

ANASTOMOTIC LEAK AFTER COLORECTAL SURGERY: A NARRATIVE REVIEW OF CLASSIFICATION, RISK FACTORS, DIAGNOSIS, AND STRATEGIES FOR PREVENTION AND MANAGEMENT

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ABSTRACT

Anastomotic leak (AL) remains the most feared complication following colorectal surgery, contributing to significant morbidity, mortality (2–16%), and poorer long-term oncological outcomes. Despite advancements in surgical technology and perioperative care, its incidence has remained stable, ranging from 3% to 19% depending on anastomosis location. In this review, we synthesize current evidence on multifaceted risk factors of AL and propose integrated, multimodal strategies for its prevention and management. Key findings suggest that effective prevention must span the entire perioperative continuum, beginning with preoperative optimization of nutritional status, smoking cessation, and adoption of combined mechanical bowel preparation with oral antibiotic prophylaxis. Intraoperatively, meticulous technical execution focused on tension-free union and adequate perfusion—increasingly assessed through indocyanine green (ICG) fluorescence angiography—is essential to ensuring biological integrity. Postoperatively, early diagnosis is facilitated by standardized surveillance protocols utilizing biochemical markers—specifically dynamic C-reactive protein (CRP) trajectories—alongside contrast-enhanced computed tomography (CT) imaging. Management of AL has become increasingly tailored to individual's clinical stability and leak severity according to the International Study Group of Rectal Cancer (ISREC) grading, utilizing wide spectrum of interventions from conservative percutaneous drainage and emerging endoscopic vacuum therapy to definitive surgical re-intervention for source control. In conclusion, while technological innovations continue to evolve, the persistent challenge of AL necessitates coordinated, evidence-based approach to perioperative care, highlighting urgent need for further high-quality, multicenter research to validate emerging predictive models and salvage techniques.

KEYWORDS: Anastomotic leakage, colorectal surgery, colorectal cancer, C-reactive protein, computed tomography, indocyanine green fluorescence angiography, diverting stoma, endoscopic vacuum therapy, multimodal prevention.

INTRODUCTION

Anastomotic leak (AL) is formally defined as defect of intestinal wall integrity at the surgical join between two hollow viscera, leading to communication between intraluminal and extraluminal spaces.^{1,3} It encompasses leaks originating from suture and staple lines of neorectal reservoirs or pelvic abscesses adjacent to anastomosis and considers them as failure of intestinal integrity.^{1,4,5}

The reported incidence of AL in contemporary series typically ranges from 3% to 19%, though literature estimates as high as 26%, even approaching 30%.^{4,6,8} This variability is heavily contingent upon anatomical location and type of surgery performed; while right-sided colonic resections exhibit lower leak rates (1-3%), others, such as high-risk procedures of low rectal and coloanal anastomoses, are associated with rates as high as 20%.^{6,8}

Clinical significance of AL remains primary concern in colorectal surgery, as it is one of the most severe and life-threatening complications following colorectal procedures. Postoperative mortality directly attributed to anastomotic failure is reported to range between 2% and 16%, accounting for approximately one-third of all deaths.⁷ Additionally, patients experiencing leaks face prolonged hospitalizations, higher readmission rates, and likelihood of requiring further operative interventions.^{9,10}

Furthermore, AL significantly impacts long-term oncological outcomes for cancer patients.¹¹⁻¹³ Occurrence of leak is correlated with higher risk of local tumor recurrence and decrease in both overall and disease-free survival.^{11,13,14} Economic burden is also immense, with healthcare costs for such patients approximately two to three times higher than usual, driven by increased length of stay and intensive care requirements.¹¹

Rationale for this review stems from the fact that despite significant advancements in perioperative care, surgical expertise, and technology—including the adoption of robotic platforms and advanced stapling devices—incidence of AL has remained unacceptably stable over recent decades.^{10,12} This persistence indicates that fundamental pathogenesis and virtual mechanisms of AL are not yet fully understood and likely involve complex interactions between patient physiology,

technical execution, and emerging factors such as gut microbiome. Consequently, there is an urgent need for integrated, multimodal strategies that encompass the entire perioperative continuum to improve prevention and management of this devastating complication.¹¹⁻¹³

DEFINITION AND CLASSIFICATION OF ANASTOMOTIC LEAK

Lack of single, universally accepted definition has resulted in significant variability in reported incidence and clinical outcomes across literature.^{1,13,15,16} The International Study Group of Rectal Cancer (ISREC) proposed a definition that has since gained widespread acceptance, characterizing AL as defect of intestinal wall integrity at the surgical join between two hollow viscera, which leads to communication between intraluminal and extraluminal compartments.^{3,4,10,11,17} This definition explicitly includes leaks originating from suture or staple lines of neorectal reservoirs and recommends that any pelvic abscess located adjacent to anastomosis should also be classified as an anastomotic failure.^{4,5,18} In 2015, the International Multispecialty Anastomotic Leak Global Improvement Exchange (IMAGInE) endorsed and further expanded this standardized definition to apply to the entire gastrointestinal tract (GIT).^{3,5}

AL is categorized into three distinct grades based on its impact on clinical management.^{2,3,5} Grade A leaks, identified through radiological imaging, are considered subclinical without causing obvious symptoms and require no change in patient's treatment plan.^{2,4,10} Grade B leaks require active therapeutic intervention, such as administration of antibiotics or percutaneous drainage, but can be managed successfully without any surgical re-intervention. Grade C leaks are the most severe, characterized by significant clinical deterioration or peritonitis that necessitate an urgent surgical re-intervention, often involving take-down of the anastomosis or creation of diverting stoma.^{2,5}

Additionally, AL is also classified by the time to its onset into early and late leaks.^{13,19,20} While definitions vary, early leaks are those that are diagnosed within first week postoperatively and attributed to technical failures, including iatrogenic vascular disruption or excessive

tension at the site. Late leaks, which may be diagnosed more than 30 days after surgery, are associated with patient-related factors, including poor nutrition, radiation exposure, or chronic immunosuppression.^{13,19,20}

RISK FACTORS FOR ANASTOMOTIC LEAK

Risk factors for AL are generally categorized into patient-related, disease-related, and intraoperative factors.^{3,11,13,21}

PATIENT-RELATED FACTORS

Male sex has been consistently identified as an independent risk factor for AL in colorectal resections. It is partially attributed to the technical challenges of creating an anastomosis within the narrower male pelvis and potentially negative metabolic impact of higher visceral fat levels found in men.^{22,24} While advanced age is often associated with higher postoperative mortality when leak occurs, its role as predictor for AL remains subject to debate.^{5,8,16} Some studies suggest that older patients have reduced physiological resilience, whereas others have surprisingly found younger age to be an independent risk factor in specific large-scale audits.⁵

Malnutrition and hypoalbuminemia (serum albumin <3.5 g/dL) significantly impair biological healing process, leading to higher leak rates.^{10,25} Lifestyle factors such as smoking and excessive alcohol consumption also elevate risk; nicotine-induced vasoconstriction and microvascular disease can lead to local tissue ischemia, while alcohol abuse often serves as surrogate for poor underlying nutritional status.³ Patient comorbidities and overall health status, frequently quantified by an American society of Anesthesiologists (ASA) score of III or higher, are strong predictors of anastomotic failure.²⁶ Diabetes mellitus is particularly challenging, as hyperglycemia impairs neutrophil function and angiogenesis, directly hindering tissue repair.¹⁰ Other systemic conditions, including cardiovascular, pulmonary, and renal diseases, further increase risk by compromising microvascular perfusion to the healing anastomosis.²⁴ Furthermore, use of certain medications can be deleterious; chronic steroid and immunosuppressant use has been shown to significantly increase incidence of AL.^{27,29}

Emerging evidence also suggests that biological agents, such as bevacizumab, may impair healing due to their anti-angiogenic properties.³⁰

DISEASE-RELATED FACTORS

The anatomical location of tumor is perhaps the most significant disease-related predictor, with low rectal tumors posing the highest risk.³¹ Anastomoses located within 5 to 7 cm of the anal verge are associated with leak rates much higher than those of more proximal colon, likely due to limited pelvic space and compromised blood supply in deep pelvis.^{5,8}

Inflammation, in setting of obstruction, peritonitis, inflammatory bowel disease, or acute diverticulitis, also complicates healing.^{32,33} Radiation therapy is another major factor, especially in rectal cancer management. While preoperative radiotherapy or chemoradiotherapy reduces local recurrence, it can cause radiation injury to intestinal wall and decrease microvessel density at surgical margins, potentially predisposing the site to failure.²⁴

INTRAOPERATIVE FACTORS

Iatrogenic disruption of microvascular supply or watershed areas, such as Griffith's point, can lead to localized ischemia and subsequent dehiscence.¹ Consequently, preserving the left colic artery during high vascular ligation is often advocated to improve stump perfusion. Equally important is avoidance of anastomotic tension, which can create gaps in suture or staple line and further exacerbate ischemia.¹

Technical errors, including improper stapler selection, staple line disruptions, or the need for multiple stapler firings (>2), have been correlated with increased leak rates.^{34,35} Prolonged operative time, often exceeding 180 to 220 minutes, is another reported risk factor, possibly reflecting the complexity of such cases or the impact of surgeon fatigue. Additionally, emergency procedure is associated with higher risk of AL compared to elective, attributed to gross contamination, bowel obstruction, and hemodynamic instability often seen in emergency patients, leading to compromised primary anastomosis.^{36,37}

STRATEGIES FOR PREVENTION *PREOPERATIVE OPTIMIZATION*

Preoperative optimization can help identify and mitigate modifiable patient-related risk factors.^{3,11} Hypoalbuminemia, a potent predictor of anastomotic failure, should be corrected through targeted nutritional support.³⁸ Use of enteral nutrition for at least 7 to 14 days in severely malnourished patients can stimulate intestinal function and reduce postoperative complications.³⁹ While role of immunonutrition containing arginine and omega-3 fatty acids remains debated subject, some evidence suggests it may reduce overall inflammatory response and improve outcomes in GIT surgery.^{40,41}

Lifestyle modifications, specifically smoking and alcohol cessation, are essential components of preoperative optimization.⁴ Smoking increases risk of AL by inducing tissue ischemia through nicotine-associated vasoconstriction and carbon monoxide-induced cellular hypoxia.⁴² Even long-term smoking cessation is beneficial, though some studies suggest that individuals who have quit for fewer than 10 years still carry higher risk compared to those who have never smoked.⁴³ Excessive alcohol consumption also elevates risk, often serving as surrogate marker for poor underlying nutritional status.⁴²

Prehabilitation has emerged as novel multimodal strategy within Enhanced Recovery After Surgery (ERAS) protocols to improve physiological resilience before stress of the surgery. This process typically involves nutritional counseling, psychological support, and physical training, including aerobic exercise and inspiratory muscle training.⁴⁴ Research indicates that a structured four-week prehabilitation program can be more effective than postoperative rehabilitation alone in enhancing functional capacity and reducing overall morbidity.⁴⁵

Role of bowel preparation remains one of the most debated topics in colorectal surgery.¹¹ While mechanical bowel preparation (MBP) alone was dogmatically practiced for decades, numerous randomized controlled trials and meta-analyses have demonstrated that MBP alone does not significantly reduce the incidence of AL and may even cause dehydration and electrolyte imbalances. However, contemporary evidence has shifted toward a combined approach utilizing both MBP and oral

antibiotics.⁴⁶⁻⁴⁸ Recent large-scale reviews and clinical guidelines now suggest that this combination significantly reduces overall rates and surgical site infections by decreasing colonic bacterial load and modulating gut microbiome. Although some controversy persists regarding use of oral antibiotics alone versus combined regimen, the trend in modern surgical practice strongly favors integration of oral antibiotic prophylaxis into standard preoperative protocols.^{47,48}

INTRAOPERATIVE STRATEGIES

Intraoperative strategies for preventing AL center on meticulous surgical technique and the use of adjunct technologies to ensure integrity of the union. The fundamental principles of successful anastomosis include the use of healthy bowel ends, maintenance of an adequate blood supply, and creation of tension-free union.¹³ Tension is particularly deleterious as it may create gaps in the suture or staple line while inducing secondary ischemia through longitudinal stretching of gastrointestinal conduit.^{8,17} Surgeons often employ techniques such as extensive mobilization of splenic flexure or preservation of left colic artery during vascular ligation to optimize perfusion and minimize tension.²

Choice between stapled and hand-sewn techniques remains subject of ongoing clinical debate.⁴⁹ Systematic reviews and Cochrane analyses of colorectal anastomoses have generally failed to demonstrate definitive superiority for either method regarding AL rates, though intraoperative technical problems and postoperative strictures are reported more frequently with stapling.⁸ However, evidence specifically concerning ileocolic anastomoses tends to favor the stapled approach, which has been correlated with significantly lower leak rates compared to manual suturing.⁹ In deep pelvis, circular stapling devices are often preferred due to their technical ease and ability to perform sphincter-saving operations that might otherwise require permanent colostomy.^{50,51}

The objective assessment of perfusion has evolved from subjective visual cues, such as mucosal color and bleeding at cut edges, to more advanced technological modalities. Indocyanine green (ICG) fluorescence angiography has

emerged as prominent tool, utilizing near-infrared light to visualize real-time microperfusion. Several studies indicate that ICG angiography can lead to change in surgical plan—specifically selection of more proximal transection line with better vascularity—thereby reducing incidence of AL.⁷ Despite these findings, some multicenter randomized controlled trials, such as PILLAR III, did not show significant reduction in low anterior resections, suggesting that its benefit in routine is still being defined.¹¹

Role of diverting stoma (either loop ileostomy or colostomy) is a critical consideration, particularly in high-risk procedures like low anterior resection.¹ While it does not necessarily prevent occurrence of an anastomotic defect, it is highly effective in reducing clinical consequences and severity of leak by diverting fecal stream away from site of failure.⁵ Randomized trials and meta-analyses have confirmed that defunctioning significantly lowers the rates of symptomatic AL and need for urgent surgical re-intervention. However, these benefits must be balanced against stoma-related morbidities, including dehydration, electrolyte imbalances, and inherent risks of secondary procedure for stoma reversal.¹

Intraoperative leak testing is a standard practice designed to identify and immediately repair non-air-tight or non-water-tight anastomoses. The air leak test (insufflation of bowel with air while anastomosis is submerged) and the dye test (instillation of methylene blue) are the most common methods. Evidence suggests that identifying and repairing defects intraoperatively can significantly reduce rate of subsequent clinical leaks.^{52,53} Additionally, intraoperative colonoscopy may be utilized for direct visualization of staple line to check for bleeding, proper alignment, and integrity of the tissue "donuts".⁵⁴

Advancements in minimally invasive surgery, including laparoscopic and robotic approaches, have largely replaced traditional open surgery for many colorectal indications. Laparoscopic procedures are associated with reduced intraoperative blood loss, less pain, and shorter hospitalizations.^{55,56} While some large-scale database reviews suggest that laparoscopy may be associated with lower AL rates, most randomized clinical trials indicate that risk of leakage is

comparable between open and laparoscopic approaches when performed by skilled surgeons.⁵ Robotic platforms offer further technical advantages, such as enhanced maneuverability in confined male pelvis and more precise stapling, yet major trials like ROLARR have found no significant difference in AL incidence between robotic and laparoscopic rectal resections.⁵⁷

POSTOPERATIVE PREVENTION

Postoperative prevention and mitigation of clinical impact of AL rely on standardized recovery pathways and protocols for early detection. Implementation of ERAS protocols is central to this strategy, emphasizing early mobilization, optimized pain control, and avoidance of traditional practices that may delay intestinal recovery.^{13,15} While ERAS aims to reduce overall morbidity, its success in preventing AL is often tied to maintaining physiological homeostasis and identifying subtle signs of failure before they progress to systemic sepsis.^{13,58}

Critical component of postoperative care is avoidance of hypotension and hypoperfusion, as adequate blood pressure is essential for microvascular perfusion of the healing anastomosis.^{7,17}

Intraoperative and postoperative hypotensive episodes have been directly associated with increased leak rates, likely by exacerbating local tissue hypoxia.^{4,11} Findings from the LekCheck study indicate that requirement for vasopressors in perioperative period significantly increases AL risk, with the use of phenylephrine associated with fourfold higher risk of leak compared to noradrenaline (odds ratio=4.2), potentially due to its more pronounced vasoconstrictive effects on microcirculation.¹⁷ Consequently, standardized continuous monitoring of perioperative hemodynamics is pivotal to ensure biological integrity of the join.⁴

Management of postoperative diet has evolved from the traditional "nil by mouth" approach to promotion of early enteral nutrition. While historical practice was to fast patients until the return of bowel function to protect anastomosis, contemporary evidence suggests that early oral intake within 24 hours is well-tolerated and may stimulate intestinal function while accelerating wound healing through increased protein

availability.^{38,39} A Cochrane meta-analysis of 13 randomized controlled trials found that while early enteral nutrition significantly reduces length of hospital stay, it does not statistically alter biological incidence of AL.⁵⁴ Nevertheless, prospective studies suggest that early feeding can reduce incidence of postoperative ileus and stimulate intestinal barrier, making it safe and recommended component of modern recovery.^{9,61}

Early detection protocols are vital because clinical signs of AL are often non-specific and can be masked by the use of neoadjuvant therapy or diverting stoma.^{62,63} Standardized surveillance frequently utilizes biochemical markers, with C-reactive protein (CRP) being the most extensively studied. CRP level below 135 mg/L or 172 mg/L on postoperative days 3 to 5 has high negative predictive value (89-97%), allowing for safe exclusion of AL and potential early discharge. Conversely, an increase in CRP of more than 50 mg/L in 24-hour period after third day is highly specific for leak.⁷ Procalcitonin (PCT) is also utilized as more specific marker of bacterial infection, with elevated levels on first or second postoperative day serving as an early warning sign of sepsis.¹⁷ To further standardize clinical judgment, various scoring systems have been developed, such as the Dutch Leakage (DULK) score and the Colon Leakage Score (CLS).¹ These models incorporate parameters including vital signs, respiratory rate, and laboratory data to identify high-risk patients who require urgent imaging or re-intervention.³ Surgeons must remain particularly vigilant for insidious presentations such as low-grade fever, diarrhea, or subtle increase in heart rate, as delayed diagnosis significantly increases risk of mortality and permanent stoma formation.^{62,63}

DIAGNOSIS OF ANASTOMOTIC LEAK

AL commonly becomes apparent on 5-7th postoperative days, although it can occur till 30 or more days.⁷ Clinical picture has a broad spectrum, ranging from subclinical radiological findings to fulminant peritonitis and multi-organ failure.¹⁵ Classic presentation includes abdominal pain, diffuse guarding with positive peritoneal signs, and hemodynamic instability.¹² However, it can be more subtle with non-specific indicators like fever, tachycardia, tachypnea, and

oliguria.¹² Prolonged postoperative ileus, cardiac arrhythmias like atrial fibrillation, and lower respiratory tract infections may also serve as early clues to an underlying anastomotic failure.⁶⁴ These symptoms are often insidious with diverting stoma or previous neoadjuvant therapy, often manifesting as low-grade fever, diarrhea, or pus discharge per anal.¹² Given low specificity of early clinical signs, biochemical markers, CRP and PCT play crucial role. CRP negative predictive value ranges between 89-97%, allowing to safely exclude leak.¹ While definite cut-off values vary between 135 mg/L and 172 mg/L across different series, CRP trajectory increase of more than 50 mg/L in 24-hour period after third postoperative day is highly specific (96%) for leak.¹ PCT is more specific for bacterial infection and sepsis than CRP, with elevations above 2.0 ng/mL on first or second postoperative day providing an early warning of dehiscence.¹⁷ Combining CRP and PCT measurements further enhances diagnostic accuracy up to 0.9 for predicting major leaks.¹ Other less specific markers include raised white blood cell count and neutrophil-to-lymphocyte ratio on fourth day, though less predictive than CRP.⁶⁴

Computed tomography (CT) scan has superseded water-soluble contrast enemas as the gold standard imaging modality for diagnosing AL.¹ CT accuracy is further enhanced by adding rectal contrast enema, reaching the site of union. It is more reliable than oral contrast and increases diagnostic sensitivity from 65% to 75%.¹⁷ Radiological signs include extravasation of intraluminal contrast, localized perianastomotic air or fluid collections, extraluminal free air, and localized para-anastomotic inflammatory stranding.¹ Sometimes leak is difficult to confirm via CT during first three to four days postoperatively due to presence of expected surgical fluid and normal inflammatory changes at the site.¹⁷

MANAGEMENT STRATEGIES

GENERAL PRINCIPLES

Early diagnosis is the critical determinant of successful management for an AL, facilitating prompt resuscitation to prevent progression to septic shock and multi-organ failure. Therapeutic approach is not standardized but is instead highly individualized, predicated

primarily on patient's clinical stability, severity of the leak, and its anatomical location.¹³ Hemodynamically stable patients without peritonitis are typically candidates for non-operative approach, whereas those with physiological compromise or diffuse peritonitis mandate urgent surgical re-intervention.³ Furthermore, presence of proximal diverting stoma fashioned during index operation often shifts management toward conservative pathways by limiting fecal contamination and containing pelvic sepsis.^{3,12}

CONSERVATIVE MANAGEMENT

Conservative management is specifically indicated for clinically stable patients with minor, localized leaks (Grade A or B) or contained pelvic collections.²¹ This strategy include administration of broad-spectrum antibiotics, bowel rest, and intensive intravenous nutritional support.¹³ Antibiotic coverage must be broad-spectrum to address high prevalence of multidrug-resistant organisms in postoperative peritonitis, such as *Pseudomonas* and extended-spectrum β -lactamase-producing *Enterobacteriaceae*.⁶⁵ While minor abscesses (<3cm) can be managed successfully with antibiotics alone, large collections typically require ultrasound or CT-guided percutaneous drainage, with reported success rates ranging from 78% to 85%.²¹ However, source control remains primary objective; inadequate drainage after first attempt is potent predictor of an unfavorable outcome.^{1,12} Consequently, continuous surveillance for clinical signs of deterioration is mandatory and failure of source control or onset of sepsis must prompt an immediate escalation to operative intervention.¹³

ENDOSCOPIC MANAGEMENT

Endoscopic management has emerged as promising strategy for anastomotic salvage in physiologically stable patients, particularly when systemic sepsis is absent or well-controlled.¹⁵ These techniques are increasingly utilized as diagnostic and therapeutic alternatives to reduce high morbidity of surgical re-intervention, especially for extraperitoneal leaks in lower rectum.¹⁷ Endoluminal vacuum therapy (EVT), specifically utilizing the Endo-SPONGE system, promotes wound healing through application of

constant suction, which enhances granulation tissue formation, reduces local edema, and decreases bacterial colonization.¹² Systematic reviews indicate that EVT can achieve overall anastomotic salvage rates of approximately 88.8%, with some specialized series reporting success as high as 92% in patients without generalized peritonitis.²¹ However, this approach is time and resource-intensive, typically requiring 7 to 11 endoscopic sponge changes every 2 to 4 days, which often necessitate sedation or anesthesia.¹⁷

Use of self-expanding metal stents (SEMS) aims to prevent communication between lumen and extraluminal space, protecting patient from sepsis while allowing for tissue growth and regeneration.^{17,66} While long-term salvage rates are high (50-100%), stents are generally not suitable for anastomoses encroaching the anal verge due to of migration, tenesmus, and incontinence.⁶ Endoscopic clips, particularly the over-the-scope clip (OTSC) system, are emerging as reliable tools to re-approximate anastomotic dehiscence in acute leaks and small defects (<2cm).¹² Durable closure for OTSC is reported (57-100%) in clinical series, though its efficacy is significantly impaired by presence of fibrotic or inflamed sinus tracts.¹⁷ Additionally, fibrin glue or sealants may be utilized endoscopically for very small defects (2–5 mm) or as an adjunct following successful reduction of an abscess cavity by vacuum therapy.⁶⁶

SURGICAL MANAGEMENT

Surgical re-intervention remains definitive strategy for clinical instability, generalized peritonitis, or hemodynamic changes associated with severe sepsis.¹⁵ Primary objectives of operative management are rapid source control through removal of fecal contamination and thorough peritoneal washout.¹⁷ For stable patients with accessible anastomoses and limited contamination, "divert and drain" approach—involving proximal loop ileostomy and localized pelvic drainage while leaving anastomosis intact—has become increasingly popular. This salvage-oriented strategy is associated with threefold increase in likelihood of future stoma reversal compared to procedures that involve initial takedown of primary join.⁶⁶

Conversely, an ischemic/necrotic anastomosis, severe multi-organ failure, or large defect

exceeding one-third of luminal circumference necessitates formal takedown of the anastomosis. This radical approach involves creation of end stoma via Hartmann's procedure with distal rectal stump or mucous fistula for decompression. While highly effective at eliminating sepsis source, it carries significant risk of long-term morbidity, as 23% to 56% of end stomas created for leak are never reversed.¹ In exceptional cases where dense inflammatory phlegmon makes anastomosis completely inaccessible, surgeons may be restricted to intraoperative drainage of perianastomotic area to prevent further iatrogenic injury.²¹

MANAGEMENT BASED ON LEAK GRADE

Clinical approach to managing AL is increasingly guided by standardized grading system proposed by the ISREC, which categorizes leaks based on their impact on clinical management. Grade A leaks are defined as subclinical defects identified through radiological findings that do not require any active therapeutic intervention.¹³ For these patients, management remains observational, as leak does not alter postoperative course or clinical care plan.¹⁷

Grade B leaks represent symptomatic complications that mandate active therapeutic intervention but can be successfully managed without formal surgical re-intervention.¹³ Management of Grade B leaks typically involves administration of broad-spectrum antibiotics and, when localized collections are present, the use of image-guided percutaneous drainage or endoscopic vacuum therapy.²² These non-operative strategies are indicated for physiologically stable patients where source control can be achieved without opening abdominal cavity.⁵

In contrast, Grade C leaks are the most severe, characterized by clinical deterioration, generalized peritonitis, or septic shock that necessitates urgent surgical re-intervention.¹³ Operative management for Grade C leaks focuses on rapid source control through peritoneal washout and may involve either creation of diverting stoma or formal takedown of the anastomosis with creation of an end stoma.⁹ Linking management directly to ISREC grading ensures that the intensity of treatment is commensurate with clinical severity of leak,

optimizing patient safety while avoiding unnecessary re-operations.²²

OUTCOMES AND PROGNOSIS

AL has profound impact on both short-term and long-term prognosis. Postoperative mortality directly associated with it ranges between 2% and 16%, accounting for approximately one-third of all postoperative fatalities following colorectal resections.¹⁷ Morbidity rates are equally substantial, ranging from 20% to 35%, often involving multiple concurrent infectious complications.¹⁵

Economic and clinical burden of AL is reflected in significantly prolonged hospitalizations, with one report indicating mean duration of 31 days for the leak group versus 18.3 days for the no-leak group.⁸ These patients often require multiple visits to operating room for sepsis control¹⁵ and even after successful surgical management, between 23% and 56% of stomas created due to leak are never reversed, which further impacts their quality of life.⁴

Following an anastomotic failure, patients are more prone to developing Low Anterior Resection Syndrome (LARS), including symptoms of fecal urgency, incontinence, and reduced neorectal capacity.⁶⁶ They often persist long after surgical join has healed.¹

Occurrence of leak is independently correlated with higher risk of local tumor recurrence among oncological patients and significant decrease in both overall and disease-free survival.¹⁷ This recurrence has been attributed to favorable environment for exfoliated malignant cells and delay in initiating adjuvant chemotherapy.¹

EMERGING TRENDS AND FUTURE DIRECTIONS

Integration of artificial intelligence (AI) and machine learning into clinical practice represents a major shift in early prediction of AL. These systems can process vast arrays of patient and intraoperative data, demonstrating high predictive accuracy between 0.766 and 0.87. They are being used to develop risk calculators and real-time microcirculation analysis systems that utilize ICG to objectively assess anastomotic safety.^{1,13,15} Regarding biomarkers, focus has shifted from single-point cut-offs to dynamic CRP trajectories, where

increase of more than 50 mg/L in 24-hour period after third postoperative day is highly specific (96%) for an impending leak.^{1,17} Furthermore, emerging research about peritoneal markers, such as matrix metalloproteinase-9 (MMP-9), calprotectin, and neopterin, offers the potential to detect healing disturbances before sepsis onset.³ Personalized risk prediction models, such as the Colon Leakage Score (CLS) and the Rectal Anastomotic Leak (REAL) score, are increasingly being refined to help surgeons decide whether to perform primary anastomosis or diverting stoma.^{9,21} Advances, including hyperspectral and laser speckle contrast imaging, aim to provide more robust understanding of tissue perfusion than traditional visual cues.⁵

CHALLENGES AND CONTROVERSIES

Diverting stoma remains debated topic in colorectal surgeries, as it reduces severity of leak but does not prevent its occurrence. While large-scale trials support routine diversion for high-risk low rectal anastomoses, it is offset by stoma-related complications, including acute kidney injuries from high output and unintended permanent stomas.¹ The MBP debate has similarly shifted; while alone, it is considered potentially harmful due to electrolytes shift, its combination with oral antibiotics has been shown to significantly reduce AL and surgical site infection rates.⁴ However, certain large retrospective studies have found no additional benefit to the mechanical component of the regimen.⁵ Progress in establishing standard definition was achieved by ISREC classification and its extension to entire GIT, yet heterogeneity in reported incidence and outcome remains a challenge for global research comparison.¹ Finally, utilization of novel endoscopic techniques remains a challenge as optimal management algorithms often rely more on institutional expertise than on high-quality evidence.¹⁵

CONCLUSION

Despite advancements in perioperative care, surgical technology, and specialized training, AL remains the most devastating complication following colorectal resections. With incidence between 3% and 19%, it remains as leading cause of postoperative mortality, morbidity, and

poor oncological outcomes. Stable incidence rates over recent decades suggest complexity of its pathogenesis and are likely not yet fully understood.

Effective prevention of AL necessitates an integrated, multimodal strategy that encompasses entire perioperative continuum. Mitigation of clinical impact of an AL relies on early detection protocols and high index of clinical suspicion. Standardized biochemical markers and imaging modalities facilitate prompt identification before onset of systemic sepsis. Management must be tailored to each patient's physiological stability and severity of leak, utilizing spectrum of interventions ranging from conservative percutaneous and endoscopic salvage to urgent surgical re-intervention.

While adoption of robotic platforms and enhanced recovery pathways has improved surgical precision, persistent incidence of AL highlights critical need for further high-quality research. Large-scale, multicenter randomized controlled trials are essential to validate emerging technologies—such as artificial intelligence-driven risk calculators and real-time microcirculation analysis—and to definitively elucidate biological role of gut microbiota in anastomotic failure.

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