Jurnal Surya Medika (JSM) https://journal.umpr.ac.id/index.php/jsm
Volume 12, Issue 1, Page 427 – 438 DOI: https://doi.org/10.33084/jsm.v12i1.13777
e-ISSN: 2655-2051

STRENGTHENING PERIOPERATIVE TB PATHWAYS: A NARRATIVE REVIEW ON THE INTERPROFESSIONAL TRIAD OF INTERNISTS, PEDIATRIC SURGEONS, AND PHARMACISTS

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Keywords:
Tuberculosis
Perioperative Care
Pediatric Surgeon
Internist
Pharmacist

Abstract

Extrapulmonary and surgical manifestations of tuberculosis (TB), such as abdominal TB, tuberculous lymphadenitis, and spinal TB, present complex clinical challenges that require interventional precision and rigorous pharmacotherapy. The management of these cases across pediatric and adult populations necessitates a seamless continuum of perioperative care. This narrative review highlights the vital collaborative triad among internists, pediatric surgeons, and pharmacists in optimizing perioperative TB pathways. Pediatric surgeons perform diagnostic biopsies, surgical debridement, and anatomical management in young patients, whereas adult presentations, systemic complications, and chronic comorbidities are managed by internists. Pharmacists serve as the critical integrative link across pre-, intra-, and postoperative stages, evaluating anti-TB drug absorption post-surgery, adjusting dosages for organ dysfunction, managing complex drug-drug interactions with anesthetic or immunosuppressive agents, and monitoring for anti-TB drug-induced hepatotoxicity. This interprofessional synergy ensures continuity of care, minimizes perioperative drug-related harm, and enhances long-term treatment adherence during pediatric to adult patient transitions. This collaborative framework mitigates the risks of surgical treatment failure and drug resistance by combining surgical expertise, internal medicine oversight, and clinical pharmacotherapy stewardship. Institutionalizing formal interprofessional communication and perioperative protocols is essential for strengthening global TB outcomes.

INTRODUCTION

Tuberculosis (TB) remains one of the world's most persistent and formidable public health crises, continuing to exert a heavy global burden of morbidity and mortality. While pulmonary TB accounts for the majority of cases, extrapulmonary tuberculosis (EPTB) poses a distinct and growing clinical challenge that often slips under the radar. EPTB can manifest in virtually any organ system, with surgical manifestations representing some of its most debilitating forms (Kobrai-Abkenar *et al*., 2024). Clinical presentations such as tuberculous lymphadenitis, abdominal TB with intestinal strictures or bowel perforations, and spinal TB (commonly known as Pott's disease), frequently present with severe tissue destruction or structural compromised states that medical therapy alone cannot resolve (Agustina *et al*., 2025). Managing these extrapulmonary presentations is further complicated by delayed diagnostic suspicion, atypical symptom profiles, and the need to address disease burdens spanning pediatric and adult populations (Yhoshu *et al*., 2025).

The clinical trajectory of surgical TB is uniquely complicated because it demands a delicate, synchronized balance between procedural intervention and prolonged pharmacotherapy. Relying solely on standard anti-tuberculosis therapy (ATT) is often insufficient when faced with mechanical obstructions, deep-tissue

abscesses, or progressive neurological deficits caused by spinal compression (Walzl *et al*., 2026). Conversely, surgical interventions carry high perioperative risks in patients who are frequently malnourished, systemically ill, or immunocompromised. Establishing a definitive diagnosis itself often hinges on invasive tissue sampling for histopathology and molecular testing. Once in the perioperative phase, clinicians face the complex task of timing the surgery relative to ATT initiation, managing severe drug-induced hepatotoxicity, and navigating unpredictable oral drug absorption following gastrointestinal procedures, all while mitigating the risk of treatment failure or acquired drug resistance (Sulaiman *et al*., 2024).

Given these multifaceted clinical and pharmacotherapeutic hurdles, single-specialty management is no longer viable; optimizing patient outcomes requires an integrated interprofessional collaborative model. The triad of internists, pediatric surgeons, and clinical pharmacists constitutes the essential pillars of medical, surgical, and pharmaceutical care needed throughout a patient's lifespan (Spaulding *et al*., 2021). Pediatric surgeons offer critical procedural precision, diagnostic biopsy expertise, and anatomical management for young patients, while internists provide comprehensive preoperative stabilization, long-term systemic management, and oversight of adult comorbidities or transitioning adolescents (Cullis *et al*., 2024). Pharmacists serve as the key integrative link across this continuum, safeguarding pharmacotherapy through precise dosing adjustments, therapeutic drug monitoring, management of complex drug interactions during anesthesia, and oversight of post-surgical absorption (Samardžić *et al*., 2025).

The objective of this narrative review is to explore and define the synergistic roles within this interprofessional triad and to establish a structured framework to strengthen perioperative pathways for patients with surgical TB. By evaluating the intersecting responsibilities of internists, pediatric surgeons, and pharmacists across the pre-, intra-, and postoperative settings, this review highlights strategies to streamline clinical workflows, reduce perioperative drug-related harm, and enhance long-term treatment adherence. Ultimately, elucidating this collaborative model aims to bridge care transitions between pediatric and adult medicine, optimize therapeutic efficacy, and contribute to global initiatives to reduce the burden of complex extrapulmonary tuberculosis.

CLINICAL PRESENTATIONS AND SURGICAL INDICATIONS IN TB

Extrapulmonary tuberculosis (EPTB) presents marked clinical heterogeneity that varies significantly across the age spectrum, making diagnostic vigilance essential (Figure 1). In pediatric populations, EPTB often presents with non-specific, systemic symptoms such as persistent low-grade fever, growth failure, and rapidly progressive dissemination, frequently involving the lymphatic system and central nervous system. Children under five years old are particularly susceptible to severe forms like tuberculous meningitis and disseminated disease due to their developing immune systems. Conversely, adult presentations tend to be more localized but carry a higher burden of structural tissue destruction, presenting as chronic organ-specific dysfunction, fibrotic strictures, or extensive caseous necrosis. Recognizing these age-dependent differences in pathophysiological response is crucial for establishing timely suspicion before irreversible anatomical damage occurs (Cortegiani *et al*., 2022).

Surgical intervention in TB care serves both critical diagnostic and therapeutic roles. From a diagnostic standpoint, definitive identification of EPTB frequently requires invasive tissue sampling when sputum tests or non-invasive imaging yield inconclusive results. Excisional lymph node biopsies, image-guided fine-needle aspiration, and diagnostic laparoscopy allow clinicians to acquire adequate tissue for histopathological examination, acid-fast bacilli staining, mycobacterial culture, and rapid molecular testing such as GeneXpert. Obtaining clean, viable tissue samples is especially paramount in suspected multidrug-resistant TB (MDR-TB) cases or deep-seated abdominal disease where superficial testing fails to establish a diagnosis (Qian *et al.*, 2026).

Therapeutically, surgery becomes mandatory when medical therapy alone cannot resolve severe mechanical or structural complications. In abdominal TB, aggressive fibrotic responses often lead to intestinal strictures, mechanical bowel obstructions, or acute bowel perforations that require bowel resections, strictureplasty, or temporary stoma creation (Bayhan *et al*., 2023). In musculoskeletal and central nervous system manifestations, such as Pott's disease, progressive spinal instability, or severe neurological deficits from epidural abscesses, urgent spinal decompression, debridement, and stabilization. Similarly, large, cold abscesses in soft tissues or lymph nodes frequently necessitate open or percutaneous drainage to reduce systemic toxic load, alleviate pain, and prevent spontaneous rupture with sinus tract formation (Liu *et al*., 2019).

Determining the precise timing of surgical intervention requires a delicate balance between pharmacological stabilization and urgent clinical need. Initiating ATT prior to elective surgery is ideal, as pre-treating with bactericidal agents reduces mycobacterial load, minimizes intraoperative dissemination, and lowers systemic inflammatory markers. However, waiting for therapeutic drug levels is a luxury clinicians cannot afford in emergency scenarios such as acute intestinal perforation, rapidly deteriorating spinal cord compression, or acute compartment syndrome. In these acute settings, immediate life-saving or function-sparing surgical intervention must be performed in tandem with early perioperative administration of ATT, requiring tight coordination among the surgical, medical, and pharmaceutical care teams (Chen *et al*., 2023).

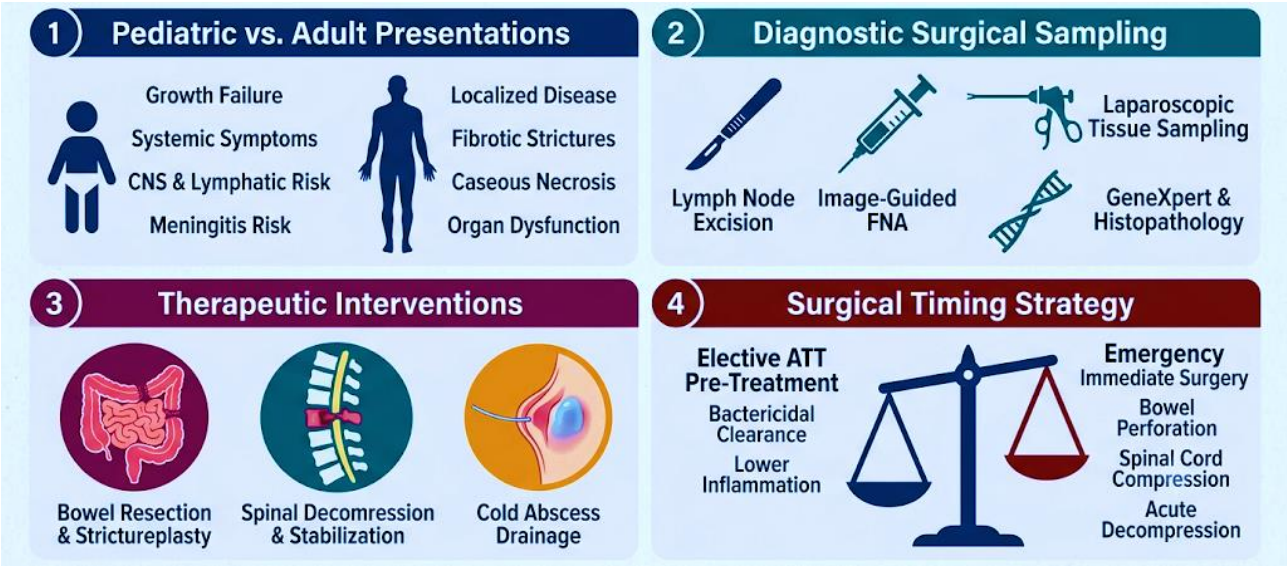

Figure 1. Clinical presentations and surgical indications in EPTB

THE ROLE OF THE PEDIATRIC SURGEON: OPERATIVE PRECISION AND ANATOMICAL MANAGEMENT

In the management of surgical TB, the pediatric surgeon assumes a role that goes far beyond procedural execution; they act as a linchpin in both diagnosis and therapeutic success for children and adolescents. Unlike adults, young patients present with unique anatomical constraints, distinct immune responses, and the potential for lifelong growth disturbances from disease or surgery (Wang *et al*., 2024). Pediatric surgery in this context is inherently conservative yet definitive, requiring a precise, function-preserving approach that is structurally and physiologically optimized for the growing body (Marais & Schaaf, 2014). Successful outcomes hinge not only on surgical technique but also on close collaboration within a multidisciplinary triad to address comorbidities and safeguard drug efficacy (Agashe *et al*., 2020). This section explores the critical contribution of the pediatric surgeon in guiding complex diagnostics, ensuring safe source control, and facilitating postoperative recovery in this vulnerable population (Figure 2).

One of the pediatric surgeon's most significant contributions is diagnostic leadership, particularly in acquiring adequate and representative tissue samples. In complex extrapulmonary TB, establishing a definitive microbiological diagnosis can be notoriously difficult, as non-invasive tests and superficial aspirates often prove inconclusive (Kumari *et al*., 2024). The surgeon must navigate access to deep-seated structures (such as the mediastinum, bone, or intestinal tissue) while minimizing procedural trauma (Mayer *et al*., 2024). This meticulous tissue harvesting is paramount for confirmatory histopathology, mycobacterial culture, and modern rapid molecular assays like GeneXpert, which are essential for identifying drug resistance in suspected MDR TB cases (Pourakbari *et al*., 2026). When drug resistance is confirmed, the surgeon plays a crucial role in preventing treatment failure and severe morbidity by coordinating the diagnostic findings with the patient's pharmacological management (Patra *et al*., 2025).

Therapeutic success in surgical TB depends heavily on precise operative debridement and effective source control. The pediatrician surgeon's objective is to systematically remove the bulk of necrotic, caseous material and deep-tissue abscesses that often harbor high mycobacterial loads, while meticulously preserving viable surrounding anatomy and underlying function (Zuo *et al*., 2026). In procedures ranging from spinal decompression to joint debridement, the risk of intraoperative TB dissemination must be actively minimized. This requires a targeted, technical approach that clears the infective foci without creating further instability or profound structural loss, which could later jeopardize the child's development or orthopedic growth plates (Tang *et al*., 2016). Source control directly improves the systemic response to therapy and lowers the threshold for concurrent medical management in both drug-sensitive and complex MDR-TB cases (Smith *et al*., 2020).

Facilitating postoperative anatomical and functional recovery presents a distinct challenge, as pediatric TB patients are frequently severely malnourished, systemically ill, and significantly immunocompromised (Díaz-Amaya *et al*., 2024). Managing these fragile patients demands meticulous attention to wound closure and the proactive prevention of catastrophic surgical site infections and sinus formation (Millán-Reyes *et al*., 2025). Often, ensuring nutritional access is the surgeon's top priority, necessitating placement of gastric feeding tubes or creation of temporary bowel stomas following extensive abdominal resections (Rajan *et al*., 2022). These

interventions are critical to reversing severe nutritional deficiencies, supporting immune-mediated healing, and stabilizing the patient physiologically. This intensive postoperative phase underscores the importance of a multidisciplinary approach, ensuring that wound management and nutritional rehabilitation are seamlessly integrated with standardized anti-TB pharmacotherapy to optimize recovery (Michońska *et al*., 2023).

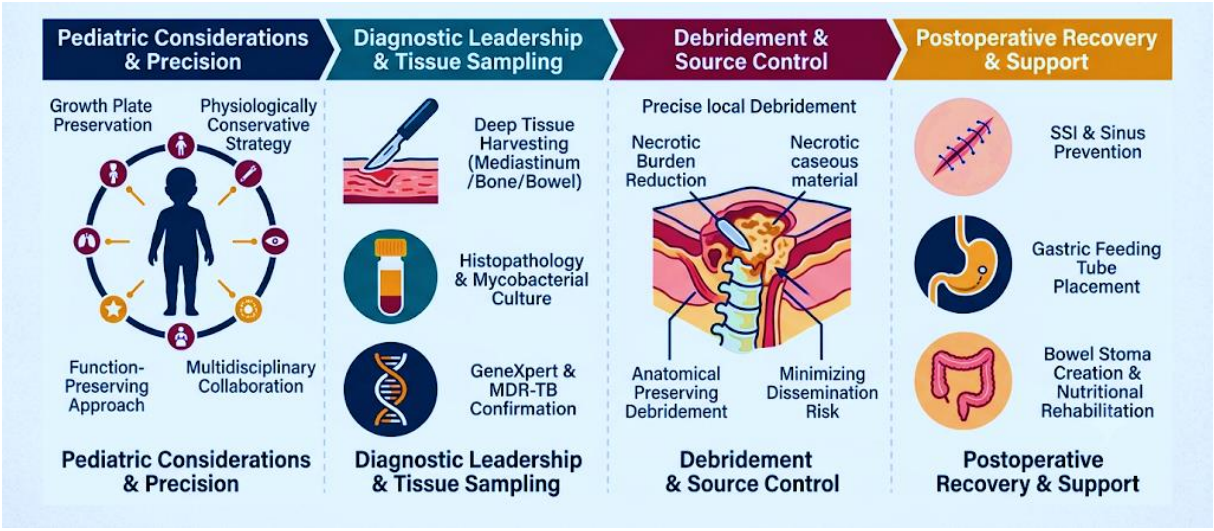

Figure 2. The role of the pediatric surgeon in extrapulmonary TB

THE ROLE OF THE INTERNIST: SYSTEMIC MANAGEMENT AND COMORBIDITY OVERSIGHT

In the perioperative management of surgical TB, the internist plays a central role in optimizing systemic health, stabilizing complex multi-system pathophysiology, and guiding long-term recovery. The perioperative window for EPTB requires thorough medical optimization, especially during the crucial transition from pediatric to adult care. Adolescent and young adult patients transferring from pediatric surgical care to adult medicine often present unique challenges in disease self-management, treatment adherence, and changing physiology (Sihoe, 2017). Preoperatively, the internist conducts rigorous risk stratifications, addresses systemic malnutrition, stabilizes baseline cardiopulmonary and metabolic parameters, and balances the urgency of surgical intervention against the benefits of medical stabilization. Hospitalist co-management and internal medicine integration in surgical care have consistently been shown to minimize perioperative organ dysfunction, reduce unexpected postoperative complications, and establish a stable foundation before patients enter the operating room (Huang *et al*., 2025).

Navigating surgical TB is further complicated by the high prevalence of concurrent co-infections and non-communicable comorbidities, particularly HIV/AIDS, diabetes mellitus, and chronic malnutrition. The intersection of HIV and TB creates an immunocompromised state that increases surgical risks and alters drug metabolism, requiring the internist to balance antiretroviral therapy (ART) alongside multi-drug anti-TB regimens (Bates *et al*., 2015). Similarly, co-existing diabetes mellitus significantly impairs host cell-mediated immunity and microvascular perfusion, doubling the risk of delayed wound healing, surgical site infections, and treatment failure. Managing these multi-morbidities demands active glycemic control, nutritional

rehabilitation, and precise adjustment of concurrent chronic medications. The internist must carefully evaluate complex drug-disease and drug-drug interactions, ensuring that organ function (particularly hepatic and renal clearance) is safeguarded throughout aggressive perioperative therapy (Dasari *et al*., 2021).

Beyond immediate surgical clearance, the internist maintains long-term oversight of the patient's systemic recovery, immune clearance, and overall disease resolution. Following surgery, patients with severe EPTB remain at high risk for systemic complications, such as drug-induced organ toxicity, treatment relapse, or paradoxical inflammatory reactions like Immune Reconstitution Inflammatory Syndrome (IRIS) when ART or ATT is initiated (Wang *et al*., 2025; Barthwal *et al*., 2015). The internist monitors host immune restoration, balances pro- and anti-inflammatory signaling to prevent excessive tissue pathology, and conducts routine microbiological and clinical evaluations to confirm treatment response. This long-term systemic monitoring bridges the gap between acute surgical intervention and full clinical cure, providing a continuous safety net that minimizes permanent organ damage, prevents secondary drug resistance, and ensures complete health restoration.

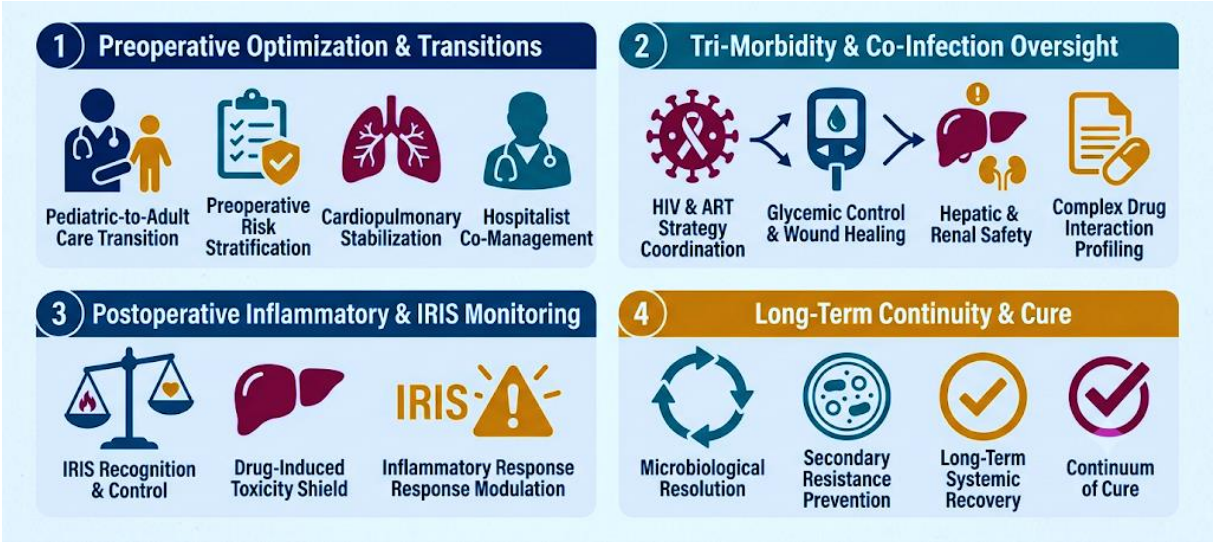

Figure 3. The role of the internist in surgical TB

THE ROLE OF THE PHARMACIST: PERIOPERATIVE PHARMACOTHERAPY STEWARDSHIP

In the intricate management of surgical TB, the clinical pharmacist serves as an essential safeguard for therapeutic efficacy and patient safety throughout the perioperative continuum. The preoperative phase begins with meticulous pharmacotherapy reconciliation, where the pharmacist evaluates baseline hepatic and renal function to establish individualized dosing parameters (Sun *et al*., 2025). First-line ATT (comprising isoniazid, rifampin, pyrazinamide, and ethambutol) carries inherent organ toxicities that can be exacerbated by perioperative stress and anesthesia. Pharmacists systematically assess organ clearance, adjust nephrotoxic or hepatotoxic regimens prior to surgery, and determine precise hold times for specific agents to mitigate intraoperative metabolic risks. This proactive risk mitigation ensures that patients are pharmacologically

stabilized, reducing the likelihood of acute organ decompensation during or immediately following surgical procedures (Bouazzi *et al*., 2016).

Intraoperatively, the pharmacist's expertise is crucial for navigating complex pharmacokinetic and pharmacodynamic interactions between ATT and surgical medications. Rifampin, a potent inducer of hepatic cytochrome P450 enzymes (specifically CYP3A4) and P-glycoprotein, dramatically accelerates the clearance of numerous anesthetic agents, sedatives, analgesics, and non-depolarizing neuromuscular blocking agents. Unrecognized enzyme induction can lead to inadequate anesthetic depth, premature reversal of neuromuscular blockade, or uncontrolled acute postoperative pain (Niemi *et al*., 2003). Conversely, concurrent administration of second-line ATT agents or fluoroquinolones with anesthetic regimens increases the risk of prolonged QT intervals and cardiac dysrhythmias. By collaborating directly with anesthesiologists, clinical pharmacists ensure prospective dosage recalibrations, select non-interacting alternative agents, and prevent severe adverse drug events in the operating room (Liu *et al*., 2017).

The postoperative period presents significant pharmacokinetic challenges that demand rigorous pharmaceutical oversight and individualized dosing. Following major abdominal resections or during postoperative ileus, oral drug absorption is severely impaired, necessitating temporary transitions to intravenous formulations or alternative administration routes to avoid subtherapeutic drug levels. Pharmacists utilize Therapeutic Drug Monitoring (TDM) to measure serum drug concentrations, making precise weight-band adjustments that are particularly vital for pediatric patients with changing body composition or adults experiencing severe disease-induced emaciation (Zeinali *et al*., 2009). Furthermore, intensive postoperative monitoring for drug-induced liver injury (DILI) and acute kidney injury is essential, as surgical inflammation and altered organ perfusion heighten toxicity risks. Through constant TDM, route optimization, and early toxicity interception, clinical pharmacists ensure uninterrupted mycobacterial suppression while safeguarding organ function throughout recovery (Tiwari *et al*., 2025).

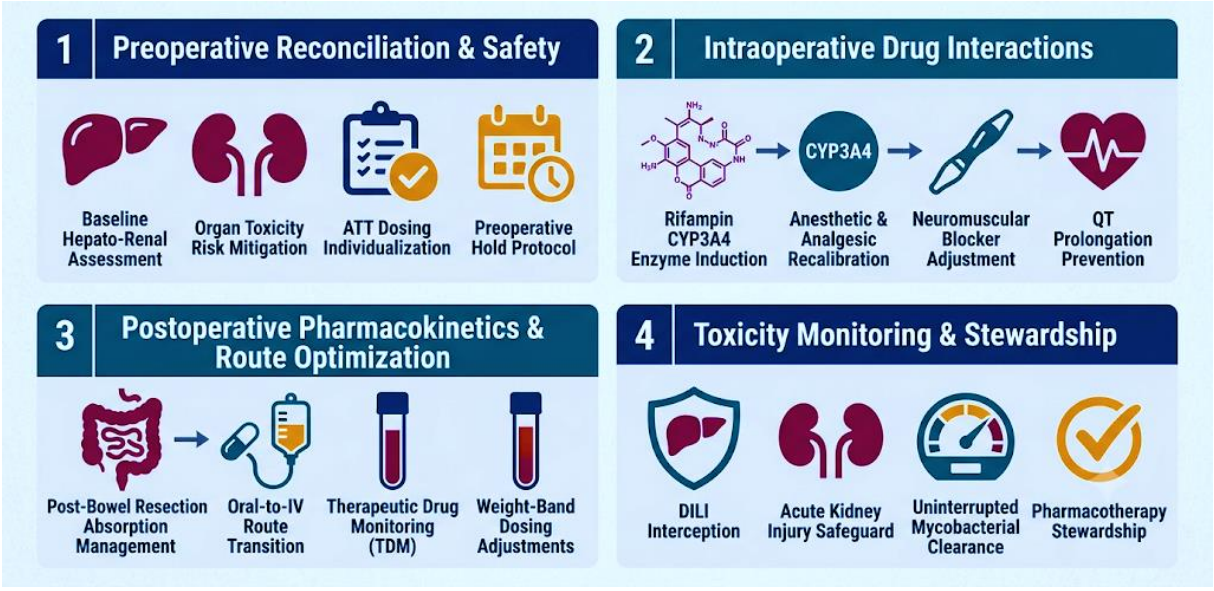

Figure 4. The role of the pharmacist in perioperative TB care

CURRENT CHALLENGES & FUTURE DIRECTIONS

Despite clear evidence supporting collaborative care, significant interprofessional barriers continue to undermine the effective delivery of perioperative tuberculosis care. Communication silos between surgical teams, medical specialists, and clinical pharmacists frequently lead to fragmented care plans and delayed interventions. Surgeons often operate under acute time constraints to achieve physical source control, while internists and clinical pharmacists focus on long-term systemic stabilization, organ preservation, and pharmacotherapy stewardship. Without formalized avenues for routine collaborative discussion, crucial clinical details such as drug-induced liver injury, subtherapeutic plasma drug concentrations following bowel resection, or complex anesthetic drug interactions can easily fall through the cracks during perioperative handoffs. Overcoming these deeply ingrained professional silos requires a deliberate cultural shift within clinical institutions, fostering mutual respect and shared decision-making across all disciplines involved in managing complex extrapulmonary TB (Dib & Belrhiti, 2025).

Leveraging modern healthcare technologies offers a powerful strategy to bridge these communication gaps and enhance perioperative safety. The integration of advanced Electronic Health Records (EHR) equipped with specialized Clinical Decision Support Systems (CDSS) provides an automated safety net for managing multi-drug anti-TB regimens. These digital platforms can automatically cross-reference scheduled surgical procedures, anesthetic administration logs, and active anti-TB prescriptions to flag high-risk drug-drug interactions, such as rifampin-mediated CYP3A4 enzyme induction or QT-interval prolongation. Furthermore, integrated EHR systems can automate alerts for weight-band dosing adjustments, trigger post-surgical therapeutic drug monitoring protocols, and track baseline liver and renal function parameters in real time. By embedding these intelligent digital tools into daily clinical workflows, care teams can intercept potentially catastrophic pharmacotherapy errors before they reach the patient (Fahim *et al*., 2025).

Ultimately, bridging the gap between current clinical hurdles and optimized patient outcomes requires a unified call to action to develop standardized, multidisciplinary perioperative TB protocols. Very few institutions currently possess formalized clinical pathways specifically designed to guide the joint management of surgical TB across pediatric, adult medical, and pharmaceutical care units. Institutional leaders and global professional societies must prioritize establishing evidence-based guidelines that define clear operational workflows, specify the timing of pre- and post-operative medical consultations, and mandate standardized pharmacist-led medication reconciliation at every care transition. Implementing these structured, standardized pathways will not only eliminate practice variability and streamline interprofessional communication but also safeguard long-term therapeutic efficacy, reduce perioperative complications, and set a new standard for complex extrapulmonary tuberculosis care worldwide.

CONCLUSION

The effective management of complex EPTB requires a seamless, highly coordinated, multidisciplinary approach spanning the entire perioperative continuum. As highlighted throughout this review, surgical intervention in EPTB is rarely a standalone solution; rather, it plays a vital dual role, serving both as a critical

gateway for definitive tissue diagnosis and molecular resistance profiling, and as a life-saving structural rescue measure for severe mechanical complications. Achieving optimal outcomes demands close collaboration among the pediatric surgeon, internist, and clinical pharmacist, each bringing specialized expertise to manage age-dependent pathophysiology, balance surgical timing against pharmacological stabilization, and safeguard organ function. Overcoming traditional interprofessional communication silos through standardized care pathways, integrated electronic health records, and clinical decision support systems is essential to preventing fragmented care and drug-related complications. By embedding real-time pharmacotherapy stewardship, proactive comorbidity oversight, and conservative yet effective surgical techniques into daily practice, healthcare teams can minimize perioperative morbidity, prevent secondary drug resistance, and ensure long-term clinical cure for both pediatric and adult patients navigating complex extrapulmonary tuberculosis.

ACKNOWLEDGMENT

The authors express their sincere gratitude to the Faculty of Medicine, Universitas Muhammadiyah Palangkaraya, for providing the internal research grant funding that supported the conceptualization, data collection, and preparation of this narrative review.

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