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Review Article

Preparation for Gastrointestinal Endoscopy and Its Complications: A Narrative Review

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ABSTRACT

Background: Gastrointestinal endoscopy is central to diagnosis and minimally invasive treatment but can cause bleeding, perforation, cardiopulmonary events, infection, and post-endoscopic retrograde cholangiopancreatography pancreatitis.
Methods: This narrative review searched PubMed/MEDLINE, Embase, Scopus, and society websites for English-language guidelines, systematic reviews, randomized trials, and major observational studies published from 2015 to 2026. Search concepts combined gastrointestinal endoscopy with preparation, fasting, bowel preparation, sedation, antithrombotic therapy, infection, adverse events, bleeding, perforation, ERCP, EUS, EMR, ESD, and prevention. Authoritative guidance and higher-level evidence were prioritized; seminal older sources were retained when necessary.
Results: Safe practice requires procedure- and patient-specific assessment, including aspiration, cardiopulmonary, bleeding, thromboembolic, renal, and infectious risks. Antithrombotic decisions must account for procedure bleeding risk, indication, renal function, coronary stents, dual antiplatelet therapy, and the need for bridging. Standardized adverse-event definitions, early imaging, and predefined escalation pathways improve recognition and management. Rectal nonsteroidal anti-inflammatory drugs and selective pancreatic stenting reduce the risk of post-ERCP pancreatitis, while complete drainage and selective antibiotics reduce the risk of infection.
Conclusions: Individualized preparation, evidence-based prophylaxis, trained sedation teams, and rapid multidisciplinary escalation are the principal safeguards across diagnostic and therapeutic endoscopy.

1. Introduction

Gastrointestinal (GI) endoscopy enables direct diagnosis, tissue acquisition, surveillance, and minimally invasive therapy. Its scope now includes endoscopic retrograde cholangiopancreatography (ERCP), endoscopic ultrasound (EUS), endoscopic mucosal resection (EMR), endoscopic submucosal dissection (ESD), peroral endoscopic myotomy (POEM), and endoscopic bariatric procedures [1–3].

Although diagnostic procedures are generally safe, adverse events remain clinically important and vary with patient comorbidity, sedation depth, procedural complexity, and operator experience. Cardiopulmonary events predominate in routine endoscopy, whereas bleeding, perforation, infection, and post-ERCP pancreatitis are major concerns after therapeutic procedures [4–6].

Risk reduction begins before the procedure through focused medical and airway assessment, appropriate fasting and bowel preparation, individualized sedation, selective antibiotic prophylaxis, antithrombotic planning, informed consent, and reliable post-procedure instructions [7–10].

Because guidance varies across procedures and continues to evolve, an integrated synthesis is needed to distinguish diagnostic from therapeutic risk and translate recommendations into operational prevention and escalation pathways.

This narrative review summarizes contemporary evidence on preparation for GI endoscopy and the prevention, standardized recognition, and management of adverse events associated with diagnostic and advanced therapeutic procedures.

2. Review Methodology

This work was designed as a narrative review. PubMed/MEDLINE, Embase, Scopus, and the websites of ASGE, ESGE, ACG, AGA, the British Society of Gastroenterology, and relevant anesthesia societies were searched for English-language material published from 2015 through 2026. Search terms combined gastrointestinal endoscopy, upper endoscopy, colonoscopy, ERCP, EUS, capsule endoscopy, device-assisted enteroscopy, EMR, ESD, POEM, preparation, fasting, bowel preparation, sedation, antithrombotic, infection, bleeding, perforation, pancreatitis, adverse event, and management. Guidelines, consensus statements, systematic reviews, randomized trials, and large observational studies were eligible when they addressed adult preparation, prevention, incidence, recognition, or

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management. Pediatric-only studies, non-endoscopic surgery, single-patient reports, and sources without directly relevant outcome or recommendation data were excluded. The author screened titles and abstracts, reviewed potentially relevant full texts, and prioritized current authoritative guidelines, systematic reviews, and randomized evidence; seminal older publications were retained for definitions or areas without newer evidence. Because selection and synthesis were narrative, no meta-analysis or formal risk-of-bias pooling was performed.

3. Preparation for Gastrointestinal Endoscopy

3.1. Pre-procedure Patient Assessment and Preparation

Appropriate patient assessment and preparation before gastrointestinal (GI) endoscopy constitute the foundation of safe, effective, and high-quality endoscopic practice. Comprehensive pre-procedure evaluation not only improves diagnostic accuracy and therapeutic success but also significantly reduces procedure-related complications, including cardiopulmonary events, bleeding, infection, aspiration, and unplanned hospital admissions. Current international guidelines emphasize that patient preparation should be individualized according to the patient's medical condition, procedural complexity, anticipated therapeutic intervention, and overall procedural risk rather than adopting a uniform approach for all patients. Careful risk stratification allows clinicians to optimize management of comorbid conditions, anticipate potential adverse events, and develop an appropriate procedural plan that maximizes both patient safety and clinical outcomes [11].

A thorough medical history remains the first and most important component of pre-endoscopic assessment. Particular attention should be directed toward cardiovascular disease, chronic respiratory disorders, diabetes mellitus, chronic kidney disease, chronic liver disease, neurological disorders, previous gastrointestinal surgery, pregnancy, inherited bleeding disorders, and prior complications related to endoscopy or anesthesia. Previous adverse reactions to sedation, difficult airway management, allergies to medications or contrast agents, and a history of aspiration should also be documented, as these factors may significantly influence procedural planning. Equally important is a comprehensive review of current medications, especially anticoagulants, antiplatelet agents, corticosteroids, immunosuppressive drugs, insulin, glucagon-like peptide-1 receptor agonists (GLP-1 RAs), and other medications that may alter procedural safety or require temporary modification before endoscopy [12].

Physical examination should focus on identifying factors that increase procedural risk. Airway assessment, including evaluation of mouth opening, neck mobility, dentition, and Mallampati classification, is particularly important for patients undergoing moderate or deep sedation. Baseline vital signs, oxygen saturation, body mass index, cardiovascular examination, respiratory status, and neurological function should be documented before the procedure. Patients with severe obesity, obstructive sleep apnea, congestive heart failure, chronic obstructive pulmonary disease, or advanced systemic illness require careful individualized planning because these conditions increase the likelihood of sedation-related cardiopulmonary complications. The American Society of Anesthesiologists (ASA) Physical Status Classification is widely used to estimate peri-procedural risk, and patients with ASA class III or higher often require additional monitoring or anesthesiology consultation, particularly before complex therapeutic procedures [13].

Routine laboratory testing is not necessary for every patient undergoing gastrointestinal endoscopy and should instead be guided by individual clinical indications. Complete blood count may be indicated in patients with suspected anemia or active gastrointestinal bleeding. In contrast, coagulation studies should be reserved for patients receiving anticoagulant therapy, those with known bleeding disorders, or individuals with advanced liver disease. Assessment of renal function is recommended before administration of nephrotoxic contrast media or when management of direct oral anticoagulants depends on kidney function. This selective approach reduces unnecessary healthcare costs while ensuring appropriate peri-procedural evaluation for patients at increased clinical risk [14].

Fasting and bowel preparation should be individualized. In patients without delayed gastric emptying, clear liquids are generally permitted until 2 hours before sedation and a light meal until 6 hours before sedation; longer restrictions or airway-protective strategies may be needed for obstruction, gastroparesis, active upper GI bleeding, severe reflux, or other aspiration risks. For GLP-1 receptor agonist users, current multisociety guidance favors continuation for most patients. At the same time, those with dose escalation, significant gastrointestinal symptoms, or other causes of delayed gastric emptying may require a 24-hour liquid diet, gastric ultrasound where available, anesthesia input, or postponement. Diabetes plans should prevent hypoglycemia and ketoacidosis. Split-dose polyethylene glycol is preferred for colonoscopy; patients with renal or cardiac disease require avoidance of inappropriate sodium-phosphate preparations and individualized hydration. Written consent and discharge instructions should address medication resumption and warning symptoms [12–15].

Overall, meticulous pre-procedure assessment and individualized patient preparation are cornerstones of safe gastrointestinal endoscopy. Integration of evidence-based risk stratification, optimization of underlying medical conditions, standardized fasting and bowel preparation protocols, careful medication management, informed consent, and patient education significantly reduce preventable complications while improving procedural quality and clinical outcomes. As gastrointestinal endoscopy continues to expand into increasingly complex therapeutic interventions, comprehensive patient preparation will remain an essential component of high-quality, patient-centered endoscopic care (Table 1).

3.2. Sedation and Anesthesia in Gastrointestinal Endoscopy

Sedation and anesthesia have become integral components of modern gastrointestinal (GI) endoscopy, substantially improving patient comfort, procedural tolerance, diagnostic accuracy, and therapeutic success. Although many diagnostic endoscopic procedures can technically be performed without sedation, most upper gastrointestinal endoscopy, colonoscopy, endoscopic ultrasound (EUS), endoscopic retrograde cholangiopancreatography (ERCP), and advanced therapeutic interventions are currently performed under moderate sedation, deep sedation, or general anesthesia. The primary objectives of sedation are to reduce patient anxiety and pain, facilitate completion of the procedure, improve procedural efficiency, and maintain adequate cardiopulmonary stability throughout the examination. The selection of the most appropriate sedation strategy should be individualized based on patient characteristics, procedural complexity, anticipated duration, underlying comorbidities, and the resources available within the endoscopy unit [16].

Comprehensive pre-sedation assessment is essential for minimizing sedation-related complications. Every patient should undergo careful evaluation of medical history, previous adverse reactions to anesthesia, current medications, allergies, cardiopulmonary disease, obstructive sleep apnea, alcohol or opioid use, and airway anatomy before sedation is administered. Airway assessment and classification

Table 1: Pre-procedure Patient Assessment Checklist

Assessment	Purpose
Medical history	Identify comorbidities
Physical examination	Evaluate procedural fitness
Medication review	Assess anticoagulants/antiplatelets
Laboratory tests	Identify bleeding risk
ASA classification	Estimate anesthesia risk
Fasting	Reduce aspiration
Informed consent	Patient education

Abbreviations: ASA, American Society of Anesthesiologists.

according to the American Society of Anesthesiologists (ASA) physical status are particularly important in identifying patients at increased risk of respiratory or cardiovascular complications. Elderly individuals, patients with obesity, chronic obstructive pulmonary disease, heart failure, chronic kidney disease, liver cirrhosis, or multiple systemic illnesses require individualized sedation plans and, in selected cases, anesthesiology consultation before complex therapeutic procedures [17].

Moderate (conscious) sedation remains the most commonly used technique for routine diagnostic endoscopy because patients maintain spontaneous ventilation and respond appropriately to verbal or tactile stimulation. Deep sedation is increasingly preferred for prolonged or technically demanding procedures such as ERCP, EUS-guided interventions, endoscopic submucosal dissection (ESD), and peroral endoscopic myotomy (POEM), as it provides greater patient immobility and procedural efficiency. General anesthesia is generally reserved for highly complex interventions, anticipated difficult airway management, patients with a high risk of aspiration, or situations in which complete patient immobility is essential. Regardless of the depth of sedation, clinicians should recognize that sedation exists on a continuum and that patients may unintentionally progress to a deeper level, requiring immediate airway support and advanced resuscitation skills [18].

Several sedative agents are routinely used during gastrointestinal endoscopy. Midazolam remains the most commonly administered benzodiazepine because of its rapid onset, anxiolytic effect, and short duration of action. Opioids such as fentanyl provide effective analgesia and are frequently combined with benzodiazepines to improve patient comfort during therapeutic procedures. Propofol has become the preferred agent for deep sedation because it provides rapid induction, excellent patient satisfaction, predictable recovery, and shorter discharge times. However, propofol possesses a narrow therapeutic window and may cause hypotension, respiratory depression, or apnea, emphasizing the importance of continuous monitoring and personnel trained in advanced airway management. Dexmedetomidine has emerged as an alternative sedative in selected patients because it produces minimal respiratory depression, although its use may be limited by bradycardia, hypotension, and slower onset of action. Continuous physiological monitoring is mandatory throughout sedation and the recovery period. Standard monitoring includes pulse oximetry, non-invasive blood pressure measurement, heart rate, respiratory rate, and assessment of the patient's level of consciousness. Electrocardiographic monitoring is recommended for patients with significant cardiovascular disease, while capnography is increasingly advocated during deep sedation because it detects hypoventilation earlier than pulse oximetry alone. The availability of supplemental oxygen, suction equipment, airway devices, reversal agents such as flumazenil and naloxone, and trained personnel capable of managing airway emergencies is essential in every endoscopy unit [19].

Although sedation is generally safe, cardiopulmonary complications remain the most common adverse events associated with gastrointestinal endoscopy. Respiratory depression, hypoxemia, airway obstruction, aspiration, hypotension, arrhythmias, and vasovagal reactions account for the majority of sedation-related morbidity. These complications occur more frequently among elderly patients, individuals with obesity or obstructive sleep apnea, those receiving excessive sedative doses, and patients with advanced cardiopulmonary disease. Most adverse events can be prevented through careful patient selection, appropriate dose titration, continuous monitoring, and prompt recognition of physiological deterioration. Patients should remain under observation until they have fully recovered, demonstrate stable vital signs, and meet standardized discharge criteria. Written post-procedure instructions should emphasize temporary restrictions on driving, operating machinery, alcohol consumption, and important decision-making for at least 24 hours following moderate or deep sedation [20].

Overall, safe sedation and anesthesia require a multidisciplinary approach involving appropriate patient assessment, individualized sedative selection, continuous monitoring, trained healthcare personnel, and adherence to international clinical guidelines. Advances in capnographic monitoring, computer-assisted sedation systems, artificial intelligence-supported physiological monitoring, and newer sedative agents are expected to further improve procedural safety while enhancing patient comfort and procedural efficiency in future gastrointestinal endoscopy practice (Table 2).

3.3. Infection Prevention and Antibiotic Prophylaxis

Infection prevention is a fundamental component of safe gastrointestinal (GI) endoscopy and plays a critical role in minimizing procedure-related morbidity and healthcare-associated infections. Although diagnostic and therapeutic endoscopic procedures are generally associated with a very low risk of clinically significant infection, the increasing complexity of therapeutic interventions, widespread use of reusable endoscopes, and emergence of multidrug-resistant microorganisms have highlighted the importance of comprehensive infection control practices. Current international guidelines emphasize that effective infection prevention requires a multidisciplinary approach incorporating meticulous endoscope reprocessing, strict adherence to standard infection control precautions, appropriate patient selection, evidence-based use of antibiotic prophylaxis, and continuous quality assurance within endoscopy units. When these

Table 2: Common Sedative and Anesthetic Agents Used During GI Endoscopy

Drug	Class	Main indication	Advantages	Major adverse effects
Midazolam	Benzodiazepine	Moderate sedation	Anxiolysis	Respiratory depression
Propofol	Sedative	Deep sedation	Rapid recovery	Hypotension
Fentanyl	Opioid	Analgesia	Strong analgesia	Respiratory depression
Dexmedetomidine	α_2-agonist	Selected patients	Minimal respiratory depression	Bradycardia

Abbreviations: GI, gastrointestinal.

measures are consistently implemented, the incidence of endoscopy-related infectious complications remains extremely low despite the growing complexity of modern endoscopic procedures [21].

The majority of procedure-related infections result from either endogenous bacterial translocation during therapeutic intervention or exogenous contamination from inadequately reprocessed endoscopes, contaminated accessories, medications, or environmental surfaces. Although transient bacteremia may occur after mucosal biopsy, esophageal dilation, or therapeutic interventions, clinically significant bloodstream infection is uncommon because circulating microorganisms are usually eliminated rapidly by the host immune system. Nevertheless, patients undergoing advanced therapeutic procedures, particularly those involving biliary or pancreatic interventions, immunosuppression, or prosthetic device placement, require careful evaluation because they may be at increased risk of infectious complications. Consequently, every endoscopy unit should maintain standardized infection prevention protocols, staff competency programs, and regular surveillance of endoscope reprocessing practices to ensure patient safety [22].

Proper endoscope reprocessing remains the cornerstone of infection prevention in gastrointestinal endoscopy. Effective reprocessing includes immediate bedside pre-cleaning after completion of the procedure, leak testing, meticulous manual cleaning using enzymatic detergents, high-level disinfection with approved chemical agents, thorough rinsing, complete drying of internal channels, and appropriate storage in ventilated cabinets designed specifically for flexible endoscopes. Failure at any stage of this process may permit microbial survival, biofilm formation, and patient-to-patient transmission of infectious organisms. Particular attention has been directed toward duodenoscopes because their complex elevator mechanism makes complete cleaning more difficult and has been associated with outbreaks involving carbapenem-resistant Enterobacterales (CRE) and other multidrug-resistant pathogens. Recent innovations, including disposable distal caps, enhanced reprocessing protocols, microbiological surveillance, and partially or fully disposable duodenoscopes, have significantly improved infection control during endoscopic retrograde cholangiopancreatography (ERCP) [23].

Routine administration of prophylactic antibiotics before gastrointestinal endoscopy is not recommended for most diagnostic procedures because the risk of clinically significant infection is extremely low and unnecessary antibiotic use contributes to antimicrobial resistance, adverse drug reactions, and increased healthcare costs. However, current evidence supports antibiotic prophylaxis in carefully selected clinical situations. Percutaneous endoscopic gastrostomy (PEG) placement remains the strongest indication because prophylactic antibiotics significantly reduce peristomal wound infection. Antibiotic therapy is also recommended for patients undergoing ERCP when complete biliary drainage is unlikely, for drainage of infected pancreatic fluid collections, for selected endoscopic ultrasound (EUS)-guided therapeutic interventions, and for other procedures associated with a substantial risk of bacterial contamination. Conversely, routine prophylaxis is no longer recommended solely to prevent infective endocarditis in patients undergoing standard gastrointestinal endoscopy, reflecting updated recommendations from international cardiology and gastroenterology societies [24].

Standard infection control measures should be integrated into every stage of endoscopic practice. Rigorous hand hygiene before and after patient contact, appropriate use of personal protective equipment, safe injection practices, environmental cleaning, proper handling of contaminated accessories, and correct disposal of medical waste are essential components of routine clinical practice. In addition, comprehensive patient education regarding post-procedure symptoms, prompt recognition of fever, abdominal pain, or signs of infection, and timely clinical evaluation of suspected complications contribute to improved patient outcomes. Continuous auditing of infection control practices, staff education, and adherence to evidence-based guidelines remain critical to quality indicators in modern endoscopy units [25].

Overall, prevention of endoscopy-related infection requires meticulous reprocessing, standard precautions, selective antibiotic prophylaxis, staff competency assessment, traceability, and continuous quality improvement. These measures reduce healthcare-associated infections in both diagnostic and therapeutic endoscopy [21–25].

3.4. Management of Anticoagulant and Antiplatelet Therapy

The management of anticoagulant and antiplatelet therapy before gastrointestinal (GI) endoscopy is one of the most challenging aspects of peri-endoscopic care because clinicians must carefully balance the risk of procedure-related bleeding against the potentially life-threatening consequences of thromboembolic events. With the increasing prevalence of atrial fibrillation, prosthetic heart valves, venous thromboembolism, ischemic heart disease, and cerebrovascular disease, a growing proportion of patients presenting for endoscopy receive long-term antithrombotic therapy. Current international guidelines from the American Society for Gastrointestinal Endoscopy (ASGE), the European Society of Gastrointestinal Endoscopy (ESGE), and the American College of Gastroenterology (ACG) emphasize that peri-endoscopic management should be individualized according to both the patient's thromboembolic risk and the bleeding risk associated with the planned endoscopic

procedure rather than adopting a uniform approach for all patients [26].

Endoscopic procedures are generally classified into low- and high-risk categories based on their potential for clinically significant bleeding. Low-risk procedures include diagnostic esophagogastroduodenoscopy (EGD), diagnostic colonoscopy, flexible sigmoidoscopy, capsule endoscopy, and routine mucosal biopsy, where clinically significant bleeding is uncommon even in patients receiving antithrombotic therapy. In contrast, therapeutic procedures such as endoscopic mucosal resection (EMR), endoscopic submucosal dissection (ESD), large polypectomy, endoscopic sphincterotomy, pneumatic dilation, endoscopic ultrasound-guided interventions, percutaneous endoscopic gastrostomy (PEG), and treatment of varices are considered high-risk procedures because they carry a substantially greater risk of immediate or delayed hemorrhage [27].

Aspirin remains the most commonly prescribed antiplatelet medication worldwide and is frequently used for secondary prevention of cardiovascular and cerebrovascular disease. Current evidence demonstrates that continuation of low-dose aspirin is safe for the majority of endoscopic procedures and discontinuation is generally discouraged because interruption may significantly increase the risk of myocardial infarction, ischemic stroke, or cardiovascular death. Only a limited number of ultra-high-risk therapeutic procedures may require individualized consideration after consultation with the treating cardiologist. Therefore, both ASGE and ESGE recommend continuing aspirin during most diagnostic and therapeutic endoscopic procedures while carefully monitoring for post-procedural bleeding. P2Y12 receptor inhibitors, including clopidogrel, prasugrel, and ticagrelor, require closer monitoring because they produce more profound platelet inhibition. For low-risk endoscopic procedures, these agents can usually be continued safely. However, for high-risk therapeutic procedures, temporary discontinuation is generally recommended after careful assessment of the patient's thrombotic risk. Patients with recent coronary stent placement, acute coronary syndrome, or recent myocardial infarction should not discontinue dual antiplatelet therapy without consultation with an interventional cardiologist because premature interruption may result in catastrophic stent thrombosis. Elective endoscopic procedures should preferably be postponed until completion of the recommended duration of dual antiplatelet therapy whenever clinically feasible [28].

Warfarin continues to be widely prescribed for patients with mechanical heart valves, atrial fibrillation, and venous thromboembolism. The international normalized ratio (INR) should be evaluated before high-risk procedures, and warfarin is generally discontinued approximately five days before the intervention to allow adequate normalization of coagulation. For patients at low thromboembolic risk, temporary interruption without bridging anticoagulation is usually sufficient. Conversely, selected high-risk patients, particularly those with mechanical mitral valves, recent venous thromboembolism, or recent ischemic stroke, may require bridging therapy with low-molecular-weight heparin (LMWH). However, recent evidence suggests that routine bridging increases bleeding without providing significant thromboembolic benefit in many patients. Consequently, bridging should be reserved for carefully selected individuals after multidisciplinary assessment. Direct oral anticoagulants (DOACs), including apixaban, rivaroxaban, edoxaban, and dabigatran, have become increasingly preferred because of their predictable pharmacokinetics, rapid onset of action, and reduced need for laboratory monitoring. Their shorter half-life allows temporary discontinuation for 1 to 3 days before high-risk procedures, depending on renal function and the specific drug administered. Resumption of therapy should occur as soon as adequate hemostasis has been achieved, usually within 24 hours after low-risk procedures and 48–72 hours after high-risk interventions. Individualized adjustment according to renal impairment, advanced age, and bleeding risk remains essential [29].

After intervention, resumption is individualized according to procedural hemostasis and competing risks. Patients should receive explicit written instructions for restarting each agent and for symptoms of delayed hemorrhage. Urgent procedures, recent coronary stenting or acute coronary syndrome, mechanical valves, recent venous thromboembolism or stroke, severe renal impairment, and dual or triple therapy warrant multidisciplinary planning with cardiology, hematology, anesthesia, or the prescribing clinician [26–29] (Table 3).

4. Complications of Gastrointestinal Endoscopy

4.1. Complications of Upper Gastrointestinal Endoscopy

Upper gastrointestinal endoscopy (esophagogastroduodenoscopy; EGD) is one of the most frequently performed diagnostic and therapeutic procedures in gastroenterology and is generally considered safe, with a low overall incidence of serious adverse events. It plays a pivotal role in the diagnosis and management of esophageal, gastric, and duodenal disorders, including upper gastrointestinal bleeding, peptic ulcer disease, Barrett's esophagus, malignancy, foreign body removal, enteral feeding access, and various therapeutic interventions. Although diagnostic EGD carries a very low risk of complications, the frequency and severity of adverse events increase substantially during therapeutic procedures such as endoscopic hemostasis, esophageal dilation, variceal ligation, endoscopic mucosal resection (EMR), endoscopic submucosal dissection (ESD), radiofrequency ablation (RFA), and percutaneous endoscopic gastrostomy (PEG). Most complications are preventable through careful patient selection, meticulous procedural technique, appropriate sedation, and early recognition of adverse events [30].

Cardiopulmonary complications remain the most common adverse events associated with upper GI endoscopy and account for the majority of procedure-related morbidity and mortality. These complications are primarily related to sedation rather than the endoscopic procedure itself and include hypoxemia, respiratory depression, airway obstruction, aspiration, cardiac arrhythmias, hypotension, myocardial ischemia, and vasovagal reactions. Patients of advanced age, those with obesity, obstructive sleep apnea, chronic obstructive pulmonary disease, heart failure, or American Society of Anesthesiologists (ASA) physical status class III or IV are at significantly higher risk. Continuous monitoring of oxygen saturation, blood pressure, heart rate, and respiratory status, together with appropriate oxygen supplementation and capnography during deep sedation, substantially reduces cardiopulmonary adverse events [31].

Bleeding represents another important complication of upper GI endoscopy, particularly after therapeutic interventions. Diagnostic endoscopy with or without routine mucosal biopsy rarely causes clinically significant hemorrhage. However, procedures such as EMR, ESD, polypectomy, PEG placement, endoscopic sphincterotomy, and endoscopic treatment of vascular lesions are associated with a higher risk of immediate or delayed bleeding. Patient-related factors including anticoagulant or antiplatelet therapy, thrombocytopenia, liver cirrhosis, renal failure, and coagulopathy further increase the likelihood of hemorrhage. Most bleeding episodes can be managed successfully using endoscopic hemostatic techniques, including epinephrine injection, thermal coagulation, through-the-scope clips, over-the-scope clips, hemostatic powders, and topical hemostatic

Table 3: Management of Anticoagulant and Antiplatelet Therapy

Clinical situation	Recommended peri-endoscopic approach	Resumption/safeguards
Low-risk procedure	Continue aspirin and P2Y12 inhibitors. Continue warfarin if INR is within therapeutic range. For DOACs, omit the morning dose or time the procedure at trough according to local guidance.	Resume/continue once immediate hemostasis is confirmed.
High-risk procedure; low thromboembolic risk	Continue aspirin. Withhold clopidogrel/prasugrel/ticagrelor 5-7 days if used alone. Stop warfarin 5 days and confirm INR <1.5. Hold DOACs at least 3 days; hold dabigatran longer when renal function is reduced.	Restart P2Y12 therapy within 2-3 days, warfarin the evening of or day after the procedure, and DOACs 48-72 h after secure hemostasis; individualize for delayed-bleeding risk.
High thrombotic risk, recent coronary stent/ACS, DAPT, mechanical valve, recent VTE/stroke	Defer elective high-risk endoscopy when feasible. Continue aspirin and consult interventional cardiology before interrupting a P2Y12 inhibitor. Bridging is not routine; reserve LMWH for selected very-high-risk warfarin patients after specialist assessment.	Use a documented multidisciplinary plan; resume as early as safely possible after hemostasis is achieved.
Urgent endoscopy or active bleeding	Do not delay life-saving endoscopy solely for complete drug clearance. Stabilize, identify the drug/last dose, assess renal function, and consider reversal only for severe or uncontrolled bleeding.	Reassess bleeding versus thrombotic risk daily and document the restart decision.

Abbreviations: ACS, acute coronary syndrome; DAPT, dual antiplatelet therapy; DOAC, direct oral anticoagulant; INR, international normalized ratio; LMWH, low-molecular-weight heparin; P2Y12, platelet P2Y12 receptor; VTE, venous thromboembolism.

agents. Early endoscopic intervention has significantly reduced the need for emergency surgery in patients with post-procedural bleeding [19].

Perforation is an uncommon but potentially life-threatening complication of upper gastrointestinal endoscopy. The risk is extremely low during diagnostic examinations but increases considerably during esophageal dilation, EMR, ESD, POEM, foreign body extraction, and treatment of malignant strictures. The esophagus is particularly vulnerable because of its relatively thin wall and lack of a serosal layer. Clinical manifestations include severe chest or abdominal pain, subcutaneous emphysema, dyspnea, fever, tachycardia, and signs of mediastinitis or peritonitis. Early diagnosis with computed tomography or contrast radiography is essential, as delayed recognition is associated with significantly increased mortality. Advances in therapeutic endoscopy have enabled successful endoscopic closure of many perforations using endoscopic clips, over-the-scope clips, endoscopic suturing systems, covered self-expandable metal stents, and endoscopic vacuum therapy, thereby reducing the need for surgical intervention in appropriately selected patients. Aspiration pneumonia is another clinically significant complication that primarily occurs during sedation, especially in patients with inadequate fasting, impaired consciousness, gastric outlet obstruction, severe gastroesophageal reflux disease, or delayed gastric emptying. Preventive strategies include strict adherence to fasting recommendations, careful airway assessment, appropriate patient positioning, suctioning of retained gastric contents when necessary, and involvement of anesthesiology specialists in high-risk patients. Prompt recognition and supportive management are essential because aspiration may progress rapidly to respiratory failure and sepsis [32].

Procedure-specific complications should also be considered. Percutaneous endoscopic gastrostomy (PEG) may be complicated by peristomal wound infection, leakage, tube dislodgement, buried bumper syndrome, bleeding, or visceral perforation. Endoscopic treatment of Barrett's esophagus using radiofrequency ablation or EMR may result in chest pain, delayed bleeding, and esophageal stricture formation. Similarly, esophageal dilation carries a small but important risk of transmural perforation, particularly in patients with complex strictures or previous radiation therapy. Fortunately, the majority of these complications can be prevented through adherence to standardized procedural protocols, careful patient selection, prophylactic antibiotics when indicated, and structured post-procedure follow-up [33].

Overall, upper gastrointestinal endoscopy maintains an excellent safety profile when performed by experienced endoscopists in accordance with established quality standards. Continuous training, implementation of evidence-based guidelines, optimization of sedation practices, meticulous procedural technique, and early recognition of adverse events remain fundamental strategies for minimizing complications and improving patient outcomes. Ongoing technological advances, including artificial intelligence-assisted lesion detection, improved endoscopic closure devices, and novel hemostatic technologies, are expected to further enhance the safety of both diagnostic and therapeutic upper gastrointestinal endoscopies (Table 4).

4.2. Complications of Colonoscopy

Colonoscopy is regarded as the gold standard for the diagnosis, surveillance, and treatment of colorectal diseases and plays a pivotal role in colorectal cancer screening and prevention. Advances in endoscopic imaging, therapeutic techniques, and quality improvement programs have substantially enhanced the safety and

Table 4: Major Complications of GI Endoscopy

Procedure / adverse event	Approximate incidence or risk	Major risk factors	Prevention and initial management
Diagnostic EGD: major adverse event	Usually <0.1%; cardiopulmonary events are more frequent than perforation	Advanced age, ASA III-IV, OSA, cardiopulmonary disease, aspiration risk	Risk-adjusted sedation/monitoring; stabilize first; CT for suspected perforation; early surgery/IR when unstable.
Colonoscopy: perforation / post-polypectomy bleeding	Perforation about 0.03-0.1% diagnostic and higher with therapy; clinically important bleeding commonly 0.3-1% after polypectomy, higher after large-lesion EMR	Large/right-sided lesions, thermal resection, anticoagulants, age, comorbidity	Cold-snare technique when appropriate; selective defect closure; endoscopic hemostasis; CT and multidisciplinary escalation for perforation.
ERCP: pancreatitis	About 3-10% overall; ≥15% in selected high-risk patients	Prior PEP, difficult cannulation, pancreatic instrumentation, sphincter of Oddi dysfunction	Rectal indomethacin/diclofenac 100 mg unless contraindicated; selected 5-Fr pancreatic stent; individualized lactated Ringer's hydration.
ERCP: bleeding/cholangitis/perforation	Bleeding about 0.3-2%; cholangitis about 0.5-3%; perforation about 0.1-0.6%	Sphincterotomy, coagulopathy; incomplete drainage; altered anatomy/difficult access	Correct modifiable risk; ensure drainage; antibiotics if incomplete drainage anticipated; CT, antibiotics, drainage and early surgical/IR input when indicated.
Diagnostic EUS / tissue acquisition	Overall, adverse events commonly occur in 1-3%; pancreatitis, bleeding, infection, and perforation are uncommon.	Cystic lesion, vascular target, antithrombotics, multiple passes	Doppler, appropriate needle/pass strategy, selective antibiotics; observe and image symptomatic patients.
Interventional EUS / LAMS	Higher and procedure-specific; bleeding, leakage, infection, migration/occlusion and buried stent may occur	Vascular proximity, immature collection, poor apposition, delayed stent removal	Expert-center selection, Doppler, rescue plan, scheduled imaging/stent review; antibiotics/drainage and IR/surgery for deterioration.
Capsule endoscopy / DAE	Capsule retention is about 1-2% overall and higher with suspected strictures; DAEs are usually <1% diagnostic and higher therapeutic.	Crohn's disease/stricture, prior surgery; therapeutic DAE, prolonged procedure	Cross-sectional imaging or patency capsule; enteroscopic retrieval; surgery for obstruction/perforation.
EMR/ESD/POEM	Bleeding and perforation vary by organ, lesion size, and technique; the risk exceeds that of diagnostic endoscopy.	Large lesion, colon location, fibrosis, antithrombotics, operator learning curve	Expertise, CO2, traction/closure strategies, planned observation; endoscopic closure only in stable selected patients with surgical backup.

Abbreviations: ASA, American Society of Anesthesiologists; CO2, carbon dioxide; CT, computed tomography; DAE, device-assisted enteroscopy; EGD, esophagogastroduodenoscopy; EMR, endoscopic mucosal resection; ERCP, endoscopic retrograde cholangiopancreatography; ESD, endoscopic submucosal dissection; EUS, endoscopic ultrasound; GI, gastrointestinal; IR, interventional radiology; LAMS, lumen-apposing metal stent; OSA, obstructive sleep apnea; PEP, post-ERCP pancreatitis; POEM, peroral endoscopic myotomy.

effectiveness of colonoscopy. Despite its excellent overall safety profile, colonoscopy remains an invasive procedure that carries a small but clinically important risk of adverse events. The incidence of complications varies with patient-related factors, procedural complexity, therapeutic interventions, bowel preparation quality, and endoscopist experience. Diagnostic colonoscopy is associated with a very low complication rate. In contrast, therapeutic procedures such as large polypectomy, endoscopic mucosal resection (EMR), endoscopic submucosal dissection (ESD), endoscopic full-thickness resection, and colonic stent placement significantly increase the risk of bleeding, perforation, and other procedure-related complications [34].

Post-polypectomy bleeding is the most frequent clinically significant complication of therapeutic colonoscopy and may occur either immediately during the procedure or several days after polypectomy. Immediate bleeding is usually identified and successfully managed using endoscopic hemostatic techniques, including epinephrine injection, thermal coagulation, through-the-scope clips, over-the-scope clips, and topical hemostatic agents. Delayed bleeding typically develops within 7–14 days following polypectomy and is more common after removal of large polyps, right-sided colonic lesions, pedunculated polyps with thick stalks, and lesions requiring electrocautery. Additional risk factors include advanced age, anticoagulant or antiplatelet therapy, chronic kidney disease, liver cirrhosis, hypertension, and inadequate post-procedural medication management. Careful lesion assessment, prophylactic clipping in selected high-risk lesions, and appropriate management of antithrombotic therapy have significantly reduced post-polypectomy hemorrhage in recent years [35].

Colonic perforation represents the most serious complication of colonoscopy despite its relatively low incidence. Perforation may result from excessive mechanical force, barotrauma caused by excessive insufflation, or thermal injury following electrocautery. The sigmoid colon remains the most common site of perforation because of its angulation and frequent presence of diverticular disease. Therapeutic procedures such as EMR, ESD, balloon dilation, and endoscopic full-thickness resection further increase the risk of perforation. Patients usually present with severe abdominal pain, abdominal distension, fever, tachycardia, leukocytosis, and signs of peritonitis. Early diagnosis with computed tomography is essential because prompt recognition enables successful endoscopic closure with clips, endoscopic suturing devices, or over-the-scope clips in appropriately selected patients. In contrast, delayed diagnosis often necessitates emergency surgical intervention [36].

Post-polypectomy electrocoagulation syndrome, also known as transmural burn syndrome, is an uncommon complication caused by thermal injury extending through the muscularis propria without complete perforation. Patients typically develop localized abdominal pain, fever, leukocytosis, and peritoneal irritation within several hours after therapeutic colonoscopy. Computed tomography usually

demonstrates localized colonic wall thickening without free intraperitoneal air, distinguishing this syndrome from frank perforation. Conservative treatment consisting of bowel rest, intravenous fluids, analgesia, and broad-spectrum antibiotics is usually successful, with most patients recovering completely without surgical intervention [36].

Cardiopulmonary complications remain the most common non-procedural adverse events during colonoscopy and are primarily related to sedation rather than the endoscopic examination itself. Hypoxemia, respiratory depression, aspiration, hypotension, arrhythmias, vasovagal reactions, and myocardial ischemia occur predominantly in elderly individuals and patients with significant cardiopulmonary disease or multiple comorbidities. Continuous physiologic monitoring, individualized sedation protocols, supplemental oxygen administration, and capnography during deep sedation have significantly improved procedural safety and reduced the incidence of serious cardiopulmonary events [34].

Bowel preparation itself may contribute to procedure-related complications. Inadequate bowel cleansing reduces adenoma detection rates, prolongs procedure time, increases procedural difficulty, and often necessitates repeat colonoscopy. Conversely, excessive bowel preparation may result in dehydration, electrolyte disturbances, acute kidney injury, and worsening heart failure, particularly among elderly patients and those with chronic kidney disease or advanced liver disease. Split-dose polyethylene glycol (PEG)-based bowel preparation is currently recommended by international guidelines because it provides superior cleansing quality with an excellent safety profile [35].

Less common complications include splenic injury, acute appendicitis, mesenteric tears, post-procedural infection, abdominal wall hematoma, and gas explosion during electrocautery when inadequate bowel preparation leaves combustible gases within the colon. Although these events are exceedingly rare, clinicians should maintain a high index of suspicion when patients present with severe abdominal pain, hemodynamic instability, or persistent symptoms following colonoscopy. Early diagnosis and multidisciplinary management substantially improve clinical outcomes [37].

Overall, colonoscopy remains an exceptionally safe procedure when performed according to established quality standards. Comprehensive patient assessment, optimal bowel preparation, appropriate antithrombotic therapy management, careful procedural technique, and prompt recognition of adverse events are fundamental components of complication prevention. Ongoing advances in artificial intelligence-assisted polyp detection, cold snare polypectomy techniques, carbon dioxide insufflation, and novel endoscopic closure devices are expected to further improve procedural safety while enhancing the effectiveness of colorectal cancer screening and therapeutic colonoscopy (Table 4).

4.3. ERCP-related Complications

Endoscopic retrograde cholangiopancreatography (ERCP) is one of the most technically demanding and therapeutically valuable procedures in gastrointestinal endoscopy. Unlike diagnostic upper gastrointestinal endoscopy or colonoscopy, ERCP is now performed almost exclusively for therapeutic purposes, including the management of choledocholithiasis, malignant and benign biliary strictures, pancreatic duct disorders, bile leaks, cholangitis, and pancreaticobiliary malignancies. Although ERCP has revolutionized the management of pancreaticobiliary diseases by reducing the need for surgical intervention, it is associated with a considerably higher complication rate than other endoscopic procedures because of its technical complexity and manipulation of the pancreaticobiliary system. The overall incidence of ERCP-related adverse events ranges from approximately 5% to 10%, while severe complications occur in 1–2% of procedures and procedure-related mortality remains below 1% in experienced centers. Careful patient selection, meticulous procedural technique, and adherence to evidence-based preventive strategies are therefore essential to maximize therapeutic benefit while minimizing complications [38].

Post-ERCP pancreatitis (PEP) is the most common and clinically significant complication, accounting for nearly half of all ERCP-related adverse events. It is characterized by new or worsening abdominal pain associated with elevation of pancreatic enzymes and the need for hospitalization following the procedure. The pathogenesis of PEP is multifactorial and involves mechanical trauma during cannulation, hydrostatic injury from contrast injection, thermal injury caused by sphincterotomy, chemical irritation, and activation of inflammatory pathways within the pancreas. Several patient-related risk factors have been identified, including female sex, younger age, suspected sphincter of Oddi dysfunction, previous episodes of pancreatitis or post-ERCP pancreatitis, normal serum bilirubin levels, and difficult biliary cannulation. Procedure-related factors such as repeated pancreatic duct cannulation, precut sphincterotomy, pancreatic sphincterotomy, and balloon dilation of an intact papilla further increase the risk of PEP. Contemporary international guidelines strongly recommend routine administration of rectal nonsteroidal anti-inflammatory drugs (NSAIDs), particularly indomethacin or diclofenac, immediately before or after ERCP in patients without contraindications. In addition, prophylactic pancreatic duct stent placement is recommended for patients at high risk of pancreatitis because multiple randomized controlled trials have demonstrated significant reductions in the incidence and severity of PEP. Aggressive peri-procedural hydration using lactated Ringer's solution has also emerged as an effective preventive strategy in selected patients [39].

Bleeding is another important complication of ERCP and most commonly occurs following endoscopic sphincterotomy. Hemorrhage may present immediately during the procedure or several hours to days later. The risk is increased in patients receiving anticoagulant or antiplatelet therapy, those with thrombocytopenia or liver cirrhosis, individuals with coagulopathy, and patients undergoing large sphincterotomy or complex therapeutic interventions. Minor bleeding often resolves spontaneously or responds to conservative measures. In contrast, clinically significant hemorrhage usually requires endoscopic hemostasis using diluted epinephrine injection, thermal coagulation, endoscopic clips, covered self-expandable metal stents, or topical hemostatic agents. Surgical or angiographic intervention is rarely required when endoscopic therapy is successful [40].

Perforation is an uncommon but potentially life-threatening complication of ERCP. Perforations may occur because of guidewire manipulation, excessive sphincterotomy, endoscope trauma, or instrumentation of the biliary or pancreatic ducts. The Stapfer classification categorizes ERCP-related perforations by anatomical location and mechanism, thereby guiding therapeutic decision-making. Clinical manifestations include severe abdominal pain, fever, tachycardia, subcutaneous emphysema, retroperitoneal air, or generalized peritonitis. Early diagnosis using computed tomography is essential because prompt management significantly improves outcomes. Many guidewire-related or small retroperitoneal perforations can be managed conservatively with bowel rest, intravenous antibiotics, and close observation. In contrast, larger perforations

may require endoscopic closure using through-the-scope clips, over-the-scope clips, endoscopic suturing devices, or fully covered self-expandable metal stents. Surgical intervention remains necessary for patients with generalized peritonitis, large intraperitoneal perforations, or failure of endoscopic management [41].

Infectious complications, particularly acute cholangitis and cholecystitis, may develop following ERCP, especially when adequate biliary drainage cannot be achieved. Bacterial contamination of an obstructed biliary system may rapidly progress to sepsis if drainage remains incomplete. Consequently, current guidelines recommend prophylactic antibiotic administration in patients with anticipated incomplete biliary drainage or hilar biliary obstruction and continuation of antimicrobial therapy until satisfactory drainage has been established. Routine antibiotic prophylaxis is not recommended for uncomplicated ERCP when complete drainage is expected. Careful endoscope reprocessing, sterile accessory handling, and strict adherence to infection control protocols further reduce the risk of procedure-related infection [42].

Cardiopulmonary complications associated with ERCP are primarily related to deep sedation or general anesthesia and include hypoxemia, aspiration, hypotension, arrhythmias, and respiratory depression. Because ERCP procedures are frequently prolonged and technically complex, careful pre-procedure risk assessment, continuous physiologic monitoring, capnography during deep sedation, and close collaboration with anesthesia providers are recommended for high-risk patients. Elderly individuals and those with significant cardiopulmonary disease require particular attention throughout the peri-procedural period [43].

Overall, the prevention of ERCP-related complications depends on comprehensive patient selection, appropriate procedural indications, operator expertise, standardized cannulation techniques, routine use of rectal NSAIDs, selective pancreatic duct stenting, aggressive hydration in high-risk patients, meticulous infection prevention, and early recognition of adverse events. Continued technological innovation, including wire-guided cannulation techniques, advanced guidewires, artificial intelligence-assisted fluoroscopic interpretation, and improved endoscopic accessories, is expected to further enhance the safety and therapeutic success of ERCP while reducing procedure-related morbidity in future clinical practice (Table 4).

4.4. Endoscopic Ultrasound-related Complications

Endoscopic ultrasound (EUS) has become an indispensable diagnostic and therapeutic modality in modern gastroenterology, providing high-resolution imaging of the gastrointestinal wall, mediastinum, pancreas, biliary system, and surrounding structures. Over the past two decades, the role of EUS has expanded from a purely diagnostic technique to a versatile therapeutic platform capable of performing fine-needle aspiration (FNA), fine-needle biopsy (FNB), pancreatic fluid collection drainage, biliary drainage, celiac plexus neurolysis, gastroenterostomy, and other minimally invasive interventions. Despite these advances, EUS remains an invasive procedure that carries procedure-related risks, particularly when therapeutic interventions are performed. Although diagnostic EUS has an excellent safety profile with an overall complication rate generally below 1%, therapeutic EUS procedures are associated with a higher incidence of adverse events because of tissue puncture, device manipulation, and transmural access to adjacent organs. Careful patient selection, operator expertise, standardized procedural techniques, and strict adherence to evidence-based guidelines are therefore essential to maximize procedural success while minimizing complications [5, 44–46].

Diagnostic EUS without tissue acquisition is associated with very few complications, and most adverse events are related to sedation rather than the examination itself. Cardiopulmonary events such as hypoxemia, hypotension, arrhythmias, and aspiration may occur, particularly in elderly patients and those with significant cardiopulmonary comorbidities. Appropriate pre-procedure evaluation, individualized sedation strategies, and continuous physiologic monitoring substantially reduce these risks. Mechanical injury to the oropharynx, esophagus, or stomach is uncommon but may occur in patients with severe esophageal strictures, cervical osteophytes, or altered upper gastrointestinal anatomy [44, 45].

Endoscopic ultrasound-guided fine-needle aspiration (EUS-FNA) and fine-needle biopsy (EUS-FNB) are widely used for the diagnosis of pancreatic masses, lymph nodes, subepithelial lesions, and mediastinal abnormalities. These procedures have excellent diagnostic accuracy and a low overall complication rate, generally ranging from 1% to 3%. Bleeding is usually mild and self-limited but occurs more frequently in patients receiving anticoagulant or antiplatelet therapy, those with thrombocytopenia, or individuals undergoing puncture of highly vascular lesions. Careful peri-procedural management of antithrombotic medications according to current guidelines is therefore essential to minimize hemorrhagic complications [5, 45, 46].

Acute pancreatitis represents one of the most important complications following EUS-guided tissue acquisition of pancreatic lesions. Although the incidence is relatively low, inflammatory injury may occur because of repeated needle passes or direct trauma to the pancreatic parenchyma. Most cases are mild and respond to conservative treatment consisting of intravenous fluids, analgesia, and bowel rest. The risk of pancreatitis may be reduced by minimizing unnecessary needle manipulation, selecting the most appropriate puncture route, and limiting the number of passes required to obtain an adequate tissue sample [5].

Infectious complications are uncommon after EUS-guided aspiration of solid lesions but become more relevant during aspiration or drainage of cystic lesions and pancreatic fluid collections. Historically, prophylactic antibiotics were routinely administered before EUS-guided aspiration of pancreatic cysts; however, recent evidence suggests that the incidence of infection is extremely low when sterile technique is maintained. Current practice increasingly supports selective rather than routine antibiotic prophylaxis, while antimicrobial therapy remains recommended for drainage of infected collections, walled-off necrosis, or other contaminated fluid spaces. Strict aseptic technique, appropriate accessory handling, and meticulous endoscope reprocessing remain fundamental components of infection prevention [44, 46].

Perforation is a rare but potentially life-threatening complication of EUS. It may occur during difficult intubation, advancement of the echoendoscope through areas of luminal narrowing, or therapeutic transmural interventions. The rigid design of linear echoendoscopes and limited maneuverability increase the risk of perforation in patients with cervical esophageal disease, postoperative anatomical alterations, or severe strictures. Clinical manifestations include severe chest or abdominal pain, fever, subcutaneous emphysema, mediastinal air, or generalized peritonitis. Early diagnosis using computed tomography is essential because prompt endoscopic closure using clips, over-the-scope clips, endoscopic suturing devices, or covered stents may avoid emergency surgery in selected patients [45, 47].

Therapeutic EUS procedures, including EUS-guided biliary drainage, pancreatic pseudocyst drainage, gallbladder drainage, gastroenterostomy, and placement of lumen-apposing metal stents (LAMS), have

significantly expanded the therapeutic role of EUS but are associated with higher complication rates than diagnostic procedures. Potential adverse events include bleeding, perforation, bile leakage, stent migration, stent occlusion, infection, pneumoperitoneum, and injury to adjacent organs. Appropriate imaging review before intervention, careful selection of puncture sites, Doppler assessment to avoid vascular structures, and use of dedicated accessories substantially improve procedural safety. Increasing operator experience and advances in device technology have also contributed to progressive reductions in complication rates [5, 46, 47].

Overall, EUS remains one of the safest and most valuable minimally invasive procedures in modern gastroenterology. Most complications are uncommon, recognized early, and successfully managed with endoscopic or conservative approaches. Continuous training, adherence to international guidelines, multidisciplinary collaboration, and ongoing technological innovation, including improved needle design, enhanced imaging systems, artificial intelligence-assisted image interpretation, and dedicated therapeutic accessories, are expected to further improve the safety and effectiveness of diagnostic and therapeutic EUS in future clinical practice (Table 4).

4.5. Capsule Endoscopy and Device-assisted Enteroscopy

Capsule endoscopy (CE) and device-assisted enteroscopy (DAE) have transformed the evaluation and management of small-bowel diseases by enabling direct visualization and therapeutic access to regions of the gastrointestinal tract that were previously difficult to examine with conventional endoscopy. Capsule endoscopy is now considered the first-line diagnostic modality for obscure gastrointestinal bleeding, suspected small-bowel Crohn's disease, inherited polyposis syndromes, celiac disease, and selected small-bowel tumors because it is noninvasive, well tolerated, and provides excellent mucosal visualization. Device-assisted enteroscopy, including double-balloon enteroscopy (DBE), single-balloon enteroscopy (SBE), and spiral enteroscopy (SE), complements capsule endoscopy by allowing tissue sampling, endoscopic hemostasis, polypectomy, foreign body retrieval, stricture dilation, and therapeutic intervention within the small intestine. Although both techniques have favorable safety profiles, clinicians should be aware of procedure-specific complications, appropriate patient selection, and preventive strategies to minimize adverse events and optimize clinical outcomes [48–51].

Capsule endoscopy is associated with an extremely low rate of serious complications, making it one of the safest procedures in gastrointestinal endoscopy. The most important complication is capsule retention, defined as persistence of the capsule within the gastrointestinal tract for more than two weeks or failure of spontaneous passage due to an underlying pathological lesion. Capsule retention most frequently occurs in patients with Crohn's disease, small-bowel strictures, radiation enteritis, nonsteroidal anti-inflammatory drug (NSAID)-induced enteropathy, intestinal tuberculosis, postoperative adhesions, or small-bowel neoplasms. In most patients, capsule retention remains asymptomatic and is detected incidentally during follow-up imaging; however, prolonged retention may occasionally result in bowel obstruction, abdominal pain, or perforation. Current guidelines recommend careful preprocedural risk assessment and the use of cross-sectional imaging or a dissolvable patency capsule in patients with suspected small bowel strictures to reduce the likelihood of capsule retention. When retention occurs, management depends on the underlying pathology and may include medical therapy, device-assisted enteroscopic retrieval, or surgical removal if endoscopic retrieval is unsuccessful or intestinal obstruction develops [48–50].

Capsule aspiration is another rare but potentially serious complication. Aspiration generally occurs in elderly patients, individuals with neurological disorders, impaired swallowing mechanisms, previous cerebrovascular accidents, Parkinson's disease, or severe oropharyngeal dysphagia. Clinical manifestations range from transient coughing to respiratory distress and airway obstruction. Careful evaluation of swallowing ability before capsule ingestion and endoscopic placement of the capsule directly into the duodenum in high-risk individuals significantly reduce the risk of aspiration. Although spontaneous expectoration is possible in some patients, bronchoscopic retrieval may be required when aspiration persists [49].

Unlike capsule endoscopy, device-assisted enteroscopy is an invasive procedure that carries a slightly higher risk of complications because of prolonged procedure duration, deep sedation, and therapeutic interventions. Diagnostic DBE and SBE have an excellent safety profile. In contrast, therapeutic procedures such as polypectomy, endoscopic mucosal resection, balloon dilation of strictures, and hemostatic interventions are associated with higher rates of adverse events. The most frequently reported complications include bleeding, perforation, acute pancreatitis, mucosal tears, and cardiopulmonary events related to sedation. Overall complication rates remain low in experienced centers, and most adverse events can be managed conservatively or with endoscopic therapy [50–52].

Bleeding is the most common therapeutic complication during device-assisted enteroscopy and usually follows biopsy, polypectomy, or endoscopic resection of vascular lesions. Patients receiving anticoagulant or antiplatelet therapy, those with inherited coagulation disorders, and individuals with advanced liver disease are at increased risk. Most bleeding episodes are minor and respond to conventional endoscopic hemostatic techniques, including injection therapy, thermal coagulation, endoscopic clips, and topical hemostatic agents. Appropriate peri-procedural management of antithrombotic medications according to current international guidelines substantially reduces clinically significant hemorrhage [51].

Perforation is an uncommon but potentially life-threatening complication of device-assisted enteroscopy. Mechanical trauma during scope advancement, therapeutic interventions, balloon dilation of strictures, or excessive insufflation may result in transmural injury. Patients with Crohn's disease, radiation-induced strictures, postoperative adhesions, diverticula, or altered surgical anatomy are particularly vulnerable. Clinical manifestations include severe abdominal pain, fever, tachycardia, abdominal rigidity, and signs of peritonitis. Early diagnosis with computed tomography enables prompt management, and many small perforations can now be successfully treated with endoscopic clips, over-the-scope clips, or endoscopic suturing devices. In contrast, generalized peritonitis or failed endoscopic closure necessitates surgical intervention [50–52].

Acute pancreatitis has been reported primarily after antegrade double-balloon enteroscopy, although its incidence remains low. The proposed mechanisms include repeated mechanical compression of the pancreas, prolonged manipulation within the duodenum, and ischemic injury associated with overtube advancement. Most cases are mild and respond to conservative treatment consisting of bowel rest, intravenous hydration, and analgesia. Limiting procedure duration, minimizing excessive mechanical manipulation, and appropriate patient selection may further reduce the risk of pancreatitis [52].

Overall, capsule endoscopy and device-assisted enteroscopy have significantly expanded the diagnostic and therapeutic capabilities of small bowel endoscopy while maintaining excellent safety profiles.

Appropriate patient selection, pre-procedure assessment for intestinal strictures, careful management of antithrombotic therapy, meticulous procedural technique, and early recognition of complications remain essential for optimizing patient outcomes. Ongoing technological advances, including artificial intelligence-assisted capsule interpretation, magnetically controlled capsule systems, improved battery technology, motorized spiral enteroscopy, and next-generation therapeutic enteroscopes, are expected to further enhance diagnostic accuracy, therapeutic efficacy, and procedural safety (Table 4).

4.6. Complications of Advanced Therapeutic Endoscopy

Advanced therapeutic endoscopy has revolutionized the management of gastrointestinal diseases by providing minimally invasive alternatives to conventional surgery for a wide range of benign and malignant conditions. Techniques such as endoscopic mucosal resection (EMR), endoscopic submucosal dissection (ESD), peroral endoscopic myotomy (POEM), endoscopic sleeve gastroplasty (ESG), endoscopic full-thickness resection (EFTR), endoscopic suturing, and lumen-apposing metal stent (LAMS) placement have significantly expanded the therapeutic capabilities of gastrointestinal endoscopy. These procedures offer substantial benefits, including organ preservation, reduced postoperative pain, shorter hospital stay, faster recovery, and lower healthcare costs compared with surgical intervention. However, because they involve extensive tissue dissection, transmural access, or complex device deployment, advanced therapeutic endoscopic procedures are associated with higher complication rates than conventional diagnostic endoscopy. Consequently, successful outcomes depend on careful patient selection, experienced endoscopists, multidisciplinary collaboration, and strict adherence to evidence-based procedural protocols [53–57].

Endoscopic mucosal resection (EMR) is widely used to treat superficial gastrointestinal neoplasms, particularly large colorectal adenomas and early esophageal or gastric neoplasms. The most common complications include immediate and delayed bleeding, perforation, post-polypectomy electrocoagulation syndrome, and local lesion recurrence. Immediate bleeding usually responds to endoscopic hemostatic techniques. In contrast, delayed hemorrhage may occur several days after the procedure, particularly in patients receiving anticoagulant therapy or those with large right-sided colonic lesions. Although perforation during EMR is uncommon, early recognition and prompt endoscopic closure using through-the-scope clips or over-the-scope clips have substantially reduced the need for emergency surgery. Careful lesion assessment, submucosal injection to create an adequate safety cushion, and meticulous electrosurgical technique remain essential for minimizing EMR-related adverse events [53, 55].

Endoscopic submucosal dissection (ESD) has become the preferred treatment for selected early gastrointestinal cancers because it enables en bloc resection regardless of lesion size, thereby improving histopathological assessment and reducing recurrence rates. Nevertheless, ESD is technically demanding and is associated with longer procedure times and a higher incidence of complications than EMR. Intraprocedural and delayed bleeding, perforation, post-procedural stricture formation, and localized infection are the principal adverse events. The risk of perforation is particularly significant during colorectal ESD because of the thin colonic wall, while extensive esophageal ESD may result in clinically significant strictures requiring repeated endoscopic dilation. Recent advances in electrosurgical knives, traction devices, carbon dioxide insufflation, prophylactic clipping, and endoscopic closure techniques have substantially improved the safety profile of ESD, especially in high-volume expert centers [54–56].

Peroral endoscopic myotomy (POEM) has emerged as an effective minimally invasive treatment for achalasia and other esophageal motility disorders. Although clinical success exceeds 90% in experienced institutions, POEM is associated with procedure-specific complications including capnoperitoneum, capnomediastinum, subcutaneous emphysema, mucosal injury, bleeding, delayed perforation, pneumothorax, and gastroesophageal reflux disease (GERD). Carbon dioxide insufflation has markedly reduced the clinical significance of gas-related events because carbon dioxide is absorbed more rapidly than room air. The most common long-term adverse outcome following POEM is reflux esophagitis, emphasizing the importance of long-term surveillance and proton pump inhibitor therapy when indicated. Careful tunneling technique, preservation of mucosal integrity, and immediate endoscopic closure of mucosal entry sites contribute significantly to procedural safety [55, 57].

Endoscopic sleeve gastroplasty (ESG) has gained increasing acceptance as a minimally invasive endoscopic bariatric procedure for the treatment of obesity. ESG reduces gastric volume through full-thickness endoscopic suturing without surgical resection. Most post-procedural adverse events are mild and transient, including nausea, vomiting, abdominal pain, and self-limited gastrointestinal bleeding. Serious complications such as perigastric fluid collection, gastric perforation, splenic injury, pulmonary embolism, and severe infection are uncommon but require prompt recognition and multidisciplinary management. Appropriate patient selection, careful suture placement, peri-procedural antibiotic prophylaxis, and structured postoperative follow-up significantly reduce complication rates and improve long-term outcomes [56].

Endoscopic full-thickness resection (EFTR) has expanded therapeutic options for difficult colorectal lesions, subepithelial tumors, and recurrent neoplasia that cannot be removed safely using conventional techniques. Potential complications include perforation, bleeding, localized peritonitis, post-procedural infection, and clip-related adverse events. The development of dedicated full-thickness resection devices and improved endoscopic closure systems has substantially enhanced procedural safety and reduced the need for surgical intervention. Similarly, endoscopic suturing devices and lumen-apposing metal stents (LAMS) have become increasingly important for the management of gastrointestinal perforations, fistulas, pancreatic fluid collections, gallbladder drainage, and EUS-guided gastroenterostomy. Although these technologies have improved therapeutic outcomes, stent migration, buried stent syndrome, bleeding, infection, and delayed perforation remain recognized complications requiring careful follow-up and timely intervention [53–57].

Overall, advanced therapeutic endoscopy continues to evolve rapidly and now represents an essential component of modern gastrointestinal practice. Although these procedures are inherently associated with higher procedural risk than conventional endoscopy, complication rates have steadily declined because of improved patient selection, standardized procedural protocols, technological innovation, enhanced training, and increasing operator experience. Future developments in robotic endoscopy, artificial intelligence-assisted procedural guidance, next-generation closure devices, and novel hemostatic technologies are expected to further improve procedural safety while expanding the therapeutic applications of advanced endoscopic interventions (Table 4).

4.7. Prevention and Management of Endoscopic Complications

The prevention and effective management of endoscopy-related complications are fundamental components of high-quality gastrointestinal endoscopy and represent key quality indicators recommended by international professional societies. Although most diagnostic and therapeutic endoscopic procedures are performed safely, adverse events remain unavoidable because of patient-related factors, procedural complexity, underlying comorbidities, and operator-dependent variables. Contemporary endoscopy therefore emphasizes a proactive approach focused on comprehensive risk assessment, meticulous procedural planning, standardized safety protocols, and early recognition of complications, rather than relying solely on treatment after adverse events. Numerous studies have demonstrated that implementation of evidence-based preventive strategies, multidisciplinary collaboration, structured training, and continuous quality improvement programs significantly reduce morbidity, mortality, healthcare costs, and procedure-related hospitalizations while improving overall patient outcomes [44, 58–61].

Successful prevention begins with comprehensive pre-procedure evaluation. Every patient should undergo careful assessment of medical history, previous anesthesia-related complications, cardiopulmonary disease, anticoagulant and antiplatelet therapy, allergies, renal and hepatic function, pregnancy status, and procedure-specific risk factors. The American Society of Anesthesiologists (ASA) physical status classification, airway evaluation, and individualized bleeding and thromboembolic risk assessment should be incorporated into routine pre-endoscopy evaluation. Appropriate laboratory testing should be performed only when clinically indicated, while adherence to fasting recommendations and standardized bowel preparation protocols remains essential to minimize aspiration risk and improve procedural quality. Careful patient selection is particularly important for advanced therapeutic procedures, including ERCP, endoscopic submucosal dissection (ESD), endoscopic ultrasound-guided interventions, and peroral endoscopic myotomy (POEM), where complication rates are inherently higher than those of routine diagnostic endoscopy [58, 59].

During the procedure, meticulous technique, continuous physiologic monitoring, and procedure-specific prophylaxis are essential. Carbon dioxide insufflation is preferred for many advanced interventions. For ERCP, administer rectal indomethacin or diclofenac 100 mg immediately before or after the procedure unless contraindicated by allergy, active ulceration/bleeding, severe renal failure, or pregnancy-specific concerns. Place a prophylactic 5-Fr pancreatic stent in selected high-risk cases, such as repeated or inadvertent pancreatic duct instrumentation or double-guidewire cannulation; evidence also supports combining a stent with rectal indomethacin in high-risk patients. Lactated Ringer's hydration may be considered when not contraindicated, but aggressive regimens should be avoided in heart failure, renal failure, or fluid-overload risk. Antibiotics are indicated when incomplete biliary drainage is anticipated, in selected severely immunocompromised patients, and for cholangioscopy, but not routinely when complete sterile drainage is expected [5, 43–47].

Suspected adverse events require a stability-first pathway. Assess airway, breathing, circulation, obtain blood tests, stop antithrombotic agents when clinically appropriate, and use contrast-enhanced computed tomography when perforation or significant extraluminal injury is suspected. Stable patients with small, early-recognized defects, adequate preparation, and no diffuse peritonitis may undergo endoscopic closure plus fasting, intravenous fluids, broad-spectrum antibiotics, and close observation. Hemodynamic instability, a large or delayed defect, free leakage, diffuse peritonitis, failed closure, uncontrolled bleeding, or clinical deterioration mandates immediate surgical consultation; ongoing hemorrhage after repeat endoscopic therapy should prompt interventional radiology or surgery. Endoscopic therapy is therefore not automatic but depends on stability, defect characteristics, timing, local expertise, and rescue capability [47].

Management of severe complications frequently requires a multidisciplinary approach involving gastroenterologists, anesthesiologists, surgeons, interventional radiologists, intensivists, infectious disease specialists, and specialized nursing staff. Institutions performing advanced therapeutic endoscopy should maintain clearly defined emergency response protocols, immediate access to surgical consultation, and standardized pathways for escalation of care. Regular multidisciplinary case review meetings, morbidity and mortality conferences, simulation-based training, and periodic competency assessment contribute substantially to improving procedural performance and reducing preventable adverse events. Furthermore, standardized documentation of complications and participation in national or international quality registries facilitate continuous benchmarking and identification of opportunities for quality improvement [44, 58].

Patient education also represents an important component of complication prevention. Before discharge, patients should receive clear verbal and written instructions regarding expected post-procedure recovery, medication resumption, dietary recommendations, and warning symptoms requiring immediate medical attention. Early communication with the endoscopy unit following discharge facilitates prompt evaluation of delayed complications such as post-polypectomy bleeding, post-ERCP pancreatitis, delayed perforation, or infection. Increasingly, electronic follow-up systems, telemedicine consultations, and automated symptom-monitoring platforms are being incorporated into post-endoscopy care to improve patient safety and early detection of adverse events [61].

Overall, prevention and management require standardized definitions and severity grading, explicit denominators and timing, patient- and procedure-specific planning, early diagnosis, and multidisciplinary escalation. Evidence is strongest for selected preventive measures, but incidence estimates vary by case mix, operator expertise, definitions, and follow-up. Many recommendations for advanced EUS, robotic platforms, and new closure technologies remain based on observational studies or expert consensus; local capability and uncertainty should therefore be stated when applying them [4, 43, 44, 46, 58–61].

5. Future Perspectives

Near-term progress is most likely from validated computer-aided detection, improved image enhancement, safer closure and hemostatic devices, and auditable reprocessing systems. These technologies may improve detection or technical performance, but evidence that they reduce mortality, major adverse events, or long-term costs remains incomplete [62–66].

Randomized trials show that computer-aided detection can increase adenoma detection, while clinical benefit depends on appropriate use, training, withdrawal technique, and avoidance of unnecessary resection. Applications in upper GI endoscopy, capsule endoscopy, and EUS remain promising but require external validation and outcome-based evaluation [62, 63]. High-definition and image-enhanced modalities improve mucosal visualization and optical characterization. Their value is greatest when linked to validated classification systems, competency standards, and management pathways rather than used as stand-alone technology [63–65]. Robotic and computer-assisted platforms may improve stability and ergonomics during complex therapy, but most remain concentrated

in specialist centers, and comparative evidence on patient outcomes is limited. Adoption should be accompanied by structured training, prospective registries, and cost-effectiveness assessment [64]. Single-use components, improved duodenoscope designs, automated reprocessing, drying, traceability, and surveillance may reduce the risk of contamination. Their environmental impact, cost, and incremental clinical benefit require continued evaluation [65].

Novel stents, suturing platforms, hemostatic agents, and closure systems may expand the use of minimally invasive treatment. Their safe introduction requires credentialing, multidisciplinary rescue pathways, and transparent reporting of adverse events [64, 66]. Digital decision support and remote quality monitoring may help personalize preparation and identify safety gaps, particularly where specialist access is limited; data governance, bias, interoperability, and prospective clinical validation remain important constraints [63, 66]. Simulation and competency-based assessment can support safer training, but technology should complement supervised clinical experience and objective quality indicators [62, 65, 66]. Accordingly, future innovation should be judged by clinically meaningful outcomes, reproducibility, equity, cost, and environmental impact, not only technical feasibility.

6. Conclusion

Safe GI endoscopy depends on matching patient risk, procedure complexity, sedation resources, antithrombotic management, and preventive measures. Standardized adverse-event reporting and rapid, multidisciplinary escalation are essential when bleeding, perforation, pancreatitis, infection, or cardiopulmonary deterioration occurs. New technologies should be adopted when validated clinical benefit outweighs the costs and implementation risks.

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The author declares that no generative artificial intelligence or AI-assisted technology was used in the preparation of this manuscript.

Author Contributions

S.R.H. conceived the review, performed the literature search and synthesis, drafted and critically revised the manuscript, and approved the final version.

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