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THE INTERDISCIPLINARY SYNERGY OF SURGERY AND PHARMACY: A NARRATIVE REVIEW OF PERIOPERATIVE PHARMACOTHERAPY AND CLINICAL OUTCOMES

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Abstract

Modern surgical care increasingly relies on complex, high-risk pharmacotherapy to optimize outcomes across the perioperative continuum. This narrative review evaluates the multidisciplinary synergy between surgery and clinical pharmacy, focusing on the specialized contributions of surgical pharmacists in preoperative, intraoperative, and postoperative settings. Preoperatively, pharmacists facilitate medication reconciliation and risk mitigation, particularly regarding high-risk chronic regimens and antithrombotics. Intraoperatively, their expertise supports optimal timing of antimicrobial prophylaxis to prevent surgical site infections, hemodynamic stability, and efficient blood conservation strategies. Postoperatively, clinical pharmacists drive multimodal analgesia protocols to advance opioid stewardship, oversee venous thromboembolism prophylaxis, and manage acute organ dysfunction in surgical intensive care units. Specialized surgical fields, including organ transplantation and oncologic surgery, further underscore the need for targeted therapeutic drug monitoring and specialized dosing regimens. Evidence demonstrates that integrating clinical pharmacists into surgical teams significantly reduces medication errors, adverse drug events, overall length of hospital stay, and healthcare costs. Future directions highlight the expansion of pharmacogenomics and predictive analytics in perioperative drug selection. Ultimately, embedding clinical pharmacy in surgical practice improves patient safety, optimizes clinical efficacy, and enhances the quality of perioperative care.

INTRODUCTION

Historically, the pharmacist's role in the surgical sphere was largely confined to the central pharmacy, with a focus on compounding, inventory management, and traditional dispensing. However, as surgical techniques advanced and perioperative drug therapies grew increasingly complex, this passive, product-oriented model proved insufficient for modern surgical care. Over the past few decades, clinical pharmacy has undergone a fundamental shift, moving practitioners out of drug preparation rooms and directly into patient care areas. Today, clinical pharmacists are actively integrated into surgical wards and operating theaters, functioning as vital members of interprofessional perioperative teams. This transition allows pharmacists to participate in real-time clinical decision-making, providing direct oversight on drug selection, dosing adjustments, and therapeutic monitoring right where critical patient care occurs (Wireko *et al.*, 2023; Toklu & Hussain, 2013).

This shift toward direct engagement has become even more imperative due to the changing demographic and clinical profile of surgical patients. Modern surgical practice routinely encounters an aging population with complex multimorbidities and extensive baseline polypharmacy. Managing these patients requires balancing their chronic medical regimens, such as complex anticoagulation, immunosuppression, or advanced

cardiovascular therapies, with the immediate pharmacodynamic demands of anesthesia and invasive procedures. Without specialized pharmacotherapeutic oversight, the risk of perioperative medication errors, drug interactions, and organ toxicities increases dramatically. Consequently, integrating clinical pharmacists into surgical care pathways is a crucial safeguard, ensuring that drug regimens are systematically optimized to navigate these patient complexities safely (Partridge *et al*., 2018).

Transitions of care during the surgical journey, from pre-admission and intraoperative transfers to postoperative recovery and discharge, represent particularly vulnerable moments for patient safety. As patients move through these distinct phases, their medication regimens are frequently modified, held, or restarted, creating significant opportunities for errors, including unintended omissions, duplicate therapies, and improper dosing. The risk of adverse drug events (ADEs) and clinically significant drug interactions is heightened by the concurrent use of high-alert perioperative medications, including intravenous anesthetics, neuromuscular blockers, potent opioids, and prophylactic antithrombotics. When these specialized agents interact with a patient's baseline chronic medications, the potential for harm increases substantially. Integrating clinical pharmacists directly into these transition points provides a crucial layer of safety, ensuring meticulous medication reconciliation, immediate detection of potential interactions, and tailored drug monitoring that collectively protect patients from preventable harm (Silva *et al*., 2023; Bougeard & Watkins, 2019).

To address these safety challenges and optimize perioperative care, this review aims to examine the multifaceted relationship between surgery and clinical pharmacy across the entire care continuum. By synthesizing current evidence, we evaluate the impact of integrating specialized clinical pharmacists into preoperative, intraoperative, and postoperative settings on patient care. Specifically, this paper assesses the impact of surgical pharmacy services on key clinical outcomes, including reductions in surgical site infections, adverse drug events, and hospital readmissions, and explores their broader economic value and patient-centered benefits.

PREOPERATIVE PHARMACOTHERAPY & OPTIMIZATION

The preoperative phase provides a vital clinical window to identify pharmacological vulnerabilities and optimize patient physiology before surgical stress. Central to this phase is structured medication reconciliation, a standardized process that systematically audits all prescription drugs, over-the-counter products, and dietary supplements a patient is taking (Barnsteiner, 2005). Unrecorded home medications and hidden herb-drug interactions remain a persistent source of preventable perioperative complications. Herbal products such as ginkgo biloba, garlic, and St. John's wort can significantly alter hemostasis or induce hepatic cytochrome P450 enzymes, interfering with anesthetic metabolism and therapeutic drug levels (De Smet, 2007; Gurley *et al*., 2005). To address these complexities, targeted risk stratification tools empower clinical pharmacists to identify high-risk cardiovascular and metabolic profiles early in the surgical pathway, ensuring that drug regimens are systematically evaluated well before patient admission, as schemed in Figure 1 (Carbó *et al*., 2026).

Determining whether to continue or withhold chronic maintenance medications requires a precise balance between thromboembolic protection and bleeding risk. Baseline cardiovascular agents, such as beta-blockers and statins, are generally continued up to the morning of surgery to preserve cardioprotective benefits and endothelial stability (Buse *et al*., 2009). Conversely, managing antithrombotic and antiplatelet therapies requires nuanced protocols based on the procedure's bleeding risk, renal clearance, and the patient's underlying thromboembolic status. Clinical pharmacists establish tailored timelines for withholding direct oral anticoagulants (DOACs) or vitamin K antagonists, implementing low-molecular-weight heparin bridging protocols only when thrombotic risk clearly outweighs potential bleeding hazards (Gutierrez & Rocuts, 2020; Ortel, 2012).

As metabolic pharmacotherapy rapidly evolves, preoperative guidelines must adapt to newer drug classes that introduce novel perioperative challenges. Recent clinical consensus emphasizes strict holding protocols for metabolic agents, including SGLT2 inhibitors and GLP-1 receptor agonists. SGLT2 inhibitors present a documented risk of perioperative euglycemic diabetic ketoacidosis under surgical stress, while GLP-1 receptor agonists delay gastric emptying, increasing the risk of intraoperative pulmonary aspiration during anesthesia induction (Almonacid-Cardenas *et al*., 2024). Integrating pharmacotherapeutic oversight into preoperative care pathways ensures that these complex metabolic agents are held at appropriate intervals, maintaining metabolic stability while supporting intraoperative hemostatic and hemodynamic equilibrium (Safi *et al*., 2025).

Beyond managing baseline drug regimens, preoperative optimization focuses on correcting underlying physiological deficits to build surgical resilience. Preoperative anemia, which is present in up to 40% of elective surgical candidates, directly correlates with increased postoperative morbidity, cardiovascular complications, and prolonged hospital stays. Pharmacist-guided patient blood management programs evaluate iron parameters weeks before scheduled surgery and initiate targeted intravenous or oral iron supplementation, combined with erythropoietin-stimulating agents when indicated. Optimizing hemoglobin mass before incision significantly reduces reliance on allogeneic blood transfusions, minimizing transfusion-related immune reactions and infectious risks while improving overall clinical recovery (Goiabeira *et al*., 2026; Ali *et al*., 2022).

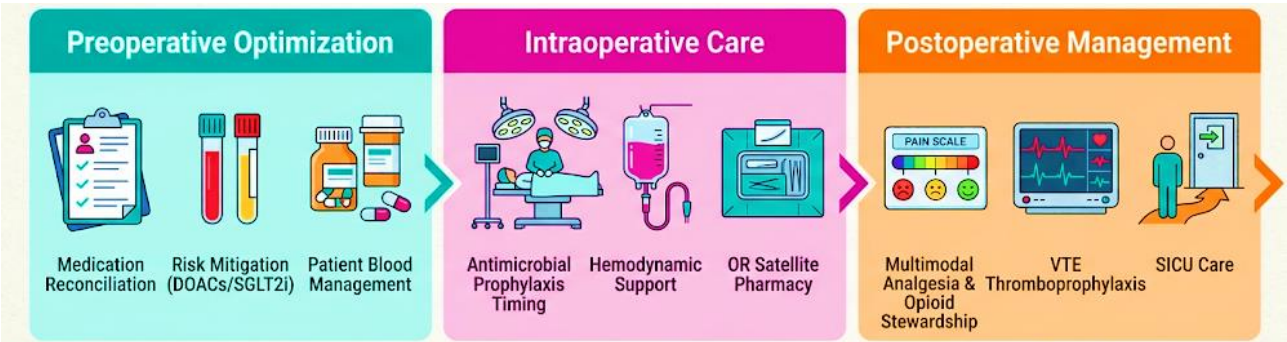

Figure 1. Perioperative clinical pharmacy integration in surgical care

INTRAOPERATIVE PHARMACY & SURGICAL SUPPORT

Within the operating theater, precise pharmacological management is necessary to maintain cardiovascular stability and protect patient physiology during invasive surgery. The choice and titration of anesthetic induction agents, neuromuscular blocking agents, and local anesthetics dictate systemic hemodynamic trajectories, particularly in high-risk or physiologically vulnerable patients undergoing airway management and surgical stress (Karamchandani *et al*., 2026; Okolo *et al*., 2025). In complex cardiovascular or high-acuity operations, achieving a balance between depth of anesthesia and organ perfusion requires tailored drug regimens and the continuous deployment of vasopressors and inotropes (Sun *et al*., 2025). Additionally, managing specialized biological products such as fresh-frozen plasma helps rapidly restore essential clotting cascades and factor levels during major intraoperative fluid shifts or massive transfusions (Jamali *et al*., 2024; Jentzer & Hollenberg, 2021).

Surgical site infection (SSI) prevention remains a core tenet of intraoperative pharmacy support, hinging on meticulous antimicrobial prophylaxis protocols. Optimal prophylaxis requires selecting appropriate broad-spectrum agents tailored to the surgical site, precise weight-based dosing, and strict timing of administration (typically within 60 minutes prior to incision) to achieve bactericidal tissue levels. However, maintaining therapeutic tissue concentrations throughout the procedure duration is equally vital; failure to perform intraoperative antibiotic re-dosing during prolonged operations or extensive blood loss is one of the most common causes of non-compliance in SSI prevention strategies. Adjusting these prophylactic regimens for baseline renal clearance ensures both clinical efficacy and safety against drug toxicity (Garnier *et al*., 2025; Goede *et al*., 2013).

Effective intraoperative blood conservation and hemostasis rely on a combination of systemic therapies and local interventions to minimize blood loss and avoid exposure to allogeneic blood products (Chiara *et al*., 2018). Pharmacologic strategies include systemic antifibrinolytics, such as tranexamic acid, alongside targeted volume and factor replacement protocols using fresh-frozen plasma or clotting factor concentrates when coagulopathy is identified (Jamali *et al*., 2024). In addition to systemic agents, topical hemostats (including fibrin sealants, active thrombin matrices, and mechanical collagen fleeces) are applied directly to surgical beds to control persistent capillary oozing and promote rapid, localized clot formation, regardless of a patient's baseline systemic coagulation status (Chiara *et al*., 2018).

The establishment of dedicated satellite pharmacies within the operating room suite provides an operational framework to support intraoperative demands. Operating room satellite pharmacies provide immediate access to critical high-alert medications and controlled substances, and enable real-time sterile compounding, removing barriers to timely access during intraoperative emergencies. Beyond streamlining workflows, satellite pharmacy services enhance the safety of medication preparation, enforce strict drug accountability, reduce pharmaceutical waste, and enable ongoing therapeutic drug monitoring and antimicrobial stewardship directly at the point of surgical care (Sharifan, 2025).

POSTOPERATIVE CARE & PATIENT MANAGEMENT

Managing acute pain in the postoperative ward requires a shift away from sole reliance on systemic opioids toward structured multimodal analgesia protocols (Figure 2). Combining non-opioid analgesics, such as acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDs), and gabapentinoids, with regional nerve blocks targets pain pathways synergistically while reducing total opioid consumption. Dedicated opioid stewardship initiatives led by surgical teams and clinical pharmacists focus on tailoring discharge prescriptions to actual inpatient consumption, establishing clear tapering schedules, and educating patients on safe disposal. These proactive strategies directly mitigate the risk of long-term opioid dependence and opioid-related adverse events without compromising pain control during surgical recovery (Kincaid *et al*., 2025; Jin *et al*., 2020).

Preventing routine postoperative complications remains critical to reducing hospital length of stay and readmission rates. Risk-stratified combination antiemetic therapy incorporating 5-HT3 receptor antagonists, corticosteroids, and NK1 receptor antagonists ensures effective prevention and treatment of postoperative nausea and vomiting (PONV) in high-risk surgical cohorts (Elvir-Lazo *et al*., 2020). Concurrently, systematic assessment of patient-specific bleeding and clotting risks guides the timely initiation of chemical thromboprophylaxis, using low-molecular-weight heparin (LMWH) or DOACs to prevent deep vein thrombosis and pulmonary embolism (Castro *et al*., 2023).

In addition to thromboprophylaxis, managing gastrointestinal function is essential for restoring oral intake and baseline motility. Targeted stress ulcer prophylaxis using histamine-2 receptor antagonists or proton pump inhibitors is reserved for high-risk surgical patients, such as those requiring prolonged mechanical ventilation or presenting with severe coagulopathy, to prevent upper gastrointestinal bleeding while avoiding unnecessary drug exposure. Alongside ulcer prevention, multi-modal regimens aimed at accelerating intestinal transit help mitigate postoperative ileus, reducing abdominal distension and supporting earlier discharge (Hyland *et al*., 2021).

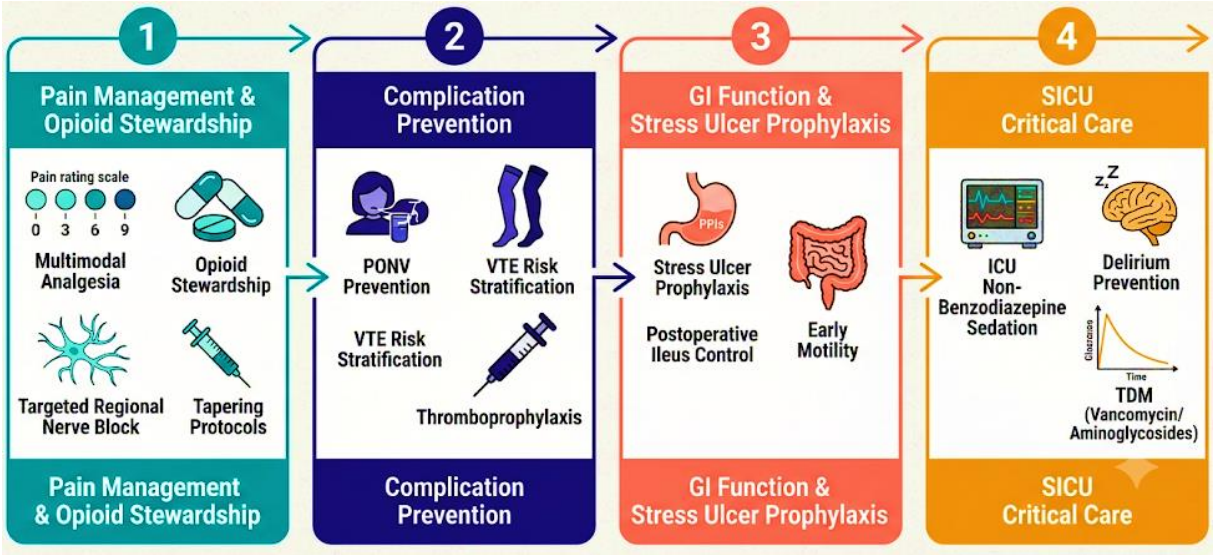

Figure 2. Postoperative care and patient management in surgical care

In the Surgical Intensive Care Unit (SICU), clinical pharmacy services focus on stabilizing critically ill post-operative patients and managing narrow-therapeutic-index drugs. Protocolized sedation pathways prioritize non-benzodiazepine sedatives to reduce the incidence and duration of ICU delirium. Furthermore, pharmacists lead Therapeutic Drug Monitoring (TDM) programs for high-risk antimicrobials, such as vancomycin and aminoglycosides, adjusting doses based on pharmacokinetic modeling and changing renal clearance. This precise pharmacotherapeutic oversight maximizes therapeutic efficacy against severe surgical infections while safeguarding vulnerable critical-care patients from nephrotoxicity and organ failure (Sezerano *et al*., 2026).

CLINICAL, ECONOMIC, AND HUMANISTIC IMPACT

Integrating clinical pharmacists directly into surgical care teams produces measurable improvements in patient outcomes, primarily by curbing preventable postoperative complications, as illustrated in Figure 3. Dedicated pharmacotherapeutic oversight directly strengthens adherence to infection control protocols, leading to a marked reduction in surgical site infections through precise antibiotic timing, weight-based dosing, and intraoperative redosing. Furthermore, clinical pharmacists help streamline post-surgical recovery pathways, which directly translates into reduced overall hospital length of stay and fewer unplanned 30-day readmissions. By actively monitoring high-risk drug regimens and organ function, pharmacist-led care ensures that clinical recovery is both accelerated and sustained beyond the immediate inpatient setting (Khalil *et al*., 2025).

At the intersection of patient safety and quality improvement, clinical pharmacists serve as an essential safeguard against medication misadventure during critical care transitions. The discharge phase is notoriously susceptible to communication gaps, unintended drug omissions, and dosing errors that frequently result in adverse drug events. Through comprehensive discharge medication reconciliation, pharmacists ensure that home regimens are safely resumed, duplicate therapies are eliminated, and high-alert perioperative drugs (such as anticoagulants and oral opioids) are appropriately managed (Homauni *et al*., 2023). Implementing these structured safety frameworks aligns with broader institutional quality improvement initiatives, systematically removing latent hazards from perioperative care pathways and substantially lowering the incidence of preventable drug-related harm (Neumiller *et al*., 2017).

From a healthcare economics perspective, embedding clinical pharmacy services within surgical departments yields substantial financial and humanistic value. Economic analyses consistently demonstrate that clinical pharmacists generate significant cost savings through robust cost-avoidance models, preventing expensive ICU readmissions, managing adverse drug reactions early, and avoiding prolonged hospitalizations (Alghamdi *et al*., 2023). Additionally, pharmacists directly optimize pharmaceutical expenditures by auditing drug utilization, promoting biosimilar adoption, and curbing unnecessary antibiotic use and stress ulcer prophylaxis (Rayzah, 2025). Beyond the financial metrics, this multidisciplinary synergy elevates patient-centered outcomes; thorough discharge counseling, tailored pain management education, and continuous

therapeutic support empower patients, directly improving post-surgical satisfaction and self-efficacy during home recovery (Hou *et al*., 2022).

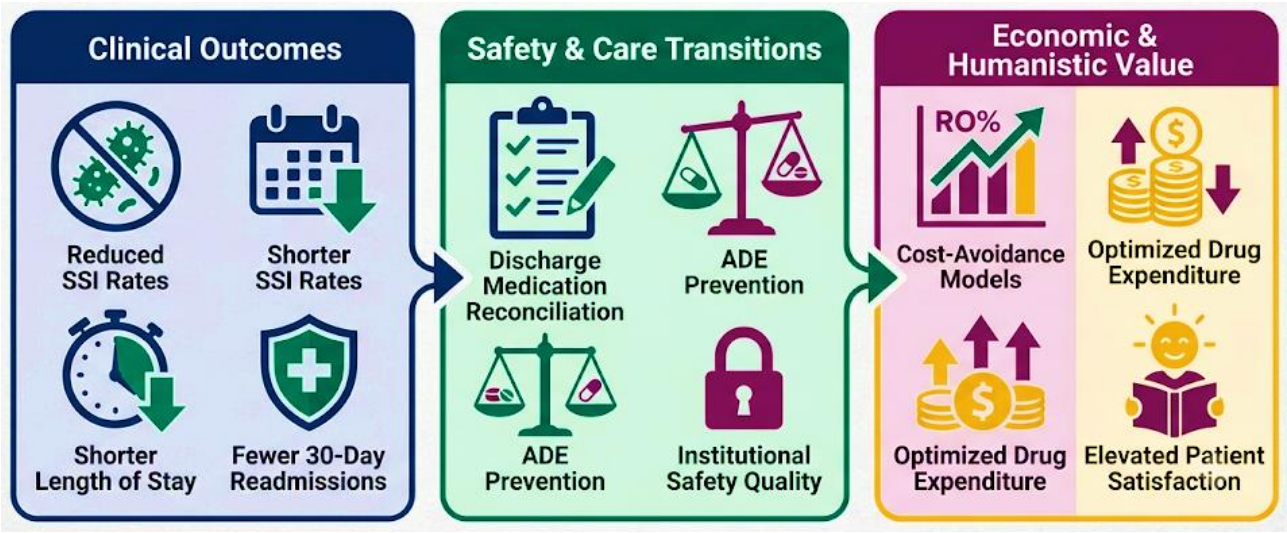

Figure 3. Clinical, economic, and humanistic impact of surgical pharmacy integration

CURRENT CHALLENGES & FUTURE DIRECTIONS

Despite the clear benefits of integrating pharmacists into the immediate surgical environment, the operational transition into the operating room (OR) remains fraught with significant professional and logistical hurdles. The high-stakes culture of the OR creates established interprofessional hierarchies that can inadvertently create communication barriers among newly integrated pharmacists, surgeons, and anesthesiology teams. Furthermore, the demanding workload and rapid-fire clinical pace typical of the intraoperative setting create intense mental workloads and a demanding workflow that differs significantly from routine ward-based practice, often complicating the consistent execution of pharmacist-led clinical interventions or patient counseling (Zielińska-Tomczak *et al*., 2021). Compounding these logistical challenges is the glaring need for structured, advanced training and recognized specialization; the current reliance on general clinical experience is insufficient, reinforcing urgent calls for the development of dedicated, specialized board certification, such as a Board Certified Surgical Pharmacist pathway, to ensure practitioners possess the highly specialized pharmacotherapeutic and procedural competencies required to function effectively and safely within surgical suites (Le *et al*., 2026).

Looking toward the future of intraoperative care, the application of emerging precision medicine technologies is poised to revolutionize traditional "one-size-fits-all" perioperative prescribing patterns. Pharmacogenomics represents a pivotal emerging frontier in which pre-surgical genetic screening enables individualized selection of volatile anesthetics and acute pain regimens (Nahid & Johnson, 2022). For example, proactively assessing a patient's CYP2D6 metabolizer status enables clinicians to predict and avoid adverse outcomes with commonly used opioids like codeine and hydrocodone, which are subject to high inter-individual variation in metabolism

and toxicity risks. Furthermore, integrating digital health and wearable technology into perioperative care pathways provides surgical teams with a robust, continuous stream of real-time patient-reported outcome measures (PROMs). This precise, data-driven approach to intraoperative care significantly enhances the safe selection of medications and facilitates the dynamic titration of high-alert systemic therapies right where it matters most, creating a truly patient-centric perioperative experience.

Complementing this genetic and real-time biometric profiling, the application of AI and predictive analytics in the immediate intraoperative period promises to redefine personalized anesthesia and dosing strategies. Rather than relying on rigid population-based pharmacokinetic models or provider intuition, modern AI algorithms can dynamically process high-fidelity, real-time vital signs and dynamic biomarker data directly from OR monitors to provide truly personalized dosing predictions and hemodynamic forecasting (Le *et al*., 2026). These complex analytic platforms can continuously predict and forecast imminent intraoperative complications, such as profound hypotension or metabolic derangements, well before they manifest clinically, providing an essential safety net for the entire surgical team. By leveraging AI-driven predictive modeling for crucial intraoperative drug selection, dosing adjustments, and proactive complication management, future surgical teams can systematically minimize preventable medication errors, enhance patient safety, and dramatically improve immediate post-surgical recovery and long-term surgical outcomes.

CONCLUSION

The seamless integration of clinical pharmacy into surgical care represents a transformative evolution in modern perioperative medicine, bridging critical care gaps to fundamentally enhance patient safety, clinical efficacy, and long-term healthcare sustainability. As surgical care grows increasingly complex, embedding specialized clinical pharmacists across the preoperative, intraoperative, and postoperative phases ensures that pharmacotherapeutic decisions are proactively optimized rather than reactively managed. This multidisciplinary collaboration directly drives measurable clinical improvements, curbing surgical site infections, optimizing pain control while advancing opioid stewardship, and eliminating preventable adverse drug events, all while delivering substantial financial return through robust cost-avoidance models and reduced length of stay. To fully realize these health system benefits, healthcare institutions and academic bodies must commit to a call to action: prioritizing expanded interprofessional training, creating dedicated board certifications in surgical pharmacy, and structurally embedding clinical pharmacists as permanent, non-negotiable members of the surgical team. Embracing this integrative model is no longer merely an operational upgrade; it is an imperative strategy to build a safer, more efficient, and patient-centered surgical ecosystem.

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