of the key goals of joint and spine surgery. Pain management might promote ambulation, physiotherapy involvement, and attainment of functional milestones, and excess motor block can disrupt the same. Even rehabilitation itself is becoming recognized as a multidimensional process of motor control, repetition, engagement, and task-specific training; the research carried out in motor rehabilitation demonstrates that interventions developed in a structured way can have an impact on the functional recovery pathways (Braun Janzen et al., 2022). In this regard, the worth of regional anesthesia must be evaluated not just by the amount of pain relief, but also by the retained mobility and rehabilitation preparedness.

Improved recovery solutions only add to this change towards integrated care. The current perioperative pathways are a combination of anesthesia, analgesia, early mobilization, rehabilitation, and discharge planning. Guided by ultrasound, regional methods have enhanced accuracy and expanded the use of targeted blocks in the postoperative care (Wen et al., 2021). Simultaneously, broad surgical innovation, such as robotic systems, is transforming the structure of operative procedures and could impact anesthetic and postoperative approaches in specialties in the future (Fairag et al., 2024). In spite of these developments, there are significant gaps of knowledge about the best choice of techniques, length of analgesia, functional outcome, safety in high-risk patients, and interprocedural consistency. The purpose of this review is thus to synthesize existing data on clinical uses of regional anesthesia in joint and spine surgery, assess its interaction with early mobilization and functional rehabilitation, and determine its role in enhanced recovery pathways, as well as existing limitations and future directions.

2. METHODOLOGY

The present study uses a comprehensive review design to synthesize the existing evidence on regional anesthesia and its interaction with early rehabilitation after joint and spine surgery. Peer-reviewed journals, clinical reviews, systematic reviews, practice guidelines, and other academic sources were searched in databases, including Google Scholar, DOAJ and ScienceDirect, to find relevant literature. The review was based on studies that covered the topics of regional anesthesia, postoperative analgesia, joint surgery, spine surgery, early mobilization, functional rehabilitation and enhanced recovery pathways but excluded the studies that were not related to perioperative anesthesia or postoperative recovery. A systematic approach to keywords was implemented involving the use of the terms combinations such as regional anesthesia, regional anaesthesia, neuraxial anesthesia, peripheral nerve block, joint surgery, hip surgery, spine surgery, early mobilization, rehabilitation, functional recovery, multimodal analgesia and enhanced recovery after surgery. The retrieved records were filtered with the relevance of the records to the review objectives and then full-text screening where necessary. Qualifying literature was then sorted under themes as perioperative recovery, major joint surgery, spine surgery, early mobilization and rehabilitation, ERAS integration, safety and patient selection and emerging trends. Results were subsequently compared to synthesize results to reveal common clinical trends, existing practices, constraints and research priorities in regional anesthesia and functional recovery after surgery. Figure 1 shows the general process of the comprehensive review of the literature, such as identifying the literature, searching databases, screening relevance, classification based on the theme, and evidence synthesis.

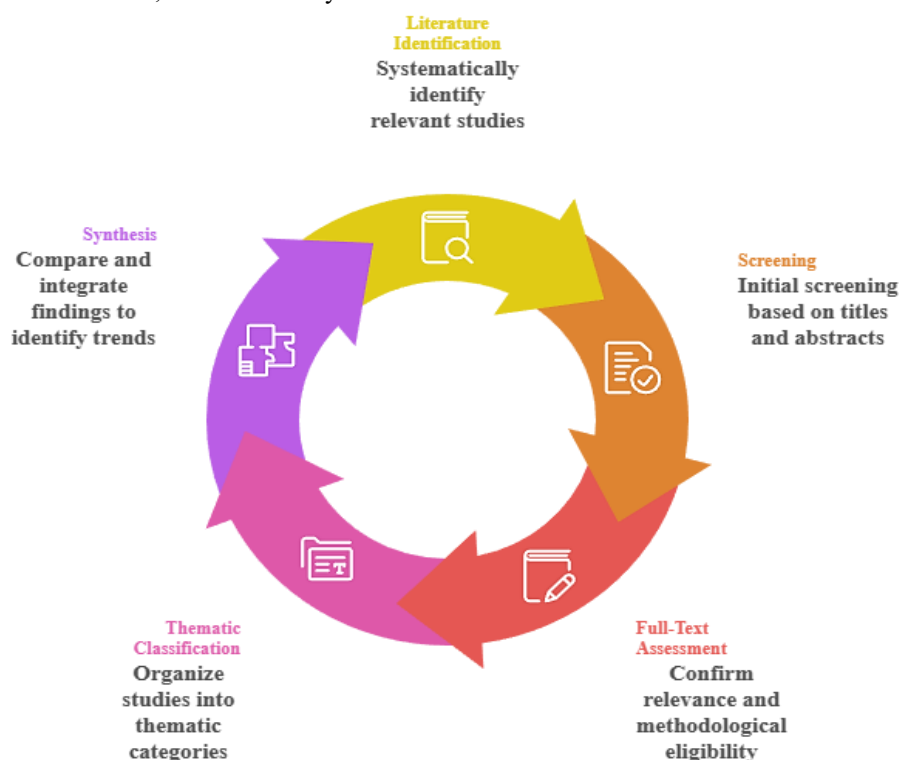


Figure 1. Overview of the Comprehensive Review Process

3. RESULTS

A literature review revealed seven significant themes on the role of regional anesthesia in joint and spine surgery. These topics encompassed its role in better perioperative recovery, clinical use in major joint and spine surgery, correlation with early rehabilitation, integration into ERAS pathways, safety and patient-selection factors, and new technologies in the field. On the whole, the evidence indicates a larger shift in the consideration of regional anesthesia no longer based on the analgesic efficacy but on the recovery-based outcomes in terms of mobility, functional rehabilitation, opioid decreases, discharge preparedness, and individualized perioperative care.

3.1 Regional Anesthesia as a Component of Enhanced Perioperative Recovery

Regional anesthesia is now a significant part of contemporary perioperative practice, and is not limited to intraoperative anesthesia, but also to assist with postoperative pain and recovery. Its combination with multimodal analgesia will be able to deliver specific pain relief and decrease the reliance on systemic analgesics. In orthopedic and spinal surgeries, there is a growing trend of achieving successful regional anesthesia balancing between pain relief and maintaining motor activity and ambulation after surgery. Its clinical utility is thus closely associated with its capability to promote comfort, activity, rehabilitation and recovery milestones. Table 1 summarizes the main clinical functions of regional anesthesia in improved perioperative recovery and its applicability to patient-centered outcomes.

Table 1. Clinical Roles of Regional Anesthesia in Enhanced Perioperative Recovery

Clinical Domain	Role of Regional Anesthesia	Relevance to Recovery	References
Postoperative analgesia	Provides targeted control of surgical pain	Supports comfort and participation in postoperative recovery	(Kamel et al., 2022; Fu et al., 2025)
Multimodal analgesia	Complements systemic and non-opioid analgesic approaches	Supports balanced perioperative pain management	(Mancel et al., 2021; Moka, 2025)
Opioid-sparing care	Reduces reliance on systemic opioid analgesia	May reduce opioid-related adverse effects	(Kamel et al., 2022; Mancel et al., 2021)
Functional recovery	Links pain control with mobility and recovery objectives	Broadens assessment beyond technical block success	(Johnston & Turbitt, 2021)
ERAS integration	Functions within coordinated perioperative pathways	Supports multimodal and recovery-oriented management	(Salamanna et al., 2022; Mancel et al., 2021)
Individualized management	Allows procedure- and patient-specific technique selection	Aligns analgesia with clinical and functional requirements	(Fu et al., 2025; Moka, 2025)

3.2 Regional Anesthesia in Hip and Major Joint Surgery

Regional anesthesia has already found a presence in the significant orthopedic surgeries, mainly the hip surgery and joint arthroplasty, where perioperative pain management needs to be weighed against early functional recovery. The strategies that are available are neuraxial anesthesia, peripheral nerve block, and procedure-specific regional that can be chosen based on the needs of surgery and patient features (Kamel et al., 2022; Evangelista et al., 2025). The comorbidities, the risk of perioperative, and the postoperative needs must also be considered to select anesthetic in geriatric hip fracture surgery (Li et al., 2025). The modern outpatient arthroplasty pathways are more inclined towards anesthesia and analgesic approaches that can be used in conjunction with early mobilization and early discharge (Osman et al., 2023). Similar to fast-track total hip arthroplasty is the combination of pain management and early rehabilitation and functional recovery (Di Martino et al., 2023). Such practices are indicative of the more extensive integration of regional anesthesia into the improved recovery pathways of orthopedic surgery (Salamanna et al., 2022).

Figure 2 shows the route by which regional anesthesia can help in the early recovery following hip and major joint surgery.

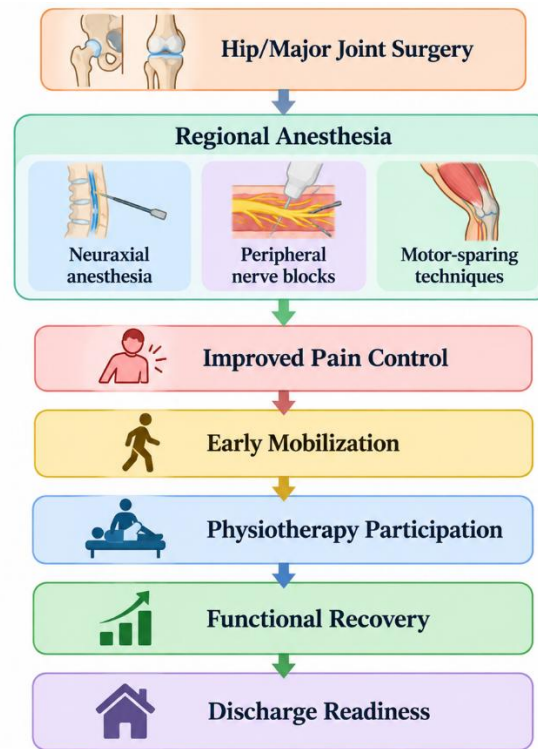


Figure 2. Regional Anesthesia and Joint Recovery

Regional anesthesia aids recovery after surgery by offering good pain management with maintenance of mobility. Neuraxial, peripheral nerve, and motor-sparing methods can support the early mobilization guidelines, enhance involvement in physiotherapy, functional recovery, and timely discharge post-major joint surgery.

3.3 Regional Anesthesia and Multimodal Analgesia in Spine Surgery

Perioperative approaches to the chosen spine surgeries are becoming more and more regional. It can be applied in neuraxial anesthesia as part of proper lumbar surgeries, regional and interfascial to achieve postoperative analgesia. They have become relevant in combination with the multimodal pain treatment and minimally invasive spine surgery. The choice of techniques varies depending on the level of surgery, length, positioning, neuro-logical and post-surgery recovery needs. Systemic analgesia can be supplemented with regional interventions, which will decrease the overall burden of postoperative pain. Their application is still procedure specific and necessitates inter-surgical, inter-anesthetic, and inter-rehabilitation. Table 2 illustrates major regional and multimodal analgesics strategies that have been outlined to be used in spine surgery.

Table 2. Regional Anesthesia and Analgesic Strategies in Spine Surgery

Approach	Clinical Application	Potential Recovery Role	Important Consideration	References
Neuraxial/regional anesthesia	Selected lumbar spine procedures	Provides an alternative anesthetic and analgesic strategy	Careful patient and procedure selection	(Lee et al., 2021; Garg et al., 2022)
Erector spinae plane block	Perioperative analgesia for spinal procedures	Contributes to multimodal postoperative pain control	Variability in technique and application	(Yang et al., 2024)
Multimodal analgesia	Broad range of spine procedures	Addresses postoperative pain through complementary interventions	Requires procedure-specific combinations	(Bullock et al., 2023; Yu et al., 2025)
Regional techniques within ERAS	Enhanced recovery spine pathways	Supports recovery-oriented postoperative management	Must be integrated with other ERAS components	(Licina et al., 2021)
Minimally invasive pathways	Minimally invasive spinal procedures	Aligns reduced surgical invasiveness with	Anesthetic requirements vary by procedure	(Drossopoulos et al., 2024)

		accelerated recovery		
Endoscopic spine procedures	Selected minimally invasive operations	Supports evolving recovery-oriented pathways	Careful patient and technique selection	(Kim et al., 2020; Pholprajug et al., 2023)

3.4 Regional Anesthesia, Early Mobilization, and Functional Rehabilitation

One of the key aspects of recovery after joint and spine surgery is early rehabilitation, as the pain after the operation may disrupt ambulation, physiotherapy and exercise, as well as functional milestones. FTPs of fast-track total hip arthroplasty focus on integrating pain management and early rehabilitation instead of addressing these aspects separately (Di Martino et al., 2023). Others follow the same principles and orthopedic ERAS programs, in which analgesia and mobilization are combined into holistic recovery pathways (Salamanna et al., 2022). Regional anesthesia might thus be used to facilitate rehabilitation in case of sufficient analgesia with minimal unjustifiable motor impairment (Mancel et al., 2021; Sutari et al., 2026). It is also crucial in this balance in the case of outpatient arthroplasty, where mobility and readiness to discharge are the main clinical goals (Osman et al., 2023). Spine ERAS pathways are also an integration of pain management and early activity and postoperative recovery objectives (Licina et al., 2021).

Figure 3 depicts the significant recovery areas related to regional anesthesia after joint and spine surgery.

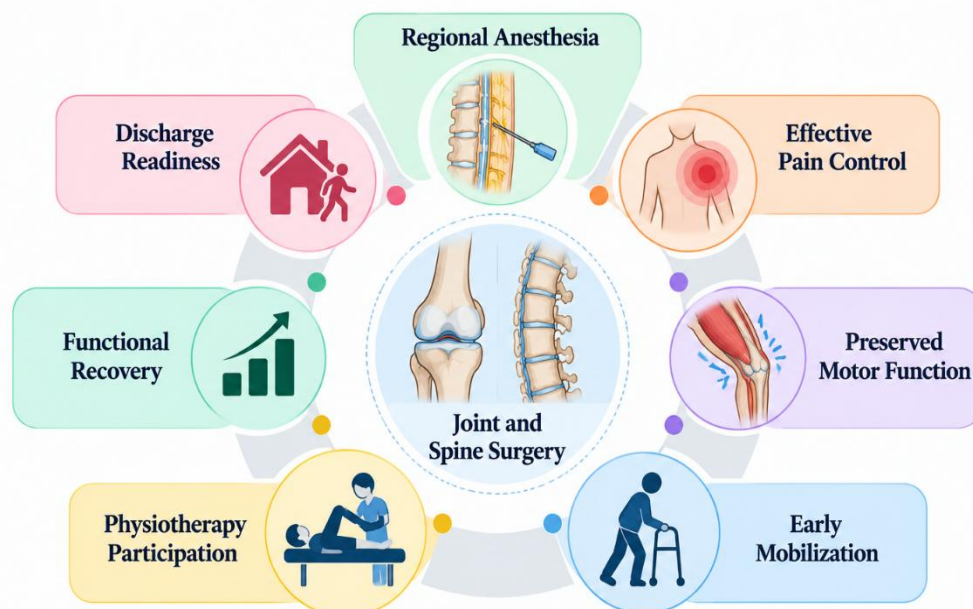


Figure 3. Regional Anesthesia and Functional Rehabilitation

The figure underscores the association between regional anesthesia and recovery-related outcomes such as effective pain management, motor functioning, early mobility, involvement in physiotherapy, functional enhancement, and discharge preparedness after joint and spine surgery.

3.5 Integration of Regional Anesthesia into ERAS and Fast-Track Surgical Pathways

Regional anesthesia is increasingly operating in multidisciplinary pathways of enhanced recovery, as opposed to being a single analgesic intervention. These routes are a combination of preoperative preparation, optimized anesthesia, multimodal pain control, early mobilization, rehabilitation and discharge planning. The role played by regional anesthesia will thus rely on its ability to facilitate other aspects of recovery. Effective analgesia in joint surgery could enable involvement in fast-track rehabilitation, and is complementary in spine surgery to the strategies aimed at minimizing postoperative impediments to activity. Anesthesiologists, surgeons, nurses, physiotherapists, and acute pain teams should coordinate to successfully integrate. Table 3 summarizes the main contributions of the concept of regional anesthesia to the ERAS and fast-track pathways.

Table 3. Regional Anesthesia Within ERAS and Fast-Track Surgical Pathways

ERAS Component	Contribution of Regional Anesthesia	Recovery Relevance	References
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Multimodal analgesia	Adds targeted regional pain control to broader analgesic strategies	Reduces reliance on a single analgesic modality	(Mancel et al., 2021; Salamanna et al., 2022)
Early mobilization	Controls movement-related postoperative pain	Supports rehabilitation and functional milestones	(Di Martino et al., 2023)
Joint fast-track pathways	Supports perioperative pain management in arthroplasty	Facilitates recovery-oriented care and discharge planning	(Osman et al., 2023; Di Martino et al., 2023)
Spine ERAS pathways	Complements multimodal postoperative analgesia	Supports coordinated postoperative recovery	(Licina et al., 2021)
Multidisciplinary care	Links anesthetic management with surgical and rehabilitation objectives	Promotes continuity across perioperative phases	(Mancel et al., 2021; Salamanna et al., 2022)

3.6 Safety, Clinical Limitations, and Patient Selection

Regional anesthesia should be used and safety, technical feasibility, patient characteristics and surgical requirements should be put in close consideration. The block must not be considered successful only in terms of its completion but functional recovery, patient experience, and avoiding adverse outcomes (Johnston & Turbitt, 2021). When it comes to orthopedic surgery, the choice of techniques relies on the anatomical targets, anticipated sensory and motor outcomes, and the specific needs of the procedure (Kamel et al., 2022). Spine surgery presents more factors regarding positioning, time of procedure, neurological evaluation, and patient aptitude (Garg et al., 2022). Specifically, antithrombotic or thrombolytic therapy is essential since the use of medication type and time may determine whether or not certain neuraxial or regional procedures can be safely conducted (Kopp et al., 2025). Modern practice is thus more conducive to the personalized planning of anesthesia instead of the use of a common regional method (Fu et al., 2025).

3.7 Emerging Trends and Future Perspectives

New advances in regional anesthesia are more about accuracy, customization, longer analgesia, motor neuromuscular sparing and incorporation of future developments in surgical technology. The image-guided methods can be improved to support regional methods, and newer methods of drug-delivery are under development to prolong the local anesthetic effects. Individualized pain management strategies, as well as cryoneurolysis, are also an emerging field of concern. In the future, AI can also play a role in perioperative decision-making, risk stratification, and planning of analgesia based on the patient. Meanwhile, endoscopic and minimally invasive surgery of the spine is also opening up new prospects of recovery-oriented anesthesia. Table 4 summarizes the key developing trends and the possible consequences they have on the field of regional anesthesia and rehabilitation.

Table 4. Emerging Trends and Future Directions in Regional Anesthesia and Rehabilitation

Emerging Trend	Potential Application	Future Relevance	References
Advanced ultrasound-guided techniques	More precise anatomical targeting for regional blocks	May improve accuracy and procedural planning	(Balan et al., 2021)
Motor-sparing regional approaches	Joint surgery and early rehabilitation	May balance analgesia with preservation of functional mobility	(Kamel et al., 2022; Evangelista et al., 2025)
Hydrogel-based local anesthetic delivery	Prolonged and targeted local analgesia	May extend duration of pain control	(Jeong et al., 2025)
Percutaneous cryoneurolysis	Extended peripheral analgesia	Potential adjunct to conventional regional techniques	(Finneran & Ilfeld, 2021)
Personalized pain management	Individualized perioperative analgesic pathways	Tailors' management to patient-specific recovery needs	(Xu et al., 2025)
Artificial intelligence	Prediction and decision support in orthopedic care	May assist individualized perioperative planning	(Andriollo et al., 2024; Song et al., 2025)
Minimally invasive spine surgery	Recovery-focused spine procedures	May support accelerated postoperative pathways	(Drossopoulos et al., 2024; Kim et al., 2020)

Endoscopic spine surgery	Less-invasive spinal procedures	Expands possibilities for rapid recovery pathways	(Pholprajug et al., 2023)
Transitional pain services	Management extending beyond immediate postoperative pain	Addresses persistent postsurgical pain and longer-term recovery	(Moka et al., 2025)

4. DISCUSSION

The results of this extensive review suggest that regional anesthesia is more and more becoming a recovery-based approach as opposed to only an intraoperative anesthesia or a postoperative analgesic technique. In joint and spine surgery, there is evidence that the clinically most significant advantage of regional procedures is that they allow an effective analgesia without compromising mobility or rehabilitation. This is more so since not only the intensity of the postoperative pain determines the extent of recovery but also how the patient is able to ambulate, engage in physiotherapy, and meet functional milestones. The analysed evidence thus informs a wider definition of the success of regional anesthesia, which includes functional recovery, opioid-sparing effects, participation in rehabilitation process, and readiness to discharge.

These results are in line with the past studies that have highlighted the importance of regional anesthesia in relation to postoperative functional outcome. The same was emphasized by Sutari et al. (2026), who pointed out that the usefulness of regional anesthesia must be evaluated against functional recovery and not pain scores. This analogy confirms the current view that motor preservation and early mobilization can be considered the main factors in clinical utility of regional methods, particularly in orthopedic fast-track. The outcomes are also consistent in the field of spine surgery, where Yu et al. (2025) demonstrated that the postoperative pain management is a multimodal process that needs to integrate the various approaches to analgesic treatment based on the surgical and patient-specific factors. The current review advances this view by highlighting the need to directly relate these analgesic interventions with rehabilitation objectives. The increased use of ultrasound-guided and interfascial methods also indicates the shift towards more specific and targeted regional anesthesia. Wen et al. (2021) revealed the clinical potential of ultrasound-guided block methods in the enhancement of postoperative pain, and Yang et al. (2024) reported the growing scope of application and analgesic processes of the erector spinae plane block. These studies reinforce the current discovery that newer regional techniques may expand the choices that can be made in regards to spine and orthopedic surgeries. Nevertheless, the clinical utility of these methods is determined by the proper choice of procedures, the level of technical skills, and their suitability with functional recovery. The other crucial realization is the rise of the focus on individualized pain management. Xu et al. (2025) highlighted personalized pain evaluation and multimodal treatment as significant aspects of the optimization of postoperative recovery. This is in line with the current review, which implies that regional anesthesia ought to be chosen based on patient factors, surgery, projected pain burden, mobility needs and rehabilitation goals other than being used based on a standardized approach. This individualized methodology can assist in the achievement of harmony between analgesic efficacy and maintenance of motor activity and patient safety. These findings have clinical implications to the anesthesiologists, orthopedic/spine surgeons, physiotherapists, nursing teams, and acute pain services. Regional anesthesia is preferable to be integrated into integrated perioperative processes where the anesthetic planning is synchronized with the mobilization and rehabilitation goals. This type of integration can be especially useful in outpatient arthroplasty, rapid-track joint surgery, or when performing a minimally invasive spinal surgery where a rapid functional recovery is one of the key goals.

There are a number of limitations to be considered. The literature available is heterogeneous with regards to the surgical procedures, regional methods, the definition of the outcomes, and follow-up. The use of pain scores and opioid use is often highlighted in the literature, but less commonly consider mobility, physiotherapy attendance, and longer-term functional recovery. The issue of variation in patient population and perioperative guidelines also preclude direct comparison of the studies. Future studies must focus on standardized functional outcomes, procedure specific comparative studies and increased follow-up. More emphasis should be put on motor-sparing methods, individualized block selection, time-consuming delivery of local anesthesia, and technology-directed decision-making as well. Not only which regional technique yields the best analgesia, but also what strategy will best support safe mobilization, rehabilitation, and long-lasting functional recovery should be determined in future studies.

5. CONCLUSION

Regional anesthesia was introduced as a significant part of contemporary perioperative education in both joint and spine surgery and its clinical application is not limited to pain relief but helps to achieve early mobilization, rehabilitation, and functional recovery. The reviewed evidence indicates that neuraxial, peripheral nerve, interfascial, and motor-sparing methods may serve as an addition to multimodal analgesia and minimize the reliance on systemic opioids. Their best attribute seems to be in the attainment of effective pain management without necessarily destabilizing motor activity, especially in fast-track and enhanced recovery pathways where ambulation and physiotherapy early are the main goals. Regional anesthesia may be used to assist recovery following arthroplasty and hip surgery in joint surgery, but is becoming more commonly combined with multimodal and minimally invasive techniques in spine surgery. Nevertheless, the choice of the technique must be personalized based on the needs of the surgery, the peculiarities of the patient, comorbidity, anticoagulation, and rehabilitation objectives. Existing evidence is constrained by procedural heterogeneity, regional methods, outcome and follow-up times, and most studies focus more on pain outcomes than functional recovery. The use of standardized measures of mobility, rehabilitation participation, discharge preparation, and long-term functioning should also be a priority in future research. The role of regional anesthesia in the recovery-centered surgical treatment can be

enhanced by further contributions of ultrasound guidance, motor-sparing, long-term delivery of local anesthesia, custom-designed pain management, and technology-aided planning.

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