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Regional Anesthesia and Postoperative Functional Recovery: A Narrative Review of Clinical Outcomes

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ABSTRACT

Background: *Postoperative pain can interfere with early mobilization and delay participation in structured rehabilitation after major surgery. Systemic opioid analgesia, the historical standard, carries adverse effects such as sedation, respiratory depression, postoperative nausea and vomiting, and opioid-induced ileus, which may directly delay functional recovery. Regional anesthesia techniques, including peripheral nerve blocks, neuraxial blockade, and ultrasound-guided interfascial plane blocks, offer opioid-sparing alternatives while preserving motor function essential for rehabilitation.*

Objective: *To evaluate the influence of regional anesthesia on postoperative functional recovery and early rehabilitation outcomes compared with conventional systemic analgesia. This review contributes a cross-specialty synthesis that frames analgesic technique selection as a rehabilitation decision, an orientation not emphasized in prior specialty-specific reviews.*

Methods: *A structured search of PubMed, CINAHL, the Cochrane Library, and Embase identified English-language randomized controlled trials, prospective cohort studies, and systematic reviews published between January 2015 and December 2024. Seminal pre-2015 references identified through hand-searching of included articles were retained where they represented foundational evidence. Studies enrolled adult surgical patients and reported at least one functional outcome, including pain scores, opioid consumption, time to ambulation, physical therapy participation, or hospital length of stay (LOS).*

Results: *Across orthopedic, abdominal, and thoracic surgical populations, regional anesthesia consistently provided superior analgesia and reduced opioid requirements versus systemic regimens. Quadriceps-sparing peripheral nerve blocks accelerated rehabilitation milestones in arthroplasty, while epidural and interfascial plane blocks reduced ileus and enhanced pulmonary recovery in abdominal and thoracic procedures. When integrated within Enhanced Recovery After Surgery (ERAS) protocols, regional techniques were associated with substantial reductions in LOS.*

Conclusion: *Regional anesthesia is a cornerstone of evidence-based perioperative analgesia and is associated with improved functional recovery. Broader integration within multimodal care pathways should be prioritized, with future research focused on standardized outcome measures and expanded access in community practice.*

Keywords: *regional anesthesia; peripheral nerve block; epidural analgesia; postoperative rehabilitation; functional recovery; opioid-sparing; multimodal analgesia; Enhanced Recovery After Surgery.*

Introduction

Postoperative pain affects more than 80% of surgical patients and remains one of their most prominent preoperative concerns [1]. Inadequately controlled acute pain activates the hypothalamic-pituitary-adrenal axis, impairs pulmonary mechanics, and increases the risk of pneumonia, venous thromboembolism, and wound complications. Severe uncontrolled acute pain also predicts transition to chronic postsurgical pain, which affects an estimated 10-50% of patients depending on procedure type [1,2]. These findings establish analgesia as a determinant of surgical outcomes rather than a measure of patient comfort alone. Prolonged hospitalization, higher readmission rates, and opioid dependence are linked to clinical and economic burden, underscoring the importance of effective perioperative pain management.

For decades, systemic opioids served as the cornerstone of postoperative analgesia, yet their adverse effect profile directly undermines rehabilitation. Sedation, respiratory depression, postoperative nausea and vomiting (PONV), urinary retention, opioid-induced ileus, and opioid-induced hyperalgesia each impair early mobilization, a central component of recovery pathways [3]. The opioid epidemic has intensified these concerns, as a substantial proportion of patients prescribed opioids after surgery progress to long-term opioid use disorder [3,4]. Clinical and public health pressures have together driven a shift toward opioid-sparing, multimodal strategies, now formalized within Enhanced Recovery After Surgery (ERAS) protocols across multiple surgical specialties [5]. Regional anesthesia has assumed a primary analgesic role within these frameworks, delivering targeted relief with safety profiles that align with early ambulation and discharge objectives.

Regional anesthesia interrupts nociceptive signaling at the peripheral nerve, plexus, neuraxial space, or interfascial compartment. Epidural analgesia provides continuous segmental blockade and remains the analgesic benchmark for open thoracic and abdominal surgery. Peripheral nerve blocks (PNBs), delivered by single injection or indwelling catheter, can yield somatic analgesia with minimal systemic effects. Ultrasound-guided interfascial plane blocks, including the transversus abdominis plane (TAP), erector spinae plane (ESP), quadratus lumborum (QL), and pectoralis (PECS) blocks, have expanded the range of regional anesthesia techniques by targeting nerve branches within defined fascial compartments, with growing evidence of broad clinical applicability.6 These techniques are technically accessible, associated with lower neuraxial risk, and are increasingly relevant to contemporary surgical populations.

Despite these advances, the effect of regional anesthesia on postoperative functional recovery remains heterogeneous across surgical populations, techniques, and outcome measures. Prior systematic reviews have addressed specific surgical specialties or specific block techniques, but no recent synthesis has integrated findings across the major surgical domains with an explicit rehabilitation orientation. This review aims to fill that gap by examining how regional anesthesia influences postoperative functional recovery compared with traditional analgesic approaches across orthopedic, abdominal, and thoracic surgery, and by identifying priorities for clinical practice and future research.

Methods

Study Design

A narrative review design was used to accommodate the various surgical specialties, regional anesthesia techniques, and functional outcome measures represented in the literature. This approach permits synthesis across randomized controlled trials (RCTs), prospective cohort studies, and systematic reviews without the strict constraints of meta-analysis. Quality appraisal informed the interpretation of findings rather than serving as a basis for exclusion.

Search Strategy

A structured search was conducted in PubMed/MEDLINE, CINAHL, the Cochrane Library, and Embase for English-language literature published between January 2015 and December 2024. Three conceptual domains were combined using Boolean operators: (1) regional anesthesia terms ("regional anesthesia," "peripheral nerve block," "epidural analgesia," "neuraxial block," "erector spinae plane block," "transversus abdominis plane block," "adductor canal block"); (2) surgical context terms ("postoperative," "perioperative," "total knee arthroplasty," "total hip arthroplasty," "colorectal surgery," "thoracic surgery"); and (3) outcome terms ("functional recovery," "rehabilitation," "ambulation," "length of stay," "opioid consumption," "pain scores"). Reference lists of included articles were hand-searched to identify additional relevant citations. Seminal pre-2015 references were retained through hand-searching when they represented foundational evidence for a technique or outcome not adequately covered by post-2015 sources.

Eligibility Criteria

Studies were eligible if they enrolled adults aged 18 years or older undergoing elective or semi-elective surgery, compared at least one regional anesthesia technique with a systemic or conventional analgesic control, and reported one or more postoperative functional outcomes. Eligible designs included RCTs, prospective cohort studies, and systematic reviews or meta-analyses. Exclusion criteria comprised pediatric-only studies, intraoperative-only outcomes, non-English publications, and case series with fewer than 20 participants.

Study Selection and Data Extraction

Two reviewers independently screened titles and abstracts against predefined eligibility criteria. Full-text reviews of potentially eligible articles were conducted independently by both reviewers. Discrepancies at either stage were resolved by discussion with a third author. The search yielded 289 citations after deduplication. Title-and-abstract screening excluded 215 citations, leaving 74 articles for full-text review. Of these, 52 were excluded (reasons: no functional outcome reported, n = 21; ineligible comparator, n = 14; non-English full text, n = 8; duplicate population or overlapping cohort, n = 6; case series below participant threshold, n = 3). The final synthesis included 22 studies. Data extraction was performed independently by two reviewers using a structured form that cap-

tured the study design, population, regional technique, comparator, outcome definitions, and key findings.

Quality Appraisal and Synthesis

Methodological quality was assessed using the Joanna Briggs Institute (JBI) critical appraisal tools corresponding to each study design. Findings were organized thematically by surgical specialty and primary outcome domain, with emphasis on the consistency of effect direction, the magnitude of benefit when reported, and areas of ongoing controversy. Quantitative pooling was not attempted because outcome definitions, particularly for physical therapy participation, time to ambulation, and discharge readiness, varied across studies.

Results

Overview

The search yielded 289 citations after deduplication. After title and abstract screening, 74 full-text articles were assessed for eligibility, and 22 met inclusion criteria: 11 RCTs, 5 prospective cohort studies, and 6 systematic reviews or meta-analyses. Surgical populations spanned orthopedic (n = 8), abdominal (n = 7), thoracic (n = 4), and mixed procedures (n = 3). Most RCTs demonstrated low-to-moderate risk of bias on JBI appraisal, while cohort studies carried a moderate confounding risk, a consideration reflected in the synthesis. Key findings are synthesized within each results subsection by surgical specialty.

Orthopedic Surgery: Motor-Sparing Blocks Drive Functional Gains

The orthopedic literature, particularly in total knee arthroplasty (TKA) and total hip arthroplasty (THA), provides the strongest evidence for the functional benefits of regional anesthesia. One central principle is that technique selection represents a rehabilitation decision rather than merely an anesthetic one. In TKA, quadriceps integrity determines a patient's capacity for weight-bearing, straight-leg raise, and stair climbing during the first 24 to 48 hours after surgery. Shah and Jain reported in a randomized controlled trial that adductor canal block (ACB) recipients achieved straight-leg raise earlier, attained greater active knee flexion at 24 hours, and more consistently completed day-one physical therapy milestones than femoral nerve block (FNB) recipients [7]. The advantage reflects the underlying anatomy, as targeting the saphenous nerve within the adductor canal preserves quadriceps motor strength while providing comparable somatic analgesia [7]. Broader evidence supports peripheral nerve blocks in improving postoperative analgesia and facilitating early mobilization, reinforcing the value of coordination between anesthesiology and physical therapy services in arthroplasty programs [8].

In THA, the benefits of regional anesthesia extend beyond analgesic quality to broader perioperative outcomes. Memtsoudis et al. analyzed a large national cohort of arthroplasty patients and demonstrated that multimodal analgesia strategies incorporating regional techniques were associated with reduced opioid use, fewer complications, and shorter length of stay (LOS) [9]. Continuous peripheral nerve block techniques may provide sustained analgesia beyond the duration of single-injection blocks, a property particularly relevant during later phases of postoperative rehabilitation when physical therapy intensity escalates. Continuous peripheral nerve blockade has been associated with earlier mobilization compared with systemic opioid-based analgesia, although the magnitude of this effect varies across studies and surgical populations [10]. Taken together, these findings support regional and multimodal strategies that align analgesic coverage with the evolving demands of postoperative rehabilitation. Overall, orthopedic evidence consistently supports motor-sparing regional techniques to enhance early functional recovery and participation in rehabilitation.

Abdominal Surgery: Epidural and Interfascial Plane Blocks

In open abdominal surgery, thoracic epidural analgesia (TEA) remains the analgesic benchmark, with functional benefits mediated by several complementary mechanisms. Somatic and visceral analgesia enable deep breathing and upright positioning, attenuation of the neuroendocrine stress response reduces catabolic muscle loss, and sympathetic blockade of gastrointestinal efferents accelerates return of bowel function, which is a prerequisite for oral nutrition and discharge. Pöpping et al. confirmed in a large meta-analysis that epidural analgesia reduced postoperative morbidity, including gastrointestinal complications such as ileus, compared with systemic opioids [11]. The clinical significance extends beyond symptomatic relief, as earlier bowel recovery enables adherence to ERAS nutritional protocols that support muscle protein synthesis and physical therapy engagement. Gustafsson et al., in updated ERAS Society guidelines, reported that colorectal programs integrating epidural analgesia and regional techniques within comprehensive pathways achieved substantial reductions in LOS and complications [12]. The multidimensional physiological effects of TEA position it uniquely for open procedures, where visceral, somatic, and autonomic pain require concurrent management.

With the predominance of laparoscopic and robotic approaches, the relative advantages of TEA have narrowed, and interfascial plane blocks have become increasingly relevant. Pędziwiatr et al., in a prospective cohort of laparoscopic colorectal patients, reported that ERAS protocols, which, in their institution, incorporated TAP blocks as a standard analgesic element, were associated with shorter LOS and fewer postoperative complications when implemented with high adherence [13]. The functional advantage in this context arises not from greater analgesic depth, as TAP blocks lack visceral coverage, but from the reduction of opioid-related side effects that would otherwise delay mobilization. Systematic review evidence supports the role of TAP blocks in reducing postoperative opioid consumption and PONV in abdominal surgery, although effect sizes vary with surgical approach and local anesthetic regimen [14]. In minimally invasive surgery, where visceral pain contribution is attenuated, the opioid-sparing property of interfascial blocks may matter more than analgesic depth, which is an insight that should guide technique selection toward the least invasive modality sufficient for the anticipated pain distribution.

The quadratus lumborum (QL) block extends this logic further,

providing broader dermatomal coverage by allowing local anesthetic to spread into the thoracolumbar paravertebral space [15]. Blanco et al. confirmed in an RCT that QL blocks delivered expanded coverage without increased adverse events or technical complexity, making the technique particularly suitable for upper abdominal and flank procedures where TAP blocks yield incomplete analgesia [15]. Technique selection may be tailored to incision location and pain characteristics by using TAP block for lower abdominal laparoscopic procedures, QL block for broader upper abdominal coverage, and TEA for open surgery. This level of individualization is unattainable with systemic opioid regimens, and its rehabilitation implications are substantial because matching block coverage to procedural pain distribution maximizes functional analgesia during the early postoperative period when physical therapy engagement is most consequential. Across abdominal procedures, the benefits of regional anesthesia are primarily mediated through opioid-sparing effects and improved physiological recovery.

Thoracic Surgery: Analgesia as Pulmonary Protection

Thoracic surgery, including video-assisted thoracoscopic surgery (VATS) and open thoracotomy, produces among the most severe postoperative pain encountered in clinical practice. Rib retraction, intercostal nerve trauma, chest tube placement, and pleural irritation generate a pain syndrome that reduces tidal volume, suppresses cough, and predisposes to atelectasis, mucus retention, and pneumonia. Effective analgesia in this population is therefore not merely rehabilitative but protective of pulmonary function. Thoracic paravertebral block has been described as an effective analgesic option for thoracic surgery, with a favorable side-effect profile relative to epidural techniques, although much of the evidence derives from smaller studies and observational data [16]. The thoracic literature illustrates that regional anesthesia translates pain control into functional recovery because preserved respiratory mechanics enable ambulation, inspiratory muscle training, and earlier discharge planning compared with opioid-heavy regimens.

For VATS, the ESP block has emerged as a technically accessible alternative to TEA. Performed by depositing local anesthetic deep to the erector spinae muscle group under ultrasound guidance, the ESP block spreads into the paravertebral space, covering multiple thoracic nerve roots [6]. Chin and El-Boghdadly reviewed the mechanistic and clinical evidence, concluding that bilateral ESP blocks provided comparable analgesia to TEA for VATS procedures in 24-hour pain scores and opioid consumption, with equivalent time to chest tube removal and discharge readiness [6]. The safety profile represents a substantive practical advantage, as feasibility in anticoagulated patients and the absence of epidural hematoma risk address a critical limitation of neuraxial approaches in this population. Forero et al. originally described the ESP block and reported its successful application in thoracic neuropathic and postoperative pain, establishing the foundation for subsequent clinical adoption [17]. Clinical effectiveness, technical accessibility, and an improved safety margin together position the ESP block as an important technique for extending thoracic analgesia to patients previously excluded from neuraxial approaches. In thoracic surgery, regional anesthesia improves functional recovery largely by preserving pulmonary mechanics and respiratory function.

Multimodal Analgesia and ERAS Integration

Across all surgical specialties, the most consistent functional gains were observed when regional anesthesia was embedded within comprehensive ERAS protocols rather than used in isolation. ERAS pathways align regional anesthesia with scheduled non-opioid analgesics (acetaminophen, nonsteroidal anti-inflammatory drugs, and gabapentinoids), goal-directed fluid management, early oral nutrition, and structured mobilization, creating a synergistic framework [5,12]. Gustafsson et al. reported that ERAS protocols incorporating regional anesthesia were associated with substantial reductions in LOS and complication rates across colorectal, urologic, gynecologic, and orthopedic populations, exceeding effects observed with either regional anesthesia or isolated ERAS components alone [12]. The implication for program design is substantial, as institutional investment in regional anesthesia is most effective when accompanied by full ERAS implementation.

Another relationship concern is patient engagement in rehabilitation. Patients receiving effective regional anesthesia within ERAS tend to be more alert, less nauseated, able to tolerate oral intake earlier, and more able to engage with physical therapy during the early postoperative period. Pędziwiatr et al. found that ERAS pathways were associated with improved patient experience and engagement with postoperative recovery compared with conventional care [18]. Future perioperative programs should therefore incorporate patient-reported outcome instruments that capture this experiential dimension alongside objective functional milestones.

Discussion

The evidence synthesized in this review supports that regional anesthesia improves postoperative functional recovery through mechanisms that extend well beyond pain relief. By reducing opioid requirements, regional techniques mitigate sedation, ileus, and respiratory depression, removing key barriers to rehabilitation engagement and creating a cascade of physiological conditions that support recovery. This mechanistic pathway supports a biologically plausible relationship between regional anesthesia and functional recovery, although causality cannot be definitively established across all study designs included here. The functional advantage of ACB in TKA, the pulmonary benefits of TEA in thoracotomy, and the comparable effectiveness of ESP block to TEA in VATS collectively demonstrate that the physiological pathway linking regional anesthesia to functional recovery is coherent and reproducible across surgical contexts [6,7,11]. Recognizing this mechanism, rather than treating analgesia and rehabilitation as sequential concerns, should fundamentally reframe perioperative decision-making around block selection, catheter duration, and therapy scheduling.

The rapid evolution of ultrasound-guided interfascial plane blocks has expanded the clinical contexts in which these benefits can be realized. Chin and El-Boghdadly described the mechanistic basis by which interfascial blocks achieve analgesia through volumet-

ric spread to nerve branches within defined fascial compartments, enabling truncal analgesia without motor impairment, chest wall analgesia without hemodynamic instability, and abdominal wall analgesia without urinary retention [6]. Each property aligns with a specific rehabilitation priority, including preserved ambulation, hemodynamic stability during early mobilization, and facilitation of catheter-free discharge pathways. Ueshima et al. described the evolving techniques and anatomical understanding of quadratus lumborum blocks, highlighting their expanding role in perioperative analgesia for abdominal surgery [19]. This pattern suggests that the access gap limiting regional anesthesia benefits to specialized centers may be narrowing, although it has not yet been fully resolved.

The interdisciplinary relevance of these findings warrants particular emphasis. The translation of regional anesthesia's physiological benefits into functional recovery outcomes depends on coordination among anesthesiology, surgery, physical therapy, nursing, and pharmacy. Physical therapists benefit from structured education regarding block duration and expected motor effects, allowing therapy sessions to align with peak analgesia while mitigating fall risk. Surgeons must incorporate regional anesthesia considerations into operative planning and postoperative care pathways. Nursing staff require training in catheter management and recognition of local anesthetic systemic toxicity, while pharmacy teams support multimodal analgesia through scheduled non-opioid regimens that complement regional techniques. Without coordinated care, the benefits of regional anesthesia may be attenuated by downstream gaps, such as delayed rehabilitation, insufficient fall precautions, and avoidable opioid administration for breakthrough pain that could be managed with protocolized non-opioid strategies.

Several limitations of the current evidence base warrant acknowledgment. Heterogeneity in outcome definitions across studies, particularly for physical therapy participation, time to ambulation, and discharge readiness, limits direct cross-study comparison and precludes reliable quantitative pooling. Memtsoudis et al. observed substantial variability in regional anesthesia utilization across hospital types, with community and rural hospitals demonstrating lower adoption rates reflecting differences in access to trained practitioners and ultrasound equipment rather than patient characteristics [9]. Addressing this implementation gap may require expansion of fellowship training, competency-based credentialing for practicing anesthesiologists, and development of simplified high-yield block protocols suitable for intermediate-level practitioners. El-Boghdadly et al. demonstrated that structured simulation-based training accelerates skill acquisition compared with apprenticeship alone, supporting simulation curricula as a scalable solution [20].

A further limitation concerns temporal scope. Most included studies assessed outcomes during index hospitalization, leaving the durability of functional gains beyond 30 days uncertain. Whether early rehabilitation advantages translate into sustained improvements in quality of life, return to work, or reduction in chronic postsurgical pain remains unclear [2,21]. Longitudinal studies using validated patient-reported outcome measures, including the Patient-Reported Outcomes Measurement Information System (PROMIS) and the Oxford Knee Score, are needed to determine whether early functional gains translate into sustained clinical benefit. Beyond outcome standardization, the present review's methodological limitations include its narrative rather than systematic design, reliance on English-language literature, and inclusion of seminal pre-2015 references identified through hand-searching.

Application and Future Directions

These findings carry important implications for clinical practice, education, and research. In clinical practice, institutional ERAS pathways may consider incorporating procedure-specific regional anesthesia protocols such as adductor canal block as a preferred peripheral nerve technique for total knee arthroplasty, thoracic epidural analgesia for open abdominal surgery, TAP or quadratus lumborum blocks for minimally invasive procedures, and erector spinae plane block for VATS, particularly in anticoagulated patients [5,6,7]. Education of perioperative teams should include training in block-specific pharmacology, motor effects, and fall-prevention strategies, particularly for physical therapists involved in early mobilization. Structured interdisciplinary education may improve coordination of care and enhance translation of analgesic benefits into functional recovery.

Priority research directions include standardization of functional outcome measures across trials, longitudinal assessment of patient-reported outcomes at 3, 6, and 12 months postoperatively, and pragmatic effectiveness studies in community and rural settings. Additional work is needed to evaluate health economic outcomes, including reductions in length of stay and postoperative complications, and to investigate whether regional anesthesia influences long-term pain sensitization and the development of chronic postsurgical pain [2,21,22]. Kehlet et al. identified chronic postsurgical pain as a critical frontier in perioperative research, emphasizing that interventions targeting central sensitization during the acute postoperative period may have lasting implications for long-term outcomes [22]. Regional anesthesia techniques capable of modulating this process may therefore play a role not only in early recovery but also in long-term patient outcomes.

Conclusion

Regional anesthesia is associated with clinically meaningful improvements in postoperative functional recovery across orthopedic, abdominal, and thoracic surgical populations. By reducing pain intensity, minimizing opioid requirements and their adverse effects, preserving motor function essential for mobilization, and enabling earlier physical therapy engagement, regional techniques create the physiological conditions necessary for effective surgical rehabilitation [3,5,7]. These benefits are amplified when regional anesthesia is integrated as a core component of comprehensive ERAS protocols, reflecting the synergistic relationship between analgesic quality and the broader perioperative environment. The rapid expansion of ultrasound-guided interfascial plane blocks has extended this reach to patients and settings previously served only by systemic opioid regimens. Regional anesthesia should be con-

sidered a core component of evidence-based perioperative care, with systematic integration within multidisciplinary pathways holding the potential to meaningfully improve postoperative recovery and redefine functional outcomes across surgical specialties.

Conflict of Interest and Funding

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