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Technical Specifications for Super Minimally Invasive Stepwise Full-thickness Resection Surgery (sft-SMIR) for Colorectal Cancer

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Abstract: This article outlines the technical specifications of super minimally invasive stepwise full-thickness resection surgery for colorectal cancer (sft-SMIR). sft-SMIR is a super minimally invasive surgery performed through natural orifices, combining endoscopic submucosal dissection (ESD) and full-thickness resection (EFTR) techniques, aimed at curing the disease while maximizing the preservation of the structure and function of the colorectal organs. The article specifies that this technique is suitable for early colon cancer, early rectal cancer, and locally advanced low rectal cancer after neoadjuvant therapy, detailing its indications and contraindications. It emphasizes the importance of multidisciplinary team (MDT) assessment, meticulous preoperative imaging and endoscopic evaluation, standardized intraoperative procedures (including marking, dissection, traction, full-thickness resection, and wound closure), as well as rigorous postoperative management and follow-up processes. Additionally, the expert consensus highlights the need for a strong focus on infection prevention and the establishment of standardized training and quality control systems to promote the safe and standardized application of this difficult endoscopic technique.

Keywords: Colorectal cancer; Super minimally invasive surgery; Stepwise full-thickness resection; Technical Specification; Therapeutic endoscopy

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1. Introduction

The surgical management of colorectal cancer is evolving from traditional open surgery to minimally invasive laparoscopic surgery, and further towards Super Minimally Invasive Surgery (SMIS), which aims to preserve organ structure and function to the greatest extent. The core objective of SMIS is to eradicate the disease while maintaining the anatomical integrity of the organ, ultimately allowing patients to be “cured and restored to their

original state" [1–3]. As a key implementation of the SMIS concept in colorectal cancer treatment, super minimally invasive stepwise full-thickness resection (sft-SMIR) utilizes a natural orifice (transanal) approach and combines the technical essences of endoscopic submucosal dissection (ESD) and full-thickness resection (EFTR). Its successful execution relies not only on proficient endoscopic operative techniques but also on strict indication selection, standardized preoperative evaluation and preparation, meticulous intraoperative procedures, vigilant postoperative management, and a robust quality control system [4]. This article aims to systematically elaborate on the technical specifications of sft-SMIR for treating different types of colorectal cancer, to promote its standardized application.

2. Technical specifications for sft-SMIR in early colon cancer [5]

2.1. Indications

(1) Early colon cancer (cT1 stage) with a tumor diameter ≤ 3 cm.
(2) Well to moderately differentiated adenocarcinoma or high-grade intraepithelial neoplasia with cancerous change.
(3) Lesion confined to within the submucosa, as confirmed by magnifying endoscope, endoscopic ultrasound (EUS) or high-resolution MRI.
(4) No evidence of lymph node metastasis or distant tumor metastasis on contrast-enhanced abdominal CT, systemic superficial lymph node ultrasonography, and PET-CT.
(5) The patient refuses surgical resection, has contraindications for surgery, or strongly desires to preserve the colonic segment and its function.

2.2. Contraindications

(1) Lesion infiltration depth extending beyond the submucosa.
(2) Suspected or confirmed lymph node or distant metastasis based on imaging.
(3) Coagulopathy that cannot be corrected to within a safe range for the procedure.
(4) Severe fibrosis of the intestinal wall, indicated by a negative lifting sign after submucosal injection.
(5) Severe comorbidities where the patient cannot tolerate painless colonoscopy treatment.

2.3. Preoperative evaluation and preparation

(1) Comprehensive Imaging Examination: Contrast-enhanced abdominal CT. Systemic superficial lymph node ultrasonography. Colonoscopic endoscopic ultrasound (EUS) for precise assessment of the lesion layer and surrounding lymph nodes. PET-CT to rule out distant metastasis.
(2) Thorough Endoscopic Assessment: Utilize high-definition chromoendoscopy to define the lesion's boundaries, morphology, surface microstructure, and microvascular pattern.
(3) Bowel Preparation: Maintain a liquid diet one day before the procedure. Administer laxatives on the evening before surgery for bowel cleansing until clear, watery stool is passed. Consider using defoaming agents (e.g., simethicone) preoperatively to improve visual field clarity if necessary.
(4) Prophylactic Antibiotic Use: Routine preoperative prophylactic antibiotics are not recommended. For patients with high-risk factors (e.g., prolonged procedure duration, extensive resection, comorbid diabetes, immunocompromised status), intravenous antibiotics covering Gram-negative bacteria and anaerobes may be administered 30-60 minutes preoperatively.

(5) Informed Consent: Provide detailed information regarding the surgical procedure, alternative treatments (including laparoscopic surgery), potential risks (e.g., perforation, bleeding, infection, conversion to open surgery), and the postoperative follow-up plan.

2.4. Surgical procedure

The procedure was demonstrated in **Figure 1**.

(1) Marking and Injection: Use an argon plasma coagulator (APC) or a Dual Knife to perform electrocoagulation marks at 0.5–1 cm outside the lesion periphery. Perform a submucosal injection of a saline-indigo carmine-epinephrine mixture to establish an adequate submucosal fluid cushion.

(2) Mucosal Incision and Dissection: Use a disposable mucosal incision knife to perform a circumferential mucosal incision. Progressively dissect the submucosal layer following the principle of "proceeding from distal to proximal and from superficial to deep," while maintaining a clear surgical field.

(3) Traction and Exposure: Adequately expose the muscularis propria using traction devices such as an "8-shaped ring" or a "clip-and-loop" system (e.g., a clip with a rubber band).

(4) Full-Thickness Resection: Under direct vision, actively and meticulously incise the muscularis propria along the direction of its fibers using a triangle knife or IT knife to enter the abdominal cavity and achieve complete lesion resection. Care must be taken to avoid injuring the contralateral serosa and surrounding organs.

(5) Wound Closure: Adopt a "close-as-you-go" method, closing the defect simultaneously with the full-thickness incision. Approximate the muscular layers using through-the-scope clips (muscularis-to-muscularis coaptation). If necessary, perform an additional interrupted mucosal layer closure (mucosa-to-mucosa apposition) with clips to form a secure, interrupted double-layer closure. Ensure the closed wound shows no significant bleeding or fluid leakage. Consider spraying a fibrin sealant (biological protein glue) to reinforce the wound.

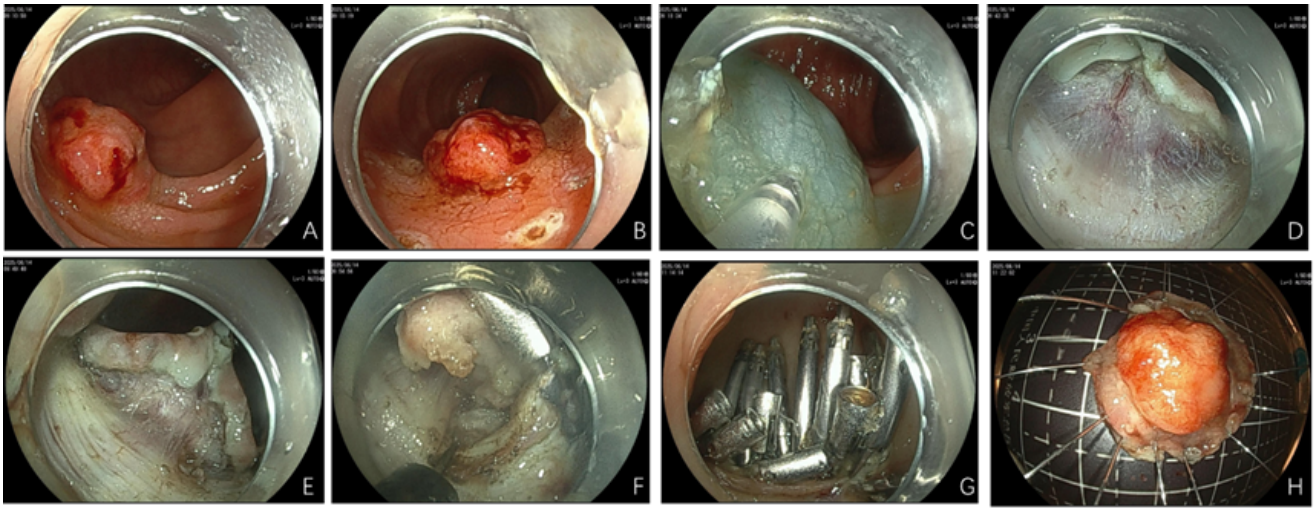

Figure 1. The procedural steps of sft-SMIR for early colon cancer. (A) White light endoscopic view of an early colon cancer lesion. (B) Electrocautery marking of the lesion margins. (C) Submucosal injection to elevate the lesion and create a submucosal fluid cushion. (D) Circumferential mucosal incision and initiation of submucosal dissection. (E) Adequate exposure of the muscularis propria layer was achieved using a traction device. (F) Full-thickness resection of the lesion along the muscular layer. (G) Closure of the post-resection defect using through-the-scope clips. (H) Gross specimen showing the resected lesion en bloc.

2.5. Postoperative management and follow-up

(1) Close Monitoring: Monitor vital signs closely postoperatively and observe for any signs of abdominal pain or peritonitis.

(2) Dietary Management: Maintain nil per os (NPO) for 3–5 days. If no complications occur, gradually advance the diet from liquids to semi-liquids.

(3) Decompression: Place a rectal tube for decompression and flatus release to prevent wound dehiscence.

(4) Prophylactic Antibiotics: Discontinue prophylactic antibiotics within 48 hours if no signs of infection are present. If follow-up complete blood count (CBC) and C-reactive protein (CRP) testing the next day indicate infection, extend the duration of antibiotic therapy and, if necessary, escalate to restricted antibiotics for rapid control of abdominal infection.

(5) Complication Vigilance: If the patient experiences persistent or sudden worsening abdominal pain, be alert for delayed perforation. Perform an upright abdominal plain film or abdominal CT scan promptly. Manage minor perforations endoscopically in a timely manner. If endoscopic closure is difficult, activate a fast-track protocol for surgical consultation and management.

(6) Follow-up Schedule: Perform follow-up colonoscopy, CEA and imaging (CT or MRI) at 3 months, 6 months, and 1 year postoperatively to assess wound healing and check for recurrence.

3. Technical specifications for sft-SMIR in early rectal cancer [6]

3.1. Indications

(1) Early rectal cancer (cT1 stage), located ≤ 8 cm from the anal verge.

(2) Tumor diameter ≤ 3 cm, identified as well to moderately differentiated carcinoma or high-grade intraepithelial neoplasia with cancerous change.

(3) Lesion confined within the submucosa and no evidence of mesorectal lymph node metastasis, as confirmed by high-resolution pelvic MRI and rectal EUS.

(4) No evidence of lymph node or distant metastasis on contrast-enhanced abdominal CT, systemic superficial lymph node ultrasonography, and PET-CT.

(5) Strong patient desire for sphincter preservation (anal preservation) with a clear understanding of the potential risks associated with local resection.

3.2. Contraindications

(1) Poorly differentiated carcinoma, signet ring cell carcinoma, or mucinous adenocarcinoma.

(2) Tumor invasion of the anal canal or sphincter complex.

(3) Suspected or confirmed lymph node metastasis on imaging.

3.3. Preoperative evaluation and preparation

(1) High-Resolution Pelvic MRI with Contrast or Rectal MRI with Contrast: To assess the distance from the tumor to the anal verge, its relationship to the sphincter complex, T-stage, circumferential resection margin (CRM) status, the presence of extramural vascular invasion (EMVI), and lymph node metastasis.

(2) Rectal Endoscopic Ultrasound (EUS): To accurately evaluate the depth of tumor invasion (uT staging) and the status of perirectal lymph nodes.

(3) Bowel Preparation: As per the protocol for colon cancer.

(4) Prophylactic Antibiotics: The principles are consistent with those for colon cancer. Given that rectal surgery involves the lower gastrointestinal tract with its complex flora (dominated by Enterococcus, Pseudomonas aeruginosa, Escherichia coli, etc.), high-risk patients should receive antibiotics covering Gram-negative bacteria and anaerobes.

(5) Anesthesia and Positioning: General anesthesia is required. The patient's position (prone, left lateral, or lithotomy) should be selected based on the lesion location (anterior wall, posterior wall, lateral wall) to ensure the lesion is positioned directly within the operative field.

3.4. Surgical procedure

The surgical procedure was demonstrated in **Figure 2**.

(1) Exposure and Marking: A therapeutic endoscope with a water-jet function may be used to obtain a stable visual field and operative space. Mark the periphery of the lesion using Argon Plasma Coagulation (APC) or an electrocautery knife.

(2) Submucosal Dissection: The steps are consistent with those for colon cancer.

(3) Full-Thickness Resection: Clearly identify the anatomical planes and perform meticulous dissection within the mesorectal fat layer. Care must be taken to preserve the pelvic autonomic nerves. For anterior wall lesions, exercise heightened caution to avoid injury to the vagina or prostate.

(4) Wound Closure: As the rectum is located below the peritoneal reflection, wound closure can be performed after the full-thickness resection is completed. Closure techniques may include: muscularis-to-muscularis coaptation, interrupted double-layer closure and reinforcement with sprayed fibrin sealant (biological protein glue).

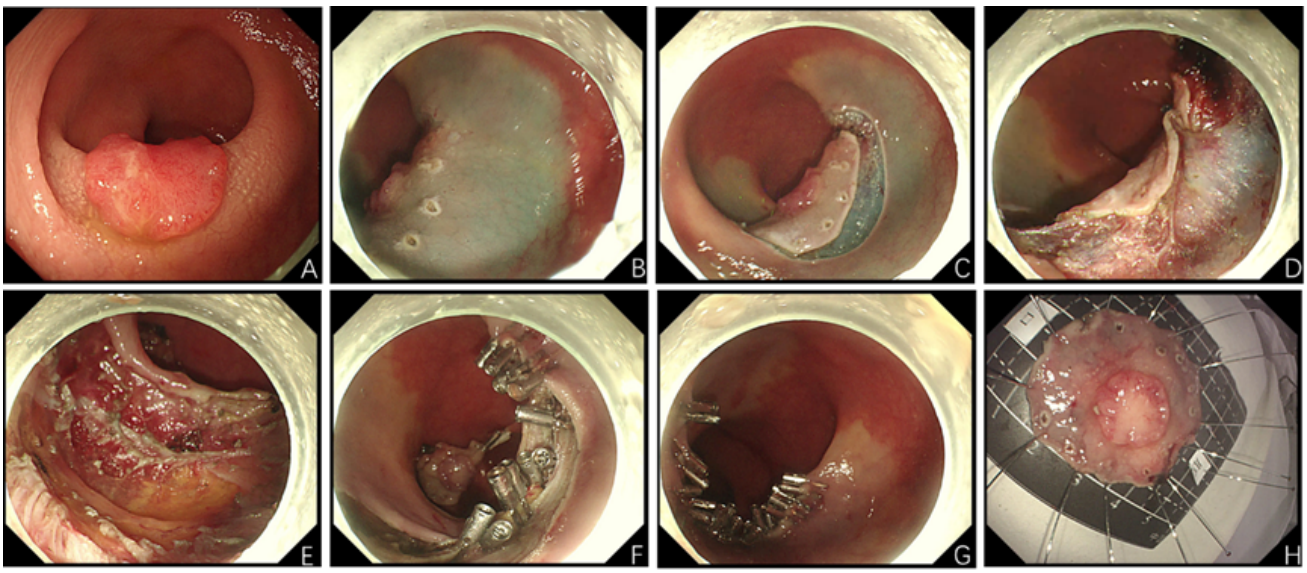

Figure 2. The procedural steps of sft-SMIR for early rectal cancer. (A) White light endoscopic view of an early rectal cancer lesion. (B) Marking of the lesion margins followed by submucosal injection. (C) Circumferential mucosal incision and submucosal dissection. (D) Adequate exposure of the muscularis propria was achieved using a traction device. (E) Full-thickness resection is being performed. (F) Closure of the muscular layer defect. (G) Apposition of the mucosal layer. (H) Gross view of the resected specimen (mucosal surface).

3.5. Postoperative management and follow-up

Postoperative management is consistent with that for colon cancer.

(1) Special Attention to Anal Function: Regularly assess bowel function using the Low Anterior Resection Syndrome (LARS) score during follow-up [7].

(2) Close Follow-up: Perform follow-up examinations, including colonoscopy, endoscopic ultrasound (EUS), CEA, and pelvic MRI at 3, 6, and 12 months postoperatively.

4. Technical specifications for sft-SMIR following neoadjuvant therapy in locally advanced low rectal cancer [8]

4.1. Indications

(1) Low rectal cancer (≤ 10 cm from the anal verge) after standard neoadjuvant chemoradiotherapy (nCRT).

(2) Clinical assessment indicating clinical complete response (cCR) or near clinical complete response (ncCR), defined as follows:

(A) Digital Rectal Examination (DRE): No palpable mass, or only mild mucosal irregularity/induration.

(B) Endoscopy: White, flat scar with telangiectasia (the "Galaxy Sign"), or a superficial ulcer, with no nodular residue.

(C) High-Resolution Pelvic MRI with Contrast or Rectal MRI with Contrast: Significant tumor regression (or residual fibrosis only), no diffusion-weighted imaging (DWI) signal restriction suggestive of residual tumor, and no signs of lymph node metastasis.

(D) Serum CEA: Normalized levels.

(3) Fully informed consent from the patient, who understands the trade-offs between the Watch-and-Wait (W&W) strategy and local excision, and has a strong desire for sphincter (anal) preservation and functional outcomes.

4.2. Contraindications

(1) Poor tumor regression after nCRT (ymrT3-4 or mrN+).

(2) Lateral lymph nodes with a short-axis diameter ≥ 5 mm or exhibiting abnormal morphology.

(3) Luminal stenosis that prevents the passage of the endoscope.

(4) Poor general condition rendering the patient unable to tolerate the procedure.

4.3. Preoperative evaluation and preparation

(1) Multidisciplinary Team (MDT) Assessment: MDT evaluation is the cornerstone of decision-making and must include specialists from gastroenterology, general surgery, radiation oncology, medical oncology, radiology, and pathology.

(2) Restaging After nCRT: A comprehensive restaging workup should be performed within 12 weeks after completing nCRT. This includes: Digital rectal examination (DRE). EUS. High-definition colonoscopy with biopsies of any suspicious areas. High-resolution pelvic MRI including diffusion-weighted imaging (DWI). Chest and abdominal CT. Serum CEA level.

(3) Thorough Communication: Detailed discussion with the patient regarding the pros and cons of the W&W strategy versus sft-SMIR after cCR. It should be explained that sft-SMIR can provide pathological confirmation for accurate staging but still carries inherent surgical risks.

(4) Bowel Preparation and Antibiotics: As per the protocol for early rectal cancer (refer to section 2.3).

4.4. Surgical procedure

The surgical procedure was demonstrated in **Figure 3**.

(1) Resection Range: The full-thickness resection should encompass the entire original tumor bed and the surrounding fibrotic tissue. The resection margin should be ≥ 0.5 cm from the edge of the scar.

(2) Technical Key Points: Due to severe tissue fibrosis following nCRT, determining the boundaries for full-thickness resection can be challenging. The following technique can be applied: Perform multiple submucosal injections around the area. Identify the boundary between areas where the mucosa can be lifted and areas where it cannot be lifted. The non-lifting area defines the extent requiring full-thickness resection, while the lifting area may be included via extended non-full-thickness dissection. Make full use of traction techniques to adequately expose the dissection planes.

(3) Specimen Handling: The specimen must be flattened and fixed with both the anterior and posterior surfaces clearly exposed. The orientation (oral side, anal side) must be clearly marked. The specimen is then sent for comprehensive pathological evaluation to determine the ypTNM stage and Tumor Regression Grade (TRG).

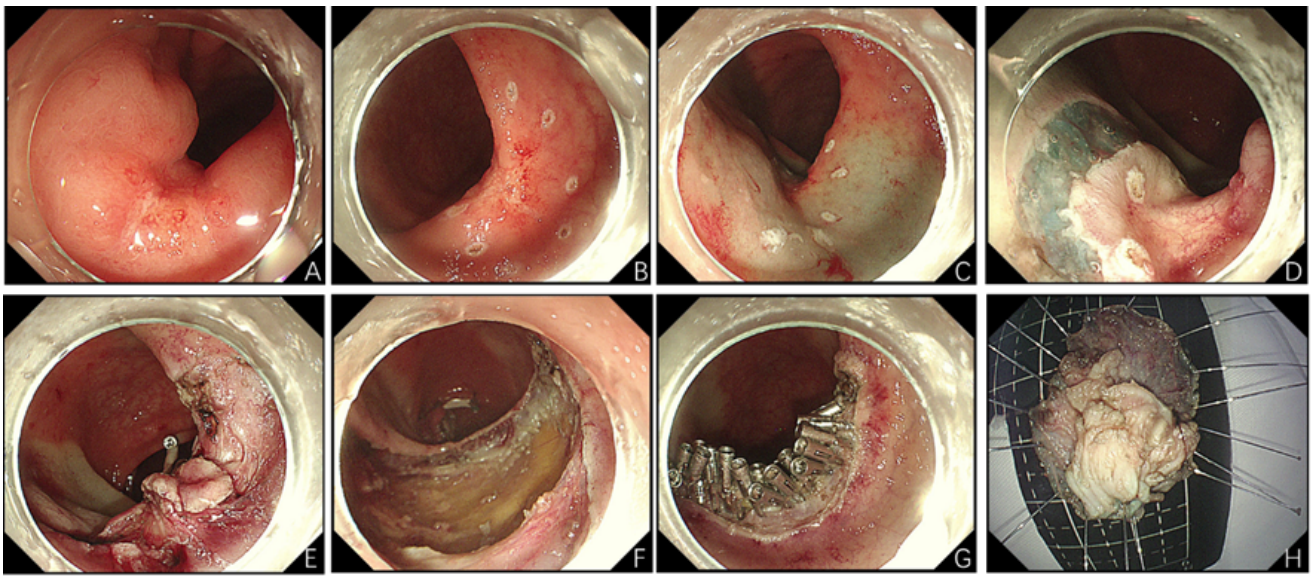

Figure 3. The procedural steps of sft-SMIR following neoadjuvant therapy for locally advanced low rectal cancer. (A) White light endoscopic view of the post-nCRT lesion. (B) Marking the perimeter of the fibrotic scar. (C) Submucosal injection around the scarred area. (D) Performing submucosal dissection. (E) Applying a clip-and-loop traction system to fully expose the muscular layer. (F) Full-thickness incision through the muscular layer at the fibrotic scar site, revealing the extramural tissue. (G) Closing the full-thickness defect with through-the-scope clips. (H) Serosal surface view of the resected specimen.

4.5. Postoperative management and follow-up

(1) If the pathology report indicates ypT0-1 and negative margins, the patient can be considered for entry into an intensive follow-up protocol.

(2) If the pathology report indicates ypT2, the patient should be recommended to undergo complementary

total mesorectal excision (TME) surgery or postoperative chemotherapy.

(3) If the pathology report indicates ypT3 or higher, the patient should be recommended to undergo complementary total mesorectal excision (TME) surgery.

(4) The postoperative follow-up schedule is consistent with that for early rectal cancer, but must be conducted more frequently and closely.

5. Summary

sft-SMIR is a complex endoscopic procedure, guided by the Super-Minimally Invasive Surgery (SMIS) concept, used for treating specific colorectal lesions [9]. Its successful implementation and widespread adoption depend on several critical aspects:

(1) Strict Adherence to SMIS Principles [10]: The core objective of sft-SMIR is to eradicate the disease while maximally preserving the anatomical structure and physiological function of the colorectal organ, truly embodying the SMIS philosophy of "curing the disease and restoring the patient to their original state."

(2) Comprehensive and Standardized Perioperative Management:

(A) Precise Preoperative Evaluation and Meticulous Preparation as the Foundation: A Multidisciplinary Team (MDT) approach is crucial in this phase.

(B) Meticulous Intraoperative Technique and Secure Wound Closure as the Technical Cornerstone: This requires proficiency in various endoscopic resection and closure/suturing techniques.

(C) Prevention, Timely Identification, and Management of Postoperative Complications, Coupled with Long-term Regular Follow-up: These elements form the cornerstone for ensuring patient safety and long-term efficacy.

(3) Heightened Emphasis on Infection Prevention and Control: The digestive lumen is a non-sterile environment. sft-SMIR breaches the gastrointestinal mucosal barrier, thereby increasing the risk of infection. Strict adherence to the "Expert Consensus on Wound Preprocessing and Antibiotic Use in Digestive Endoscopic Super-Minimally Invasive Surgery" is mandatory [11]. This includes:

(A) Adequate Bowel Preparation.

(B) Standardized Cleaning and Disinfection of Endoscopes and Accessories.

(C) An Individualized Strategy for Antibiotic Prophylaxis, based on the surgical site and patient risk factors. For example, prophylactic use is recommended for patients with full-thickness defects or those with high-risk factors.

(4) Continuous Improvement of Quality Control and Training Systems: The learning curve for sft-SMIR is steep. It is essential to establish a standardized training system utilizing structured models, such as proctorship (expert mentoring), simulation training, and video-based learning. Concurrently, a set of surgical quality evaluation metrics must be developed, including: en bloc resection rate, R0 resection rate, complication rate, and postoperative functional assessment. These measures are crucial for promoting the healthy and standardized development of this technique.

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Disclosure statement

The authors declare no conflict of interest.

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