



# **PEDIATRIC SURGERY *Update*\***

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### **Intraoperative Blood Loss Estimation**

Intraoperative blood loss estimation is a critical component in surgical practice, with implications for patient outcomes, perioperative morbidity, and mortality. Over the decades, various methods have been employed to estimate blood loss, ranging from traditional visual assessments to advanced technological approaches. Each method has strengths and limitations, which continue to inform clinical decision-making and research.

A study conducted in the 1960s at a children's hospital introduced the gravimetric method for measuring blood loss during pediatric surgeries. This method involved weighing soiled sponges and drapes before and after surgery, combined with measurements of suctioned blood. The study highlighted the practical application of gravimetric techniques in managing transfusion requirements and minimizing hypovolemia risks. Blood loss during procedures was categorized into minor, moderate, or severe, based on its relationship to total blood volume or body weight. The research underscored the importance of precise blood loss estimation in pediatric patients, who have a lower hemodynamic reserve compared to adults, necessitating accurate monitoring to avoid complications.

Despite its utility, the gravimetric method has limitations, including the potential for inaccuracies due to evaporation or the presence of non-blood fluids. These limitations have driven the development of alternative approaches over the years. For example, a more recent investigation evaluated the Triton system, an FDA-cleared application utilizing image analysis algorithms and machine learning to estimate hemoglobin content in real-time. This system demonstrated superior accuracy compared to visual and gravimetric methods, showing a strong correlation with reference spectrophotometric assays. The ability to provide real-time estimates offers significant advantages, particularly in procedures with high expected blood loss, such as pediatric orthopedic surgeries.

Visual estimation remains one of the most commonly used methods due to its simplicity and immediacy. However, numerous studies have shown that it is prone to substantial inaccuracies, often underestimating or overestimating actual blood loss. In one study, visual methods were consistently less reliable compared to hemoglobin-based calculations, especially when blood loss exceeded critical thresholds. Training programs aimed at improving the accuracy of visual estimation have shown some success, but variability between observers continues to be a challenge.

Advancements in blood loss estimation have also explored formula-based approaches. These include methods that calculate blood loss based on changes in hematocrit (Hct) or hemoglobin (Hb) levels pre- and postoperatively. While these methods offer higher precision, they are influenced by factors such as fluid replacement and postoperative blood loss, which can affect the accuracy of calculated values. Studies have emphasized the

need for further research to refine these calculation methods and address variables that impact their reliability in clinical practice.

The integration of photometric techniques represents another significant advancement in the field. These methods involve spectrophotometric analysis of blood-soaked materials to directly measure hemoglobin concentration. Compared to visual and gravimetric methods, photometric techniques have demonstrated higher accuracy and lower bias in systematic reviews and meta-analyses. However, their labor-intensive nature and requirement for specialized equipment limit their widespread adoption in routine surgical settings.

A systematic review comparing various blood loss estimation techniques highlighted the strengths and weaknesses of each method. Visual estimation, while quick and accessible, often yielded lower estimated blood loss values than formula-based or direct measurement techniques. Gravimetric methods, although more accurate than visual assessments, exhibited significant variability depending on the surgical environment and materials used. Photometric methods showed the highest correlation with reference standards, reinforcing their potential as the most precise option for intraoperative blood loss estimation.

Recent reviews have also emphasized the importance of standardized methods for measuring blood loss. The absence of universally accepted protocols contributes to inconsistencies in clinical practice and research, hindering the ability to compare outcomes across studies. Efforts to address this gap include the development of comprehensive reviews and scoping protocols aimed at summarizing existing evidence and identifying areas for improvement. These initiatives aim to establish a foundation for adopting more reliable and reproducible techniques in surgical practice.

Calculation-based methods continue to evolve, with new studies exploring their application in diverse surgical contexts. For instance, the use of hematocrit and hemoglobin calculations has been proposed as a more precise alternative to visual methods. These approaches consider patient-specific variables such as body weight and blood volume, providing tailored estimates that can guide transfusion decisions and perioperative management. However, challenges remain in standardizing these methods and accounting for dynamic changes during and after surgery.

The importance of accurate blood loss estimation extends beyond the operating room. Inappropriate transfusions, whether due to overestimation or underestimation of blood loss, can lead to significant complications, including transfusion reactions, immunosuppression, and volume overload. Studies have shown that intraoperative blood transfusions are independent risk factors for adverse outcomes in surgeries such as colorectal procedures. Accurate assessment methods are therefore essential for optimizing patient safety and surgical outcomes.

Emerging technologies, such as artificial intelligence and machine learning, hold promise for further advancing blood loss estimation. By leveraging large datasets and predictive algorithms, these technologies can enhance the accuracy and efficiency of intraoperative

assessments. Preliminary studies have demonstrated the potential of these approaches, particularly when integrated with real-time imaging systems and automated data analysis tools.

Despite these advancements, significant challenges persist in achieving widespread adoption of newer techniques. Cost, accessibility, and the need for specialized training are common barriers that limit the implementation of advanced methods in resource-constrained settings. Additionally, the variability in surgical environments and patient populations necessitates flexible and adaptable solutions that can be tailored to specific clinical needs.

In conclusion, intraoperative blood loss estimation has undergone significant evolution, from traditional visual assessments to advanced technological solutions. Each method offers unique advantages and limitations, highlighting the need for a multifaceted approach to blood loss evaluation. Ongoing research and innovation are essential for addressing existing gaps and establishing standardized protocols that can improve surgical outcomes and patient safety.

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## Mitomycin for Esophageal Strictures

The use of Mitomycin C (MMC) in the management of esophageal strictures has gained increasing attention due to its antifibrotic properties and its potential to reduce the need for repeated dilations. Esophageal strictures can arise from various etiologies, including post-surgical complications, caustic injuries, congenital conditions, and gastroesophageal reflux disease. The primary challenge in managing esophageal strictures lies in preventing fibrosis and recurrence following endoscopic interventions. Conventional treatments often involve multiple sessions of balloon or bougie dilations, and in some cases, surgical interventions. The integration of MMC into treatment protocols represents an important advancement in this field.

Esophageal strictures following surgical repair of conditions such as tracheoesophageal fistula and esophageal atresia are common complications. These strictures are often resistant to standard dilation procedures, leading to multiple interventions and potential complications such as perforation. Studies have documented cases in which the application of MMC has successfully led to the resolution of these strictures with fewer dilation sessions. The mechanism by which MMC acts is primarily through the inhibition of fibroblast proliferation and suppression of collagen deposition, thereby reducing the formation of scar tissue that contributes to recurrent strictures. The application process generally involves topical administration of MMC onto the stricture site following mechanical dilation, allowing for prolonged exposure to the affected tissue.

One of the major indications for MMC in esophageal strictures is its use in cases caused by caustic ingestion. Caustic esophageal injuries can lead to extensive fibrosis and stricture formation, often necessitating prolonged treatment courses. Comparative studies have shown that patients receiving MMC after dilations required significantly fewer sessions compared to those treated with dilation alone. The success of MMC in these cases underscores its potential to alter the natural history of caustic esophageal injuries, allowing for improved patient outcomes and reduced healthcare burdens. Furthermore, randomized controlled trials have demonstrated that MMC not only decreases the frequency of dilations but also prolongs the intervals between necessary interventions.

Despite its efficacy, there remains debate regarding the optimal concentration, frequency, and duration of MMC application. Some techniques involve the use of MMC-soaked pledges applied directly to the stricture site for a short duration, while others employ injection methods to ensure deeper penetration of the drug into fibrotic tissue. The concentration of MMC used in most studies ranges from 0.4 mg/mL to 1.0 mg/mL, with application times varying between one and five minutes. Long-term follow-up of patients treated with MMC has shown that recurrence rates of strictures remain low, supporting the notion that MMC provides durable benefits in managing esophageal narrowing.

The safety profile of MMC in esophageal applications has been a subject of investigation, given its cytotoxic nature. Reports indicate that topical MMC application does not lead to significant systemic absorption, thereby minimizing the risk of systemic toxicity. Studies following patients over extended periods have found no evidence of dysplasia or malignant transformation at the sites of MMC application. However, concerns remain regarding potential complications such as mucosal thinning, delayed healing, and perforation, though these have not been widely reported. These findings suggest that MMC, when used appropriately, offers a safe and effective adjunct to traditional dilation therapies.

Innovations in MMC application techniques have also contributed to its growing acceptance. The use of modified catheters and endoscopic delivery systems has improved precision and minimized unintended exposure to surrounding healthy mucosa. Some studies have introduced endoscopic-guided injection techniques that allow for targeted drug delivery, further enhancing the therapeutic effect while reducing the risk of complications. Additionally, comparisons between MMC and other therapeutic agents, such as

triamcinolone, indicate that MMC may offer superior long-term efficacy in reducing stricture recurrence. While steroid injections have been used for similar indications, they primarily exert anti-inflammatory effects without the long-lasting antifibrotic action of MMC.

Beyond the pediatric population, MMC has shown promise in adult patients with refractory esophageal strictures. Cases of peptic, radiation-induced, and anastomotic strictures have responded favorably to MMC application. The consistency of positive outcomes across different patient demographics supports the broader adoption of MMC in clinical practice. However, continued research is needed to refine treatment protocols, particularly regarding repeated applications and combination therapies that may further enhance outcomes.

Despite the compelling evidence supporting MMC, there are limitations to its widespread adoption. The lack of standardized protocols across institutions leads to variability in treatment outcomes. Additionally, long-term multicenter studies are necessary to establish definitive guidelines for its use. The economic impact of MMC therapy also warrants consideration, as it has the potential to reduce healthcare costs associated with repeated hospitalizations and procedural interventions.

The use of MMC in the treatment of esophageal strictures represents a significant advancement in the field of gastroenterology. Its ability to reduce stricture recurrence, decrease the number of necessary dilation sessions, and maintain long-term patency of the esophagus makes it a valuable adjunct in managing this challenging condition. While further research is needed to optimize application techniques and establish standardized protocols, current evidence supports its safety and efficacy. As more clinicians integrate MMC into their practice, the potential for improved patient outcomes and reduced treatment burden will continue to expand, making it a cornerstone therapy for refractory esophageal strictures.

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## **Moral Injury**

Moral injury is a psychological and emotional condition that arises when individuals engage in, witness, or fail to prevent actions that transgress deeply held moral beliefs. This phenomenon has been extensively explored within healthcare, particularly among physicians and surgeons, where high-stakes decision-making and ethical conflicts are inherent to the profession. Unlike post-traumatic stress disorder, which is often linked to fear-based trauma, moral injury is rooted in feelings of guilt, shame, and betrayal.

Within surgical professions, moral injury is frequently linked to adverse patient outcomes. Surgeons experience a profound emotional toll when their actions, despite best intentions, result in patient harm or complications. The psychological impact of these experiences has been characterized by phases: an initial emotional blow, a period of self-recrimination, attempts at recovery through peer discussions or self-imposed learning, and a long-term impact that can lead to either personal growth or cumulative emotional erosion. Persistent exposure to such experiences without adequate support can result in burnout and a deterioration of professional well-being.

Moral injury within healthcare extends beyond individual cases of medical error or adverse events. Systemic constraints—such as institutional policies, resource limitations, and administrative burdens—exacerbate moral conflicts. For example, the inability to provide equitable care due to financial restrictions or insurance limitations can create a moral dichotomy where providers feel compelled to act against their ethical commitment to patient welfare. The emotional strain from such systemic failures leads to disillusionment, cynicism, and an erosion of professional motivation.

The COVID-19 pandemic significantly intensified moral injury among healthcare workers. Physicians and nurses faced overwhelming patient loads, resource scarcity, and high mortality rates, all while struggling to uphold their moral commitment to patient care. The psychological burden was heightened by the necessity to ration care, a practice that contradicts the foundational principles of medical ethics. Studies have shown that during the pandemic, nearly half of healthcare professionals reported moral injury symptoms, with many experiencing persistent guilt, anxiety, and self-doubt regarding their clinical decisions.

In response to these challenges, research has explored various interventions to mitigate moral injury. One approach involves structured education and training in moral resilience, aimed at fostering emotional endurance and ethical decision-making skills. Workshops and curricula designed to enhance moral awareness and coping strategies have been shown to be effective in helping healthcare professionals navigate moral dilemmas. For instance, palliative care training has been implemented in surgical residencies to provide a framework for managing ethical conflicts and fostering self-reflection. Such initiatives encourage peer support and create opportunities for clinicians to process their experiences in a constructive manner.

Another critical factor in addressing moral injury is the role of institutional culture. A supportive work environment that encourages open discussions about moral distress and ethical challenges can significantly reduce the emotional burden on healthcare providers.

Peer debriefing sessions and mentorship programs facilitate collective coping mechanisms, allowing individuals to share their experiences and seek validation from colleagues who understand the complexities of medical decision-making. In contrast, environments that prioritize administrative efficiency over clinician well-being exacerbate moral injury by reinforcing a sense of helplessness and professional disillusionment.

Furthermore, systemic interventions that address the root causes of moral injury are essential. Policies aimed at reducing bureaucratic constraints, improving patient-to-provider ratios, and ensuring adequate mental health support for clinicians are crucial in mitigating long-term emotional distress. Institutions that recognize moral injury as a legitimate occupational hazard are more likely to implement measures that safeguard healthcare professionals from its most debilitating effects.

Despite growing awareness, barriers to addressing moral injury persist. Stigma surrounding emotional vulnerability in medical professions often prevents clinicians from seeking help or discussing their struggles openly. Many physicians fear that acknowledging moral distress may be perceived as professional weakness, leading to a reluctance to engage in support initiatives. Additionally, hierarchical structures within healthcare institutions can make it difficult for junior clinicians to voice concerns about ethical conflicts, further exacerbating their sense of isolation.

Longitudinal studies on moral injury suggest that its effects are cumulative, meaning that repeated exposure to morally distressing situations without adequate resolution can lead to profound psychological harm. Clinicians who experience chronic moral injury are at higher risk of burnout, depression, and suicidal ideation. Addressing moral injury, therefore, is not only a matter of individual well-being but also a critical factor in sustaining a functional and compassionate healthcare workforce.

In conclusion, moral injury is a pervasive issue in healthcare that stems from the complex interplay of individual experiences, systemic constraints, and institutional cultures. It manifests in profound emotional and psychological distress, particularly among surgeons and physicians who are frequently confronted with ethical dilemmas and adverse patient outcomes. While efforts to address moral injury through education, peer support, and systemic reforms show promise, persistent barriers remain. A comprehensive approach that integrates individual coping mechanisms with organizational and policy-level interventions is necessary to mitigate the long-term consequences of moral injury and preserve the ethical integrity of the healthcare profession.

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