



American Society for Gastrointestinal Endoscopy Technology Status Evaluation Report: endoscopic submucosal dissection (with videos)

Prepared by: ASGE Technology Committee

Galen Leung, MD,¹ Daniela Guerrero Vinsard, MD,² Maaza Abdi, MD,³ Paul A. Akerman, MD, FASGE,⁴ Venkata S. Akshintala, MD,³ Petros C. Benias, MD,⁵ Koushik K. Das, MD, FASGE,⁶ David J. Desilets, MD, PhD, FASGE,⁷ Mark Hanscom, MD,⁸ Nabil M. Mansour, MD,⁹ Neil B. Marya, MD,¹⁰ Girish Mishra, MD, MSc, FASGE,¹¹ V. Raman Muthusamy, MD, MAS, FASGE,¹² Swati Pawa, MD, FASGE,¹¹ Tarun Rustagi, MD,¹² Nikrad Shahnavaz, MD,¹³ Ryan J. Law, DO,¹⁴ ASGE Technology Committee Chair

New York, New York; Minneapolis, Rochester, Minnesota; Baltimore, Maryland; Providence, Rhode Island; New Brunswick, New Jersey; St Louis, Missouri; Springfield, Worcester, Massachusetts; Houston, Texas; Winston Salem, North Carolina; Los Angeles, California; Atlanta, Georgia, USA

This document was reviewed and approved by the Governing Board of the American Society for Gastrointestinal Endoscopy.

The American Society for Gastrointestinal Endoscopy (ASGE) Technology Committee provides reviews of existing, new, or emerging endoscopic technologies that have an impact on the practice of GI endoscopy. Evidence-based methodology is used, with a MEDLINE literature search to identify pertinent clinical studies on the topic and a MAUDE (U.S. Food and Drug Administration Center for Devices and Radiological Health) database search to identify the reported adverse events of a given technology. Both are supplemented by accessing the “related articles” feature of PubMed and by scrutinizing pertinent references cited by the identified studies. Controlled clinical trials are emphasized, but in many cases, data from randomized, controlled trials are lacking. In such cases, large case series, preliminary clinical studies, and expert opinions are used. Technical data are gathered from traditional and Web-based publications, proprietary publications, and informal communications with pertinent vendors. Technology Status Evaluation Reports are drafted by 1 or 2 members of the ASGE Technology Committee, reviewed and edited by the committee as a whole, and approved by the Governing Board of the ASGE. When financial guidance is indicated, the most recent coding data and list prices at the time of publication are provided. For this review, the MEDLINE database was searched through August 2024 for articles related to endoscopic submucosal dissection. Technology Status Evaluation Reports are scientific reviews provided solely for educational and informational purposes. Technology Status Evaluation Reports are not rules and should not be construed as establishing a legal standard of care or as encouraging, advocating, requiring, or discouraging any particular treatment or payment for such treatment. (Gastrointest Endosc 2026;104:152-63.)

(footnotes appear on last page of article)

BACKGROUND

Endoscopic submucosal dissection (ESD) is a minimally invasive technique first described in 1988 to treat early gastric neoplasia nonoperatively.¹ In contrast to endoscopic mucosal resection (EMR), which utilizes a snare, ESD necessitates the use of a dedicated electrosurgical knife to dissect into the submucosal plane of carefully selected mucosal and submucosal lesions. ESD allows en bloc removal of larger (>2 cm) precancerous, early-stage gastrointestinal malignant lesions, or submucosal tumors, whereas EMR relies on piecemeal resection to remove lesions >2 cm in size. En bloc resection makes a pathological evaluation possible, which includes the possibility of curative R0 resections (circumferential and deep margins microscopically free of neoplastic cells without high-risk features). Suitability and indications for ESD vary according to lesion location (esophageal, gastric, duodenal, or colorectal), morphology, predicted depth of invasion via optical diagnosis,

cerous, early-stage gastrointestinal malignant lesions, or submucosal tumors, whereas EMR relies on piecemeal resection to remove lesions >2 cm in size. En bloc resection makes a pathological evaluation possible, which includes the possibility of curative R0 resections (circumferential and deep margins microscopically free of neoplastic cells without high-risk features). Suitability and indications for ESD vary according to lesion location (esophageal, gastric, duodenal, or colorectal), morphology, predicted depth of invasion via optical diagnosis,

and predicted histopathology.²⁻⁴ Additionally, ESD can be useful to remove mucosal tumors with submucosal fibrosis, in conditions of chronic inflammation, and in local residual or recurrent neoplasia after prior endoscopic resection.⁵

TECHNOLOGY UNDER REVIEW

In the past decade, ESD indications have expanded, and the technical approach has continued to evolve in the United States.⁶ Multiple technologies have emerged to support endoscopists during this demanding procedure. Innovative techniques and technologies can improve ESD outcomes, including successful submucosal visualization and complete lesion resection while minimizing adverse events and optimizing procedural time.

ESD is accomplished in a systematic manner, and a variety of devices are available to assist the endoscopist in completing each step. ESD steps can be summarized as follows: (1) the perimeter of the lesion is marked with cautery; (2) a lifting agent is injected into the submucosa around the perimeter of the lesion; (3) the mucosa is incised and then cut circumferentially around the lesion; (4) the submucosa beneath the lesion is injected and then dissected in a free-hand manner until the specimen has been completely resected; (5) any intraprocedural bleeding that occurs during the mucosal incision or submucosal dissection is managed by using a distal endoscope cap for localization, a water jet for washing, and hemostatic forceps or an electro-surgical knife for vessel coagulation; and (6) closure of the post-ESD defect is then performed in select cases.

This ASGE Technology Review aims to provide an update on current devices used to assist with all steps of endoscopic dissection including a variety of knives with different capabilities, distal caps for improved visualization, traction devices for tissue manipulation and improved submucosal dissection, and luminal anchoring devices for better stability. There will be limited discussion on submucosal injection agents, closure devices, and electro-surgical generators, since these topics are covered in other recent ASGE Technology Review documents. In addition, a basic concept of electro-surgical generators will be provided, as specific settings depend on a variety of factors, such as tissue characteristics, carbon dioxide or saline insufflation, and desired effects. There will also be a brief discussion of ESD techniques and safety, since these discussions complement how ESD devices are used.

DEVICES FOR ESD

The foundational endoscopic tools used to perform ESD include an electro-surgical knife, a submucosal injection agent and its delivery device, optional resection snares, devices aimed at hemostasis, tissue retraction de-

vices, tools for closure of the submucosal defect, and an electro-surgical generator.

TYPES OF KNIVES

With the growth of ESD, there has been development of different classes of ESD knives, affecting dissection technique. They are primarily categorized into noninsulated-tip, insulated-tip, scissor type, other shaped type, and bipolar energy knives. In addition, most current-generation ESD knives have an injection port through the knife for submucosal lifting. There is minimal evidence comparing knives, so specific device choices are based on endoscopist preference. [Supplementary Table 1](#) (available online at www.giejournal.org) lists the ESD devices that are approved by the U.S. Food and Drug Administration, their product information, as well as specific capabilities during ESD. All ESD devices are designed for single use only and most devices are compatible with a 2.8 mm endoscopic instrument channel. Certain knives have 2 lengths specific for a gastroscope or colonoscope, while others only have 1 longer length for use through any length endoscope.

Noninsulated-tip needle knives

The noninsulated-tip needle knife can perform dissection through the tip of the knife. The needle tip comes in a variety of fixed or adjustable lengths. Electro-surgical current is conducted along the surface area of the needle tip, allowing for submucosal dissection in a 3-dimensional plane and for use during all steps of ESD. Some noninsulated-tip knives allow for injection of fluid through the knife tip or catheter to maintain the submucosal lift during dissection. Some of these knives have a wider or disc-shaped electrode at the distal sheath that allows for improved hemostasis during dissection given the wider surface area. However, those with a large disk-shaped electrode at the tip of the knife can be used to hook tissue during dissection for more controlled dissection, as well as provide a large surface area for coagulation of small vessels and minor bleeding.

Insulated-tip needle knives

The insulated-tip needle knives have a ceramic tip, which serves to reduce the risk of inadvertent dissection and potential perforation of deeper tissues. Dissection is performed in a lateral or 2-dimensional plane, perpendicular to the catheter, which requires proper positioning of the endoscope. However, certain knives, such as the IT-knife2 (Olympus America, Center Valley, Pa, USA), also have an electrode on the proximal side of the ceramic tip that also allows for vertical dissection.

Scissor-type

Scissor-type knives can grasp the target tissue and perform mucosal incision and submucosal dissection through its

conductive inner portion while protecting surrounding tissue from thermal injury and bleeding with its insulated outer edge. The scissor jaws come in a variety of sizes.

Other shaped knives

There are also knives with a rotatable L-shape knife that allows for tissue retraction during submucosal dissection or an adjustable length soft braided loop knife that allows flexibility in performing dissections in all planes while reducing risk of perforation.

Bipolar type

The Creo ESD knives (CREO Medical, Danbury, Conn, USA) are bipolar energy knives, unlike the previously described monopolar knives, which allow for mucosal incision and dissection utilizing radiofrequency ablation energy. This allows for a closed loop current within the knife with lower voltage than knives which implement monopolar energy. Hemostasis is performed by microwave energy at the knife's contact point, which can be used for coagulation with an energy cycle that limits deeper tissue injury. The knives require their own bipolar electrosurgical generator and are effective in a dry environment. CREO Medical has manufactured knives of various shapes, such as blade-type shape and a scissor type.

INJECTION AGENTS AND DELIVERY DEVICES

Injection of a colloid submucosal agent prior to mucosal incision and submucosal dissection is essential for ESD practice as it separates the lesion from the muscularis propria, thus opening the submucosal space and reducing adverse events such as bleeding, thermal injury, and perforation. The injection agent should be easy to deliver, provide a long-lasting submucosal cushion, and be nontoxic or have minimal tissue reaction.⁷ For nonproprietary injection fluids, the addition of a contrast agent, such as methylene blue or indigo carmine, is necessary. The contrast agent improves delineation of lesion borders and stains submucosal fibers, thereby exposing a safe submucosal dissection plane away from the muscular layer and decreasing the risk of perforation.⁸ The addition of epinephrine to the lifting agent has shown to reduce procedural time of gastric ESD due to less intraprocedural bleeding,^{9,10} but its utility has not been clearly established, and adverse events including gastric ischemia and myocardial infarction have been reported.^{11,12}

Injection agents available for EMR can be used for ESD prior to the mucosal incision. Multiple studies have demonstrated longer lasting cushions made with various agents including hyaluronic acid (HA), hydroxypropyl methylcellulose (HPMC), succinylated gelatin, glycerol 10%, and a fibrinogen solution.¹³ In the last decade, multiple proprietary lifting agents containing methylene blue and a viscous agent have been FDA approved in the United States (Supplementary Table 2, available online at www.giejournal.org).

Please refer to the ASGE Technology Review document on submucosal injection fluid and tattoo agents for an expanded discussion.¹⁴

After mucosal incision is created and during submucosal dissection, injection of a contrast lifting agent should be performed as needed into the submucosal space for maintenance of a safe dissection plane. These agents can be delivered with a 21- to 25-gauge injection needle catheter. More viscous agents require a larger bore needle.¹³ Some ESD knives have a central lumen in the knife that allows the colloid lifting agent to be flushed through by syringe injection. Another option would be to allow saline injection by attaching a water pump to the knife, and for specific knives (eg, Erbe HybridKnives, Erbe Electromedizin GmbH, Tübingen, Germany), high pressurized saline injection can be delivered by a proprietary hydrosurgical unit.¹⁵

ANCILLARY TOOLS FOR IMPROVED VISUALIZATION AND TISSUE MANIPULATION

Distal attachments

Distal attachments include transparent caps (straight tip) and hoods (tapered tip), which maintain an optimal field of view and facilitate dissection within the submucosal space by providing countertraction (Supplementary Table 3, available online at www.giejournal.org). Caps and hoods have a side hole that ensures that any fluid inside the cap is drained at all times.¹⁶ There are no comparative trials of cap versus no-cap assisted ESD, and evidence is limited to case reports and expert opinion.¹⁷ Outside the United States, multiple innovative caps and hoods that broaden endoscope functionality have been developed. These over-the-scope working channels enable the passage of grasping forceps, hemostatic clips, or snares to facilitate traction during dissection. Some examples of these enhanced distal attachments are the Additional Working Channel or AWC (Ovesco AG, Tübingen, Germany) and the Endolifter (Olympus America).¹⁸

Devices and methods for tissue retraction

Submucosal dissection can be technically difficult because of limited visualization and lack of traction provided with a single-channel endoscope. Traction devices serve as invaluable tools to provide more efficient and safer submucosal dissection, especially in scarred-down lesions and lesions on the side of gravity. Devices for tissue retraction can be further categorized as hemostatic clip-based and grasper-based, with both proprietary and self-made iterations available. Hemostatic clip-based traction allows for free maneuverability of the endoscope for dissection, but the traction point is fixed when the hemostatic clip or clips are deployed. Grasper-based traction allows adjustability of the traction point; however, the dissection plane is limited by movement of the endoscope and grasper, and currently the only grasper-based devices available in the United States are only compatible

with single- or dual-channel upper endoscopes. Lastly, a suture could be placed with a suturing device to hold traction, particularly if planning to close the postresection site with a suture device.

A double-channel endoscope technique can also be utilized to permit the use of additional accessories, such as grasping forceps or TracMotion (Fujifilm Endoscopy, Tokyo, Japan) to apply traction by grasping the mucosal part of the lesion away after circumferential mucosal incision, thereby providing tension and exposing the submucosal plane. As mentioned above, externalized distal attachments with an accessory working channel are also available.

Handmade traction tools

Hemostatic clip-with-line. Hemostatic clip-with-line traction is an external traction technique and one of the earliest traction techniques developed (Supplementary Table 4, available online at www.giejournal.org). This simple technique involves a line, either a suture or dental floss (off-label use), to be tied onto a hemostatic clip after it has been passed down the endoscope. The use of dental floss in this manner is considered off-label because it is not the product's approved purpose. Although extremely safe, informed patient consent is required for this and any other off-label traction technique or device used for ESD. After circumferential mucosal incision and opening of the submucosal space, the hemostatic clip is attached to the mucosal edge of the target lesion while avoiding clipping the muscle layer. The line is maintained outside the orifice, either the mouth or anus, and attached to an external weight, such as a hemostat, to provide external traction. The hemostatic clip-with-line technique shows significant reduction in perforation rates and improvement in resection times in lesions located in the greater curvature of the proximal and middle stomach during gastric ESD. However, it is limited by the direction in which the line is pulled. A modification of this technique is the hemostatic clip-with-line pulley method where an additional hemostatic clip affixed to the opposite luminal wall provides an additional vertical tract.¹⁹⁻²¹

Hemostatic clip-and-loop. The hemostatic clip-and-loop technique is an internal traction method that also provides vertical traction by tying a custom-sized O-loop with a suture, dental floss, spring, or rubber band to a hemostatic clip. The hemostatic clip is passed down the endoscope channel and attached to the mucosa of the target lesion after circumferential mucosal incision and exposure of the submucosal layer. Then another hemostatic clip is used to attach the O-loop to the opposite luminal wall or in any other desired direction. This technique can increase complete resection rates of scarred down lesions.²²

Hemostatic clip-and-snare method. The hemostatic clip-and-snare technique entails a transparent cap that is prelooped with a snare from the outside of the endoscope. A hemostatic clip is inserted through the working channel and attached to the edge of the lesion. The snare

is loosened and moved forward to grasp the hemostatic clip before deployment. The hemostatic clip is then released from the forceps. Compared to the hemostatic clip-with-line method, the snare has a stable sheath to adjust traction by pulling or pushing the hemostatic clip in forward or retroflexed views.^{23,24}

Multiloop with sutures. The multiloop (M-loop) with sutures method is similar to the hemostatic clip-and-loop but with multiple loops for locations with a wide lumen. To create a multiloop traction tool with sutures, the suture is tied around a 2.5-cc syringe and a knot is created. By repeating this process, the number of loops can be adjusted, depending on the diameter of the lumen, then the redundant thread is trimmed. After circumferential excision is made, the M-loop is attached to the edge of the lesion. The second, free end of the loop is attached to the contralateral wall with a hemostatic clip. The thread of the M-loop is dissected after the lesion is dissected off of the wall, and the specimen is collected. Studies have demonstrated reduction in dissection time using this method.^{25,26}

Multitraction with double hemostatic clip and rubber band. After circumferential incision and injection of a submucosal agent, a first hemostatic clip with a rubber band attached is introduced through the scope and placed in the medial part of the distal side of the lesion. Then 2 other hemostatic clips are placed on either side of the first hemostatic clip, also grasping the rubber band. Finally, the band is grasped with a fourth hemostatic clip and affixed on the opposite wall.²⁷ A French study evaluating this method for colorectal ESD demonstrated an increase in the percentage of R0 and curative resection and a decrease in procedure duration, particularly for residual or locally recurrent lesions post-EMR or lesions involving the appendiceal orifice.²⁸⁻³⁰

Magnetic anchor. A magnetic anchor can be applied to produce traction, similarly to the hemostatic clip-and-loop technique. A thread connected to a magnet is tied to a hemostatic clip, and in turn, a second external magnet is used to adjust the direction of traction.³¹ A benefit of using this method is the ability to move the external magnet and adjust the traction during the procedure. There are several limitations, including lack of function due to abdominal wall thickness, potential interaction between magnets and other tools, and the possible harmful effects of magnets on human tissue.³²

Proprietary traction devices

SureTrac. The SureTrac system (Micro-Tech Nanjing Co, Ltd, Nanjing, China) consists of a preloaded elastic silicone band with 2 rings on a primary clip and a secondary clip to anchor on adjacent tissue (Supplementary Table 5, available online at www.giejournal.org). The silicone band is designed to retract and release elastic potential energy for dynamic traction during submucosal dissection.

Multiloop traction device. The multiloop traction device (MLTD) (Boston Scientific Co, Ltd, Tokyo, Japan) has 3 connected rings made of polyethylene. The MLTD is delivered to the lesion site from the forceps channel of an endoscope.

The middle ring can be used to change the direction of traction after initial attachment.³³ Rotatable hemostatic clips can be used to deliver the MLTD to the resection area, and then additional hemostatic clips attached to the intermediary loops can be used to provide and adjust the traction direction. In addition, the loops can be easily cut with biopsy forceps.^{34,35} This tool is not yet available in the United States.

ProdiGi traction wire. The Traction Wire, ProdiGi Traction Wire (Medtronic, Minneapolis, Minn, USA), consists of 2 graspers: a primary tissue grasper with traction wire attached, and a secondary tissue grasper without a wire. The secondary tissue grasper is used to secure the distal end of the traction wire. This device contains nickel in the form of nitinol and stainless steel.³⁶⁻³⁸

ProdiGi traction magnet. The traction magnet device includes 2 separate clips with preattached magnetic beads. After mucosal incision, the first clip is attached to the mucosal flap, and the second is attached to the contralateral wall. The magnetic beads immediately gain contact, causing a pull on the mucosal flap, subsequently leading to opening and improved accessibility of the submucosal space. This device by Medtronic is available in Europe.³⁹⁻⁴² Similar to the ProdiGi Traction Wire, the ProdiGi Traction Magnet also contains nickel.

S-O clip. The S-O (Sakamoto-Osada) clip (Zeon Medical, Tokyo, Japan) is a traction device that has a 5 mm spring with a 4 mm nylon loop attached to a clip claw. The S-O clip provides traction in any direction and has been used for both gastric and colorectal lesions.⁴³⁻⁴⁵

EndoTrac. EndoTrac (Top Corporation, Tokyo, Japan) is a traction device consisting of a line with a loop at its tip, a plastic sheath, and a T-shaped handle. After tying the line to a hemostatic clip, the distance between the hemostatic clip and the tip of the plastic sheath can be adjusted by operating the handle. For example, pulling the handle advances the sheath forward and tightens the loop around the jaw of the hemostatic clip.⁴⁶⁻⁴⁸

TracMotion. This is a grasper-based device (Fujifilm Endoscopy) reserved for gastric and rectal ESD because of the need for a double-channel endoscope. This device is constructed with an articulating grasper and physician control knob, allowing adjustment of the direction of traction and regripping of the traction points.^{49,50} Clinical data on the performance of this device are limited, with studies demonstrating more efficient submucosal dissection and less physical demand in trainees when compared to conventional ESD in an ex vivo gravity-dependent model.⁵¹ An additional retrospective multicenter experience demonstrates high resection rates and an adequate safety profile.⁵²

DEVICES FOR NAVIGATION AND LUMINAL ANCHORING

Devices for colonic navigation can help with scope stabilization, decreased looping, improved visualization, and

ultimately decrease ESD time, particularly when the lesion is present in an unstable location.

DiLumen

In 2017, Lumendi (Lumendi LLC, Westport, Conn, USA) introduced the DiLumen Endoluminal Interventional Platform (EIP), a double-balloon endoluminal device designed for endoscopic treatment of colonic lesions. An upgraded version, DiLumen EZ Glide, now comes with a hydrophilic coating that creates a self-lubricating layer between the sheath and endoscope for easier navigation. When the colonic lesion is placed between the 2 insufflated balloons, this device stabilizes the therapeutic zone for complex EMR or ESD, which is particularly helpful for lesions located in colonic flexures and between folds.

Pathfinder

The Pathfinder (Neptune Medical, Burlingame, Calif, USA) is a rigidizing overtube comprised of a flexible tube connected to a vacuum system for stiffening through an integrated stopcock. Initially soft and flexible, the overtube stiffens by approximately 15-fold when vacuum pressure is applied. Utilizing this device for overtube-assisted colonoscopy enables colon straightening and angulation reduction to combat loop formation within the colon. Additionally, the overtube stays in place with an open lumen, allowing easy and fast reinsertion or exchange of scopes as well as retrieval of specimens. This device is particularly helpful for ESD in the hepatic flexure and right side of the colon.⁵³

CLOSURE DEVICES

Closure of mucosal defects following ESD can mitigate the risk of adverse events such as delayed bleeding and perforation. The available literature suggests that overall adverse events, specifically delayed bleeding, were significantly lower in the closure versus nonclosure of defects after gastric and rectal ESD.⁵⁴ Similarly, overall adverse events, including delayed bleeding and perforation, were significantly lower with defect closure in the duodenum and colon.⁵⁵ The optimal technique for defect closure varies based on factors such as the size and location of the lesion, skill level of the provider, and available equipment. Common strategies for closing defects rely on the use of hemostatic clips or endoscopic suturing.

Standard through-the-scope (TTS) clips can be used for relatively small defects, while anchoring clips for wider defects such as the Boston Scientific Mantis clip (Boston Scientific, Marlborough, Mass, USA)⁵⁶ and the Micro-Tech Dual Action Tissue Closure Device (Micro-Tech, Nanjing, China)⁵⁷ may be necessary.

Endoscopic suturing is better suited for addressing larger defects in the esophagus, stomach, and rectosigmoid region. For more proximal colonic defects and irregular or large

defects of difficult access, the X-Tack endoscopic HeliX tacking system (Boston Scientific, Marlborough, Mass, USA) can be used to close mucosal defects, although it is not able to perform full-thickness closure.

Endoscopic closure techniques are further explained in detail in another ASGE Technology Review.⁵⁸

ELECTROSURGICAL GENERATORS

ESD knives require an electrosurgical generator to transmit high-frequency monopolar or bipolar electrical currents to target tissue and generate thermal energy for various aspects of ESD. The electrosurgical generator allows delivery of a certain power or voltage to keep a consistent current, based on tissue impedance and the luminal environment. Typically, the waveform setting, duty cycle, and maximum peak voltage can be adjusted in order to perform the desired task during ESD. There are also proprietary programs that have specific waveforms, voltage, cutting durations and intervals, cutting and/or coagulation phases appropriate for each ESD step. Please refer to the ASGE Technology Review document, titled “Electrosurgical Generators” for further details about electrosurgical generators for a variety of purposes.⁵⁹

Regarding monopolar knives, there is no one specific electrosurgical generator setting recommended for each ESD step, as there are a variety of options depending on the diameter of the electrosurgical knife, carbon dioxide (CO₂) or saline immersion, tissue contact, target tissue characteristics, vasculature, the amount of fibrosis, and endoscopist procedural technique. Thus, there is no literature comparing each setting, and having specific settings for a dynamic procedure would not be appropriate. It is important to understand how electrosurgical generators work to be able to obtain the desired results during ESD. Mucosal incision is typically performed with a cutting current, which utilizes continuous sinusoidal waveform over 200 peak volts, allowing vaporization of cells. Dissection is typically performed with some degree of coagulation current with higher intermittent waveforms, allowing the desiccation of tissue, given the presence of submucosal vessels. Refer to [Supplementary Table 6](#) (available online at www.giejournal.org) for monopolar energy modes and desired results with the Erbe VIO 300D and VIO3 electrosurgical units (Erbe USA, Marietta, Ga, USA). Refer to [Supplementary Table 7](#) (available online at www.giejournal.org) for recommended bipolar energy modes for the Creo CROMA Advanced Energy electrosurgical unit.

ESD TECHNIQUES

There are various techniques to perform ESD ([Supplementary Table 8](#), available online at www.giejournal.org), but the procedure is dynamic, so it may be necessary to adapt combinations of techniques for efficient resection.

Conventional ESD

In conventional ESD, the lesion of interest, with a border of normal mucosa, may be marked with a coagulation current with the electrosurgical knife. A submucosal lifting agent is injected into the submucosal space, followed by complete circumferential mucosal incision with mucosal trimming. Submucosal dissection is performed until the lesion is completely resected en bloc.

Pocket creation method

The pocket creation method involves a horizontal mucosal incision approximately 1 to 2 cm away from the target lesion, near the lesion border closest to the endoscope, either on the oral side in gastric lesions or the anal side in colorectal lesions. Following access of the submucosal space, luminal air is suctioned, and the submucosal pocket is further dissected until the endoscope can enter the pocket and perform submucosal dissection from the near side of the lesion to the distant side. After submucosal dissection, the left and right sides of the distant side of the pocket are incised open. The pocket creation method allows for retention of the submucosal bleb, providing for sustained lift during dissection. Additionally, the submucosal pocket allows the endoscope to be positioned parallel to the plane of dissection, increasing access and stability. In a meta-analysis, the pocket creation method demonstrated a higher complete resection rate, shorter procedure time, and lower adverse event rate, when compared to conventional colorectal ESD.⁶⁰ The pocket creation method is helpful in scarred-down lesions, as well as lesions that are difficult to access tangentially with the endoscope, such as those along a colonic semilunar fold.

Endoscopic submucosal tunnel dissection

The tunneling ESD technique is a variation of the pocket creation method that is helpful in the esophagus, where more circumferential lesions may cause flopping of the resected mucosa, the lumen is narrow, and the submucosal plane is parallel to the direction of the endoscope. After submucosal injection, a mucosal incision is created on the anal side, then the oral side of the target lesion. Next, submucosal dissection is performed in a straight path from the oral to the anal side of the lesion. Then the left and right mucosal sides of the tunnel are opened. It allows for improved visualization and controlled dissection of the submucosal plane without losing orientation of lumen. Tunneled ESD has been shown to decrease procedure time for more circumferential esophageal squamous lesions with fewer injuries to the muscularis propria.⁶¹

Traction ESD

Traction ESD utilizes patient positioning and traction devices during submucosal dissection to create a safer and more efficient resection by visually exposing the submucosal plane, providing tension, and improving clearance of blood visually when there is bleeding. In addition, by

repositioning the patient, the lesion can be manipulated to be on the antigravity side, utilizing natural traction. Traction direction is important and dependent on the relationship with the endoscope tip and the gastrointestinal wall. Ideally, the lesion would have vertical traction, as it allows enhanced visualization of the submucosal layer without distorting the direction of the submucosal plane.⁶² Proximal traction provides exposure of the submucosal plane, but the mucosal flap can fall in the direction of the endoscope, so it is ideal in locations where the endoscope is parallel to the submucosa, such as the esophagus. Distal traction can expose the submucosal plane but has a risk of potential inadvertent dissection of the muscularis propria given that the submucosal plane would fall distally with the mucosal flap as dissection continues. Traction is recommended in colonic ESD for efficient dissection and to reduce the risk of perforation.⁶³

Water pressure method

In colorectal lesions that do not have natural traction or have submucosal fibrosis, the water pressure method can help with accessing the submucosal space. After circumferential mucosal incision, the air in the lumen is suctioned, and saline immersion is performed, allowing the mucosa to move away from the muscularis propria, based on the buoyancy of the mucosal layer. This approach decreases tension on the colonic wall. The saline immersion allows for improved conductance during dissection. During submucosal dissection, infusion of saline at a reduced rate will cause the mucosal flap to move away from the tip of the scope, allowing access to the submucosal plane. In fibrotic colorectal lesions, the water pressure method can reduce overall procedure times.⁶⁴ In duodenal ESD, where the technical aspects are considerably more challenging with a higher risk of perforation, the water pressure method has demonstrated similarly reduced rates of perforation and procedure times.⁶⁵ It is important to be cautious in less-than-ideal colon bowel preparations given the risk of leakage of soiled fluid in the setting of a perforation.

Hybrid ESD/EMR

Hybrid ESD/EMR is helpful to finalize resection of lesions with difficulty in submucosal access or dissection, and to decrease the procedure time. It combines 2 advanced endoscopic resection techniques, whereby conventional ESD technique is performed initially with a complete mucosal incision, followed by a partial submucosal dissection. Finally, a snare is enclosed around the remaining submucosal portion of the lesion, and the final part of the resection is performed with EMR. Despite decreased procedure time and fewer adverse events when compared to conventional ESD technique, this hybrid technique has demonstrated a decreased rate of en bloc resection.⁶⁶ The en bloc resection rate may be improved if more submucosa is dissected prior to snare resection.

SAFETY AND MANAGEMENT OF ADVERSE EVENTS

ESD is a technically challenging procedure with significant risks for bleeding, perforation and stricture formation. Therefore, it is important to recognize potential adverse events, and how to manage them both intraprocedurally and postprocedurally.

Bleeding

Intraprocedural bleeding is expected and occurs during the mucosal incision and submucosal dissection, though is usually insignificant. Minor bleeding from small submucosal vessels is often manageable endoscopically with the use of a coagulation current with the electrosurgical knife or hemostatic forceps, visually aided by the use of a distal endoscope cap and water insufflation. Prevention of bleeding from larger vessels can be reduced by dissecting the submucosa around the vessel (eg, skeletonize), then prophylactically coagulating the vessel with the electrosurgical knife or hemostatic forceps. Very significant bleeding requiring aborting of the procedure or referral for surgical or interventional radiologic management is quite rare.

A large prospective multicenter study on ESD in a Western population demonstrated that delayed bleeding after ESD is more common in the duodenum (9.1%), stomach (3%), and rectum (2.7%), when compared to the colon (1.9%) and esophagus (1.7%). These outcomes are comparable to outcomes from the Far East.⁶⁷ Proton pump inhibition after gastric ESD can reduce the risk of delayed bleeding.⁶⁸ Prophylactic soft coagulation of exposed vessels in the post-ESD resection defect can also reduce the risk of delayed bleeding.⁶⁹ Shielding the gastric mucosal defect with fibrin glue, polyglycolic acid, or an adhesive gel may prevent delayed bleeding, especially in patients on antithrombotic therapy.⁷⁰ In colorectal ESD, closure of the mucosal defect can reduce the risk of major bleeding. When delayed bleeding occurs, it can often be managed endoscopically.

Perforation

In a large prospective multicenter study in the United States, the overall perforation rate following ESD was 2.9% (2.2% in esophagus, 1% in stomach, 4.7% in colon, and 2.7% in rectum).⁶⁷ Several additional studies have corroborated these findings.⁷¹⁻⁷⁴ Risk factors for colorectal ESD perforations include poor endoscopic operability, right-sided colonic lesions, the presence of an underlying semilunar fold, and a less-experienced endoscopist.⁷⁵

Immediate perforation can often be managed endoscopically by through-the-scope hemostatic clips, over-the-scope clips, or by endoscopic suturing. Adjunctive management includes administering of intravenous antibiotics, placement of a nasogastric tube, and multidisciplinary management discussions, if necessary. If there are signs of

pneumoperitoneum, immediate percutaneous needle decompression with a saline-filled syringe can aid patient stabilization. For esophageal perforations, placement of a temporary fully covered self-expandable metal stent may be an option. In case of peritoneal soiling from delayed perforation after colorectal ESD, surgery would be indicated. Delayed perforation is very rare with an incidence of 0.1% to 0.4%, and may result from weakening of the muscularis propria due to excessive thermal energy.⁷⁶ See the ASGE Technology Review of Closure Devices for more details.⁷⁷

Stricture

Luminal strictures can occur after esophageal ESDs, especially those that encompass more than 50% of the luminal circumference.⁷⁸ Typically, strictures can be managed endoscopically by serial dilations. Steroid injection with triamcinolone after semicircumferential esophageal ESD has been shown to decrease the risk of esophageal stricture formation.⁷⁹ In a small study, mitomycin C was shown to decrease the risk of restricturing for post-ESD strictures refractory to endoscopic balloon dilation.⁸⁰ Other options include post-ESD placement of a fully covered self-expandable metal stent after wide circumferential ESD⁸¹ and postprocedural oral steroids.⁸² Refer to the ASGE Technology Document on Stricture Management for specific details.⁸³

TECHNICAL COMPETENCE AND PROCEDURE DURATION

Learning ESD has a steep learning curve given the need for extensive knowledge in the evaluation of neoplasia, limited traction and maneuverability provided by a flexible endoscope, submucosal vasculature, limited dissection space, higher-risk adverse events and prolonged procedural duration that is sometimes required. Currently, there is no standardized training curriculum for competency and proficiency in the United States. The ASGE recommends trainees in ESD should be proficient in general endoscopic procedures, endoscopic hemostasis, endoscopic mucosal resection, and be knowledgeable in gastrointestinal neoplasia evaluation. Training involves the achievement of technical, nontechnical, and cognitive skills, which is gained through participation in didactic and hands-on courses, longitudinal training, and mentorship with ESD faculty. Training cases ideally should be in less-complex areas, such as the rectum and distal stomach, which can begin with selected portions of the case under supervision, to eventually multiple independent cases under close supervision.⁸⁴ As more experience is obtained, ESD in more difficult locations for ESD, such as the esophagus, proximal stomach, and colon, is pursued. Proficiency is considered when the en bloc resection rate is at least 90%, the complete resection rate is at least 80%, adverse events less than 5%, and a dissection speed of 9 cm²/h.^{85,86}

FUTURE DIRECTIONS

ESD has gained much momentum in the West, resulting in multiple practice guidelines. However, there are factors limiting its accessibility, including being a technically challenging procedure with a steep learning curve, increased risks, limited training programs, and lack of proper reimbursement.⁸⁷

Various endeavors are underway to improve the procedural complexities of ESD. While the most recent improvements have focused on electrosurgical knives, traction devices, and closure devices, endoscopic robotic systems have also been in development. There are a variety of setups, including the Endoluminal Access Surgical Efficacy (EASE) System (Endomaster Pte, Ltd, Singapore) that includes an endoscope with 2 flexible robotic arms, and a console unit, which has demonstrated high technical success and safety.⁸⁸ Another robotic endoscopy system is the EndoQuest Robotics Endoluminal Surgical (ELS) System (EndoQuest Robotics, Houston, Tex, USA), which allows the use of a 6-mm endoscope and two 6-mm robotic arms. Given the costs and inaccessibility for certain colonic lesions, more developments and studies are needed to assess feasibility. In addition, with the improvement of diagnostic artificial intelligence capabilities, optical diagnosis through innovations in enhanced endoscopic imaging may help endoscopists determine which lesions are appropriate for EMR, ESD, or surgery, as well as providing enhanced localization of submucosal vessels during submucosal dissection.

There are limited training programs for ESD in the West, as proper training requires an adequate number of ESD experts, continued mentorship, and a high volume of cases. As ESD continues to gain more traction and the number of ESD experts increase, education on third-space endoscopy may start to become its own training program, separate from the traditional advanced endoscopy fellowship training program. To further increase accessibility of ESD hands-on education, virtual endoscopic training simulators have been developed, which mimic the feel and visualization of an actual endoscopic submucosal dissection procedure using virtual reality and haptic feedback.⁸⁹

A significant limitation to the implementation of ESD is the lack of reimbursement from having a proper procedural billing code. Currently, ESD is billed as an unlisted code with substantially limited payment model despite the effort needed to perform the procedure. Facility reimbursement has improved with an updated Healthcare Common Procedure Coding System code, but the physician effort, based on the Current Procedural Terminology (CPT) code, was still to be determined. However, the American Medical Association recently agreed to establish separate Category 1 CPT codes for upper GI tract ESDs and lower GI tract ESDs, which will be published in November 2026, making headway to potentially wider

adoption of this novel procedure. The reimbursement value for the CPT code is still pending but should take into consideration the location, size, and length of the procedure duration, given the variability in difficulty of each ESD case.

DISCLOSURE

The author disclosed the following financial relationships: G. Leung: Consultant for Olympus; chief medical advisor for Mirai Medical. P. Akerman: Consultant for Olympus and Prime Medical. V. Akshintala: Royalties from Origin Endoscopy Inc, Solv Endotherapy Inc, and Sotelix Endoscopy Inc; consultant for Olympus Medical; research funding from Boston Scientific Corporation. C. P. Benias: Consultant for Boston Scientific Corporation and Micro-Tech Endoscopy. K. Das: Consultant for Olympus. N. Mansour: Consultant for Medtronic. N. Marya: Consultant for Boston Scientific Corporation. G. Mishra: Consultant for Pentax Medical. V. R. Muthusamy: Consultant for Medtronic and Boston Scientific Corporation; research support from Boston Scientific Corporation; stock options or equity in Capsvision; advisory board for Endogastric Solutions and Motus GI. S. Pawa: Consultant for Boston Scientific Corporation. T. Rustagi: Consultant for Boston Scientific Corporation. R. Law: Consultant and provides research support for Olympus and Boston Scientific Corporation; royalties from UpToDate. All other authors disclosed no financial relationships.

REFERENCES

- Hirao M, Masuda K, Asanuma T, et al. Endoscopic resection of early gastric cancer and other tumors with local injection of hypertonic saline-epinephrine. *Gastrointest Endosc* 1988;34:264-9.
- ASGE Standards of Practice Committee; Forbes N, Elhanafi SE, Al-Haddad MA, et al. American Society for Gastrointestinal Endoscopy guideline on endoscopic submucosal dissection for the management of early esophageal and gastric cancers: summary and recommendations. *Gastrointest Endosc* 2023;98:271-84.
- Wang AY, Hwang JH, Bhatt A, et al. AGA clinical practice update on surveillance after pathologically curative endoscopic submucosal dissection of early gastrointestinal neoplasia in the United States: commentary. *Gastroenterology* 2021;161:2030-40.e1.
- Pimentel-Nunes P, Libânio D, Bastiaansen BAJ, et al. Endoscopic submucosal dissection for superficial gastrointestinal lesions: European Society of Gastrointestinal Endoscopy (ESGE) Guideline – update 2022. *Endoscopy* 2022;54:591-622.
- Tanaka S, Kashida H, Saito Y, et al. Japan Gastroenterological Endoscopy Society guidelines for colorectal endoscopic submucosal dissection/endoscopic mucosal resection. *Dig Endosc* 2020;32:219-39.
- Draganov PV, Wang AY, Othman MO, et al. AGA Institute clinical practice update: endoscopic submucosal dissection in the United States. *Clin Gastroenterol Hepatol* 2019;17:16-25.e1.
- Castro R, Libânio D, Pita I, et al. Solutions for submucosal injection: what to choose and how to do it. *World J Gastroenterol* 2019;25:777-88.
- Rex DK, Lahr RE. The demise of ORISE, a submucosal lifting agent for endoscopic resection. *AME Case Rep* 2023;7:11.
- Inoue S, Uedo N, Tabuchi T, et al. Usefulness of epinephrine-added injection solution to reduce procedure time for gastric endoscopic submucosal dissection. *Endosc Int Open* 2020;8:E1044-51.
- Yip HC, Uedo N, Iwagami H, et al. Epinephrine-added solution significantly reduced procedural time during gastric endoscopic submucosal dissection (ESD) – results from an international multi-center randomized controlled trial. *Gastrointest Endosc* 2024;99:AB745.
- Probst A, Maerkl B, Bittinger M, et al. Gastric ischemia following endoscopic submucosal dissection of early gastric cancer. *Gastric Cancer* 2010;13:58-61.
- Kim HH, Park MI, Park SJ, et al. Myocardial infarction thought to be provoked by local epinephrine injection during endoscopic submucosal dissection. *J Clin Med Res* 2011;3:143-6.
- Hwang JH, Konda V, Abu Dayyeh BK, et al. Endoscopic mucosal resection. *Gastrointest Endosc* 2015;82:215-26.
- ASGE Technology Committee; Bhatt A, Bucobo JC, Akshintala VS, et al. Submucosal injection fluid and tattoo agents. *Gastrointest Endosc* 2024;100:797-806.
- Harlow C, Sivananthan A, Ayaru L, et al. Endoscopic submucosal dissection: an update on tools and accessories. *Ther Adv Gastrointest Endosc* 2020;13:2631774520957220.
- Desai PN, Patel CN, Kabrawala M, et al. Distal endoscopic attachments. *J Dig Endosc* 2022;13:243-50.
- Yamamoto H, Kawata H, Sunada K, et al. Successful en-bloc resection of large superficial tumors in the stomach and colon using sodium hyaluronate and small-caliber-tip transparent hood. *Endoscopy* 2003;35:690-4.
- Liu CY, Chen PJ, Chen CC, et al. ENDOLIFTER shortens the submucosal dissection time of gastric endoscopic submucosal dissection with better safety in live porcine model [abstract]. *Gastrointest Endosc* 2012;75:AB214-5.
- Tashima T, Miyaguchi K, Tanisaka Y, et al. Successful duodenal endoscopic submucosal dissection using multiple clip-and-thread traction for a large tumor located in the duodenal bulb. *VideoGIE* 2021;6:178-80.
- Jin P, Fu KI, Yu Y, et al. Traction using a clip-with-line is a preferred method for trainees in performing esophageal endoscopic submucosal dissection: an animal model study. *Ther Adv Gastroenterol* 2017;10:343-51.
- Abe S, Wu SYS, Ego M, et al. Efficacy of current traction techniques for endoscopic submucosal dissection. *Gut Liver* 2020;14:673-84.
- Indo N, Anami T, Kitamura Y, et al. Effectiveness of counter traction using a clip with a looped thread for colorectal endoscopic submucosal dissection. *Endosc Int Open* 2021;9:E306-12.
- Khan S, Ali FS, Ullah S, et al. Advancing endoscopic traction techniques in endoscopic submucosal dissection. *Front Oncol* 2022;12:1059636.
- Hasatani K, Yoshida N, Aoyagi H, et al. Usefulness of the clip-and-snare method using the pre-looping technique for endoscopic submucosal dissection of gastric neoplasia: a randomized controlled trial. *Ann Gastroenterol* 2022;35:48-55.
- Suzuki Y, Tanuma T, Nojima M, et al. Multiloop as a novel traction method in accelerating colorectal endoscopic submucosal dissection. *Gastrointest Endosc* 2020;91:185-90.
- Suzuki Y, Tanuma T, Nojima M, et al. Comparison of dissection speed during colorectal ESD between the novel multiloop (M-loop) traction method and ESD methods without traction. *Endosc Int Open* 2020;08:E840-7.
- Schaefer M, Albouys J, Geyl S, et al. Multitraction with a single rubber band and clips: a simple tip for endoscopic submucosal dissection of a recurrent lesion with previous clip. *Endoscopy* 2023;55(suppl 1):E815-6.
- Bordillon P, Pioche M, Wallenhorst T, et al. Double-clip traction for colonic endoscopic submucosal dissection: a multicenter study of 599 consecutive cases (with video). *Gastrointest Endosc* 2021;94:333-43.
- Faller J, Jacques J, Oung B, et al. Endoscopic submucosal dissection with double clip and rubber band traction for residual or locally

- recurrent colonic lesions after previous endoscopic mucosal resection. *Endoscopy* 2020;52:383-8.
30. Oung B, Jacques J, Rivory J, et al. ESD with double clip and rubber band traction of neoplastic lesions developed in the appendiceal orifice is effective and safe. *Endoscopy* 2019;51:S12-3.
 31. Matsuzaki I, Hattori M, Hirose K, et al. Magnetic anchor-guided endoscopic submucosal dissection for gastric lesions (with video). *Gastrointest Endosc* 2018;87:1576-80.
 32. Mortagy M, Mehta N, Parsi MA, et al. Magnetic anchor guidance for endoscopic submucosal dissection and other endoscopic procedures. *World J Gastroenterol* 2017;23:2883-90.
 33. Matsui H, Tamai N, Futakuchi T, et al. Multi-loop traction device facilitates gastric endoscopic submucosal dissection: ex vivo pilot study and an inaugural clinical experience. *BMC Gastroenterol* 2022;22:10.
 34. Jinushi R, Tashima T, Terada R, et al. Effectiveness of a multi-loop traction device for colorectal endoscopic submucosal dissection performed by trainees: a pilot study. *Sci Rep* 2022;12:10197.
 35. Kawashima K, Hikichi T, Gunji N, et al. Endoscopic submucosal dissection with the combination of a scissor-type knife and novel traction method for colonic neoplasm involving a diverticulum. *VideoGIE* 2023;8:38-41.
 36. Omae M, Wang N, Löhr JM, et al. Endoscopic submucosal dissection by using a new traction device. *VideoGIE* 2021;6:543-5.
 37. Bhatt A, Mehta NA, Abe S, et al. A novel curved wire retraction device for endoscopic submucosal dissection. *VideoGIE* 2021;6:342-3.
 38. Bhatt A, Hwang JH, Sharma NR, et al. Traction wire endoscopic submucosal dissection: tips and techniques from 4 institutions. *VideoGIE* 2021;7:21-2.
 39. Ebigo A, Ayoub M, Nagl S, et al. Countertraction with the ProdiGI traction magnet facilitates colorectal ESD and can improve patient outcomes. *Tech Innov Gastrointest Endosc* 2023;25:243-5.
 40. Figueiredo M, Yzet C, Lafeuille P, et al. Endoscopic mucosal resection with a magnetic traction system: a new strategy to facilitate complete resection. *Endoscopy* 2022;54(suppl 2):E820-1.
 41. Grimaldi J, Lambin T, Rivory J, et al. Endoscopic submucosal dissection of an ileocecal valve laterally spreading tumor using an adaptable magnetic traction system. *Endoscopy* 2022;54:E1064-5.
 42. Baldaque-Silva F, Wang N, Omae M. Duodenal subepithelial neuroendocrine tumor removed by endoscopic submucosal dissection using internal traction with magnets. *VideoGIE* 2022;7:259-61.
 43. Sakamoto N, Osada T, Shibuya T, et al. Endoscopic submucosal dissection of large colorectal tumors by using a novel spring-action S-O clip for traction (with video). *Gastrointest Endosc* 2009;69:1370-4.
 44. Nagata M. Modified attachment method using an S-O clip for gastric endoscopic submucosal dissection. *VideoGIE* 2019;4:151-3.
 45. Okamoto Y, Oka S, Tanaka S, et al. Clinical usefulness of the S-O clip during colorectal endoscopic submucosal dissection in difficult-to-access submucosal layer. *Endosc Int Open* 2020;8:E437-44.
 46. Tanaka S, Toyonaga T, Kaku H, et al. A novel traction device (Endo-Trac) for use during endoscopic submucosal dissection. *Endoscopy* 2019;51:E90-1.
 47. Tashima T, Tanisaka Y, Mashimo Y, et al. Endoscopic closure assisted by a novel traction device after duodenal endoscopic submucosal dissection. *VideoGIE* 2020;5:425-7.
 48. Kinoshita J, Iguchi M, Maekita T, et al. Efficacy of the traction method for gastric endoscopic submucosal dissection: a randomized controlled trial (with videos). *Gastrointest Endosc* 2024;100:307-11.e2.
 49. Simsek C, Thompson CC, Alkhateeb KJ, et al. Novel articulating through-the-scope traction device. *VideoGIE* 2022;7:353-7.
 50. Holzwanger EA, Mahmood S, Igbiniedion S, et al. Use of a novel articulation arm device for endoscopic submucosal dissection of a rectal laterally spreading tumor. *VideoGIE* 2023;8:172-4.
 51. Yang D, Aihara H, Hasan MK, et al. Novel single-operator through-the-scope traction device for endoscopic submucosal dissection: outcomes of a multicenter randomized pilot ex-vivo study in trainees with limited endoscopic submucosal dissection experience (with video). *DEN Open* 2023;3:e174.
 52. Hayat M, Schlachterman A, Schiavone G, et al. Initial multicenter experience using a novel articulating through-the-scope traction device for endoscopic submucosal dissection. *Endosc Int Open* 2023;11:E778-84.
 53. Coronel M, Coronel E, Romero L, et al. Combination of a dynamic rigidizing overtube and a novel injectable needle-type knife to facilitate colorectal endoscopic submucosal dissection. *VideoGIE* 2021;6:297-300.
 54. Kobara H, Tada N, Fujihara S, et al. Clinical and technical outcomes of endoscopic closure of postendoscopic submucosal dissection defects. *Dig Endosc* 2023;35:216-31.
 55. Feng J, Zhai Y, Han K, et al. Defect closure after endoscopic submucosal dissection decreased the adverse events in patients with large rectal neoplasms: a propensity score matching analysis. *Surg Endosc* 2025;39:3504-13.
 56. Okimoto K, Matsumura T, Matsusaka K, et al. Successful closure of large mucosal defect with novel anchor-pronged clip after gastric endoscopic submucosal dissection. *Endoscopy* 2024;56(suppl 1):E534-5.
 57. Wilson N, Le LB, Abdallah M, et al. Closure of a gastric endoscopic resection defect with a novel closure device. *Endoscopy* 2022;55(suppl 1):E181-2.
 58. ASGE Technology Committee; Banerjee S, Barth BA, Bhat YM, et al. Endoscopic closure devices. *Gastrointest Endosc* 2012;76:244-51.
 59. Tokar JL, Barth BA, Banerjee S, et al. Electrosurgical generators. *Gastrointest Endosc* 2013;78:197-208.
 60. Pei Q, Qiao H, Zhang M, et al. Pocket-creation method versus conventional method of endoscopic submucosal dissection for superficial colorectal neoplasms: a meta-analysis. *Gastrointest Endosc* 2021;93:1038-46.e4.
 61. Fan X, Wu Q, Li R, et al. Clinical benefit of tunnel endoscopic submucosal dissection for esophageal squamous cancer: a multicenter, randomized controlled trial. *Gastrointest Endosc* 2022;96:436-44.
 62. Nagata M. Advances in traction methods for endoscopic submucosal dissection: what is the best traction method and traction direction? *World J Gastroenterol* 2022;28:1-22.
 63. Lambin T, Rivory J, Wallenhorst T, et al. Endoscopic submucosal dissection: how to be more efficient? *Endosc Int Open* 2021;9:E1720-30.
 64. Ozeki Y, Hirasawa K, Ikeda R, et al. Safety and efficacy of water pressure endoscopic submucosal dissection for colorectal tumors with submucosal fibrosis (with video). *Gastrointest Endosc* 2021;94:607-17.e2.
 65. Kato M, Takatori Y, Sasaki M, et al. Water pressure method for duodenal endoscopic submucosal dissection (with video). *Gastrointest Endosc* 2021;93:942-9.
 66. McCarty TR, Bazarbashi AN, Thompson CC, et al. Hybrid endoscopic submucosal dissection (ESD) compared with conventional ESD for colorectal lesions: a systematic review and meta-analysis. *Endoscopy* 2021;53:1048-58.
 67. Draganov PV, Aihara H, Karasik MS, et al. Endoscopic submucosal dissection in North America: a large prospective multicenter study. *Gastroenterology* 2021;160:2317-27.e2.
 68. Yang Z, Wu Q, Liu Z, et al. Proton pump inhibitors versus histamine-2-receptor antagonists for the management of iatrogenic gastric ulcer after endoscopic mucosal resection or endoscopic submucosal dissection: a meta-analysis of randomized trials. *Digestion* 2011;84:315-20.
 69. Takizawa K, Oda I, Gotoda T, et al. Routine coagulation of visible vessels may prevent delayed bleeding after endoscopic submucosal dissection—an analysis of risk factors. *Endoscopy* 2008;40:179-83.
 70. Kikuchi D, Iizuka T, Makino S, et al. Utility of autologous fibrin glue and polyglycolic acid sheet for preventing delayed bleeding associated with antithrombotic therapy after gastric ESD. *Endosc Int Open* 2019;7:E1542-8.

71. Park Y, Cho E, Kang H. The effectiveness and safety of endoscopic submucosal dissection compared with endoscopic mucosal resection for early gastric cancer: a systematic review and meta analysis. *Surg Endosc* 2011;25:2666-77.
72. Lian J, Chen S, Zhang Y. A meta-analysis of endoscopic submucosal dissection and EMR for early gastric cancer. *Gastrointest Endosc* 2012;76:763-70.
73. Repici A, Hassan C, De Paula Pessoa D, et al. Efficacy and safety of endoscopic submucosal dissection for colorectal neoplasia: a systematic review. *Endoscopy* 2012;44:137-50.
74. Isomoto H, Yamaguchi N, Minami H, et al. Management of complications associated with endoscopic submucosal dissection/endoscopic mucosal resection for esophageal cancer. *Dig Endosc* 2013;25(suppl 1):29-38.
75. Imai K, Hotta K, Yamaguchi Y, et al. Preoperative indicators of failure of en bloc resection or perforation in colorectal endoscopic submucosal dissection: implications for lesion stratification by technical difficulties during stepwise training. *Gastrointest Endosc* 2016;83: 954-62.
76. Hirasawa K, Sato C, Makazu M, et al. Coagulation syndrome: delayed perforation after colorectal endoscopic treatments. *World J Gastrointest Endosc* 2015;7:1055-61.
77. Hanscom M, Obando JV, Krishnan K, et al. Endoscopic closure devices (with videos). *Gastrointest Endosc* 2026;103:418-37.
78. Ono S, Fujishiro M, Niimi K, et al. Long-term outcomes of endoscopic submucosal dissection for superficial esophageal squamous cell neoplasms. *Gastrointest Endosc* 2009;70:860-6.
79. Hashimoto S, Kobayashi M, Takeuchi M, et al. The efficacy of endoscopic triamcinolone injection for the prevention of esophageal stricture after endoscopic submucosal dissection. *Gastrointest Endosc* 2011;74:1389-93.
80. Machida H, Tominaga K, Minamino H, et al. Locoregional mitomycin C injection for esophageal stricture after endoscopic submucosal dissection. *Endoscopy* 2012;44:622-5.
81. Wen J, Lu Z, Yang Y, et al. Preventing stricture formation by covered esophageal stent placement after endoscopic submucosal dissection for early esophageal cancer. *Dig Dis Sci* 2014;59:658-63.
82. Yamaguchi N, Isomoto H, Nakayama T, et al. Usefulness of oral prednisolone in the treatment of esophageal stricture after endoscopic submucosal dissection for superficial esophageal squamous cell carcinoma. *Gastrointest Endosc* 2011;73:1115-21.
83. ASGE Technology Committee; Akshintala VS, Shahnava N, Abdi M, et al. Tools for endoscopic management of benign luminal GI strictures. *Gastrointest Endosc* 2025;102:454-68.
84. Aihara H, Dacha S, Anand G, et al. Core curriculum for endoscopic submucosal dissection (ESD). *Gastrointest Endosc* 2021;93:1215-21.
85. Oyama T, Yahagi N, Ponchon T, et al. How to establish endoscopic submucosal dissection in Western countries. *World J Gastroenterol* 2015;21:11209-20.
86. Coman R, Gotoda T, Draganov P. Training in endoscopic submucosal dissection. *World J Gastrointest Endosc* 2013;5:369-78.
87. Wei M, Friedland S, Hwang J. The current landscape of endoscopic submucosal training in the United States. *Curr Gastroenterol Rep* 2025;27:4.
88. Chiu P, Yip C, Chu S, et al. Prospective single-arm trial on feasibility and safety of an endoscopic robotic system for colonic endoscopic submucosal dissection. *Endoscopy* 2025;57:240-6.
89. Turkseven M, De S, Jackson C, et al. Modeling haptic interactions in endoscopic submucosal dissection (ESD). *IEEE Trans Haptics* 2022;15: 603-12.
90. ORISE ProKnife Electrosurgical Knife. 2024. Available at: <https://www.bostonscientific.com/en-US/products/endoluminal-surgery-devices/orise-proknife-electrosurgical-knife.html>. Accessed June 12, 2024.
91. Erbe HybridKnife. Available at: https://register.erbe-med.com/productfinder/Marketingmaterialien/85100-158_ERBE_EN_HybridKnife_D039170.pdf. Accessed June 12, 2024.
92. Hybridknife flex I-type. Available at: https://en.erbe-med.com/fileadmin/user_upload/HybridKNIFE_flex/2024-06-03_Landingpage_HK-flex_LB_HK-flex.jpg. Accessed June 12, 2024.
93. Third space endoscopy devices: FlushKnife. Available at: https://healthcaresolutions-us.fujifilm.com/wp-content/uploads/2023/03/img_es_tabs_flushknife_1090x600-1024x564.jpg. Accessed June 12, 2024.
94. Electrosurgical precision GoldKnife. Available at: <https://mtendoscopy.com/wp-content/uploads/2022/08/MTE-WEB-2022-GoldKnifeTClose-500x500-1.png>. Accessed June 12, 2024.
95. Single-use electrosurgical knife: DualKnife J. Available at: <https://mdc.olympus.eu/asset/084438885177/b06880b90df6ce4235b788d58da7c233>. Accessed June 12, 2024.
96. ESD - Knives: triangle tip electrosurgical knife. Available at: <https://medical.olympusamerica.com/products/knives/triangle-tip-knife-kd-640l>. Accessed June 12, 2024.
97. ESD-Knives: TriangleTipKnife J. Available at: <https://medical.olympusamerica.com/products/triangletipknife-j>. Accessed June 12, 2024.
98. ProdiGI multifunctional electrosurgical knife. Available at: <https://www.medtronic.com/content/dam/medtronic-wide/public/united-states/products/digestive-gastrointestinal/prodigi-multi-functional-electrosurgical-knife-info-sheet.pdf>. Accessed June 12, 2024.
99. Knives ESD-Knives: ITknife2 electrosurgical knife (KD-611L). Available at: https://medical.olympusamerica.com/sites/default/files/styles/product_full/public/KD-611L_single-use_001_V1_20111129_680x429.jpg?itok=_xfPjEOq. Accessed June 12, 2024.
100. Disposable high frequency knife: ITKnife Nano. Available at: https://www.olympus-medical.jp/sites/default/files/2021-10/ITKnife%20nano_mv.jpg. Accessed June 12, 2024.
101. Third space endoscopy devices: clutchcutter. Available at: https://healthcaresolutions-us.fujifilm.com/wp-content/uploads/2023/03/img_es_tabs_clutchcutter_1090x600-1024x564.jpg. Accessed June 12, 2024.
102. SB Knives: SB Knife. Available at: <https://medical.olympusamerica.com/sites/default/files/us/files/splashPages/SB-Knives.jpg>. Accessed June 12, 2024.
103. SB Knives: SB Jr. Available at: <https://medical.olympusamerica.com/sites/default/files/us/files/splashPages/SB-Knives.jpg>. Accessed June 12, 2024.
104. Knives ESD-Knives: FlexKnife electrosurgical knife (KD-630L). Available at: https://medical.olympusamerica.com/sites/default/files/styles/product_full/public/prodimage/FlexKnife9504_0.jpg?itok=0tCwL8ay. Accessed June 12, 2024.
105. ESD-Knives: HookKnife J. Available at: https://medical.olympusamerica.com/sites/default/files/styles/product_full/public/prodimage/Olympus-HookKnifeJ.jpg?itok=Y0003NOK. Accessed June 12, 2024.
106. Advanced energy: Speedboat UltraSlim. Available at: <https://www.creomedical.com/en/assets/components/phpthumb/cache/sus-combined.9f7066ef3bbc1bde6a263799b778e013.png>. Accessed June 12, 2024.
107. Advanced energy: Speedboat Notch. Available at: https://www.creomedical.com/en/assets/components/phpthumb/cache/sb1_scope-1.136.32ee98db4e284aee977a117eac785006.png. Accessed June 12, 2024.
108. Advanced energy: SpydrBlade Flex. Available at: <https://www.creomedical.com/en/kamaptive-technology/spydrblade-flex>. Accessed June 12, 2024.
109. Olympus distal attachment. Available at: <https://medical.olympusamerica.com/products/distal-attachments>. Accessed March 14, 2024.
110. ST-hood distal cap. Available at: <https://www.duomed.com/en-CH/highlights-eti/st-hood-distal-cap>. Accessed March 14, 2024.
111. Reveal distal attachment cap. Available at: <https://www.steris.com/healthcare/products/endoscopy-devices/polypectomy-and-tissue->

acquisition-devices/reveal-distal-attachment-cap. Accessed March 14, 2024.

112. Schölvink D, Goto O, Bergman J, et al. The efficacy of an endoscopic grasp-and-traction device for gastric endoscopic submucosal dissection: an ex vivo comparative study (with video). *Clin Endosc* 2015;48: 221-7.
113. Resect: AWC. Available at: <https://ovesco.com/resect/awc/>. Accessed February 23, 2026.
114. Sudo G, Tanuma T, Suzuki Y, et al. Multiloop method for traction during colorectal endoscopic submucosal dissection. *VideoGIE* 2018;4:11-3.
115. SureTrac traction system. Available at: <https://us.mtmed.com/products/gastroenterology/resection-retrieval/emr-esd/suretrac-traction-system/>. Accessed March 16, 2024.
116. Review of new suretrac system for endoscopic submucosal dissection. 2025. Available at: <https://www.youtube.com/watch?v=U6-oas9IFdU>. Accessed March 16, 2024.
117. Werner Y, Rosch T. POEM and submucosal tunneling. *Curr Gastroenterol Rep* 2016;14:163-77.
118. Mizutani H, Ono S, Ohki D, et al. Recent development of techniques and devices in colorectal endoscopic submucosal dissection. *Clin Endosc* 2017;50:562-8.
119. Esaki M, Suzuki S, Horii T, et al. Reduction in the procedure time of hybrid endoscopic submucosal dissection for early gastric neoplasms: a multi-center retrospective propensity score-matched analysis. *Ther Adv Gastroenterol* 2020;13:1756284820939420.

Abbreviations: CPT, Current Procedural Terminology; EASE, endoscopically assisted surgical expansion; EIP, Endoluminal Interventional Platform; ELS, endoluminal surgery; EMR, endoscopic mucosal resection; ESD, endoscopic submucosal dissection; HA, hyaluronic acid; HCPS, Healthcare Common Procedure Coding System; HPMC, hydroxypropyl methylcellulose; MLTD, multiloop traction device; TTS, through-the-scope



Use your mobile device to scan this QR code and watch the author interview. Download a free QR code scanner by searching “QR Scanner” in your mobile device’s app store.

© 2026 by the American Society for Gastrointestinal Endoscopy
0016-5107/\$36.00

<https://doi.org/10.1016/j.gie.2026.03.038>

Received March 24, 2026. Accepted March 25, 2026.

Current affiliations: Division of Gastroenterology, NYU Langone Health, Long Island, New York, New York, USA (1), Department of Gastroenterology, Minneapolis Veterans Affairs, University of Minnesota, Minneapolis, Minnesota, USA (2), Division of Gastroenterology and Hepatology, Johns Hopkins University, Baltimore, Maryland, USA (3), Department of Gastroenterology, University Gastroenterology, Providence, Rhode Island, USA (4), Division of Gastroenterology, Rutgers University, New Brunswick, New Jersey, USA (5), Division of Gastroenterology, Washington University School of Medicine, St Louis, Missouri, USA (6), Division of Gastroenterology, Baystate Medical Center, Springfield, Massachusetts, USA (7), Department of Gastroenterology and Hepatology, Weill Cornell Medicine, New York, New York, USA (8), Division of Gastroenterology and Hepatology, Baylor College of Medicine, Houston, Texas, USA (9), Division of Gastroenterology and Hepatology, UMass Chan Medical School, Worcester, Massachusetts, USA (10), Department of Gastroenterology, Wake Forest School of Medicine, Winston Salem, North Carolina, USA (11), Division of Digestive Diseases, UCLA Health System, David Geffen School of Medicine at UCLA, Los Angeles, California, USA (12), Division of Digestive Diseases, Emory University, Atlanta, Georgia, USA (13), Department of Gastroenterology and Hepatology, Mayo Clinic, Rochester, Minnesota, USA (14).

Access to **Gastrointestinal Endoscopy Online** is reserved for all subscribers!

Full-text access to **Gastrointestinal Endoscopy Online** is available for all subscribers. ASGE MEMBER SUBSCRIBERS: To activate your individual online subscription, please visit <http://www.asge.org> and follow the instructions. NON-MEMBER SUBSCRIBERS: To activate your individual online subscription, please visit <http://www.giejournal.org> and follow the prompts to activate your *online access*. To activate your account, you will need your subscriber account/membership number, which you can find on your mailing label (*note*: the number of digits in your subscriber account number varies from 6 to 10 digits). See the example below in which the subscriber account number has been circled:

Sample mailing label

This is your Nonmember subscriber account number →

1234567-89 J037 10/00 Q: 1

CHRIS SMITH, MD
12TH & PINE STREET
CENTER CITY, NY 10001-001

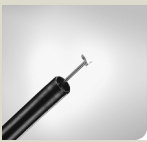
Personal subscriptions to **Gastrointestinal Endoscopy Online** are for individual use only and may not be transferred. Use of **Gastrointestinal Endoscopy Online** is subject to agreement to the terms and conditions as indicated online.

SUPPLEMENTARY TABLE 1. Knives for endoscopic submucosal dissection

Manufacturer and brand name	ESD capabilities	Needle type	Adjustable length	Minimum working channel diameter	Working length	Knife length	Water-jet function	Features	Image
Boston Scientific/ORISE ProKnife	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated-tip	No	2.8 mm	2300 mm	1.5 mm, 2.0 mm, 3.0 mm	Yes	T-shaped electrode tip to allow for high current density and precision cutting Focal injection of lifting agent through electrode tip	  90
Erbe/HybridKnife I-Type I-Knife	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated-tip	Yes	2.8 mm	1900 mm	1.0-5.0 mm	Yes	Compatible with the ERBEJET2 Hydrosurgical Unit for high pressure needle-free injection	 91
Erbe/HybridKnife Flex I-Type	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated-tip	Yes	2.8 mm	2300 mm	1.5 mm, 2.0 mm	Yes	Compatible with the ERBEJET2 Hydrosurgical Unit for high pressure needle-free injection Flexible probe for smooth passage of the knife even in retroflexion Locking mechanism for locking in fixed needle length	 92
Erbe/Hybrid I-Type T-Knife	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated-tip	Yes	2.8 mm	1900 mm	1.0-5.0 mm	Yes	Compatible with the ERBEJET2 Hydrosurgical Unit for high pressure needle-free injection T-shaped electrode tip for improved hemostasis	 91
FujiFilm/FlushKnife BT	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated-tip	No	2.8 mm	1800 mm, 2300 mm	1.5 mm, 2.0 mm, 2.5 mm, 3.0 mm	Yes	Ball tip to provide traction and improved hemostasis Focal injection of lifting agent through electrode tip	 93

(continued on the next page)

SUPPLEMENTARY TABLE 1. Continued

Manufacturer and brand name	ESD capabilities	Needle type	Adjustable length	Minimum working channel diameter	Working length	Knife length	Water-jet function	Features	Image
Micro-Tech/ GoldKnife T	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated- tip	No	2.8 mm	1950 mm, 2350 mm	1.5 mm, 2.0 mm	Yes	T shaped tip for tissue retraction and improved hemostasis Focal injection of lifting agent through electrode tip	 94
Olympus/Dual Knife J	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated- tip	No	2.8 mm	1650 mm, 1950 mm, 2300 mm	2.0 mm, 1.5 mm	Yes	Knob-shaped tip to allow tissue to be hooked during dissection Focal injection through the catheter injection port	 95
Olympus/Triangle Tip Knife	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated- tip	No	2.8 mm	1650 mm	4.5 mm	Yes	Triangular tip for improved cutting and coagulation and for efficient use of the Spray Coag setting	 96
Olympus/Triangle Tip Knife J	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Noninsulated- tip	No	2.8 mm	1650 mm	4.5 mm	Yes	Triangular tip for improved cutting and coagulation and for efficient use of the Spray Coag setting Focal injection through the catheter injection port	 97
Medtronic/ProdiGI Multifunctional ESD Knife	Marking, mucosal incision, submucosal dissection, hemostasis	Noninsulated- tip/Insulated- tip	Yes	2.8 mm	2300 mm	1.5 mm or 2.0 mm (I knife), 4 mm (O knife)	No	The insulated O-tip and I-tip knives can be interchanged with the flip of a switch	 98

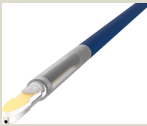
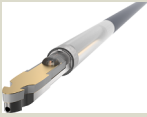
(continued on the next page)

SUPPLEMENTARY TABLE 1. Continued

Manufacturer and brand name	ESD capabilities	Needle type	Adjustable length	Minimum working channel diameter	Working length	Knife length	Water-jet function	Features	Image
Micro-Tech/ GoldKnife IT Knife	Submucosal dissection, hemostasis	Insulated-tip	No	2.8 mm	1950 mm, 2350 mm	4.0 mm	No	Ceramic tip to minimize invasiveness	 94
Olympus/ITKnife2	Submucosal dissection, hemostasis	Insulated-tip needle	No	2.8 mm	1650 mm	4.0 mm	No	Ceramic tip for safer dissection Electrode under the ceramic tip to improve cutting performance	 99
Olympus/ITKnife Nano	Submucosal dissection, hemostasis	Insulated-tip needle	No	2.8 mm	1650 mm, 2300 mm	3.5 mm	No	Smaller insulated tip for improved maneuverability Small, disc-shaped electrode tip under the insulated tip for dissection of thin submucosal layers	 100
FujiFilm/Clutch Cutter	Mucosal incision, submucosal dissection, hemostasis	Scissor type	No	2.8 mm	1800 mm	3.5 mm, 5.0 mm (forceps length)	No	Physician-controlled rotatable grasping forceps with 2 fixed inner electrode jaws and an insulated outer edge	 101
Olympus/SB Knife	Mucosal incision, submucosal dissection, hemostasis	Scissor type	No	2.8 mm	1800 mm	7 mm (forceps length)	No	Physician-controlled rotatable grasping forceps with 2 fixed inner electrode jaws and an insulated outer edge	 102
Olympus/SB Knife Jr	Mucosal incision, submucosal dissection, hemostasis	Scissor type	No	2.8 mm	1950 mm, 2300 mm	3.5 mm (forceps length)	No	Physician-controlled rotatable grasping forceps with 2 fixed inner electrode jaws and an insulated outer edge	 103
Olympus/SB Short	Mucosal incision, submucosal dissection, hemostasis	Scissor type	No	2.8 mm	1800 mm	6 mm (forceps length)	No	Physician-controlled rotatable grasping forceps with 2 fixed inner electrode jaws and an insulated outer edge	 102

(continued on the next page)

SUPPLEMENTARY TABLE 1. Continued

Manufacturer and brand name	ESD capabilities	Needle type	Adjustable length	Minimum working channel diameter	Working length	Knife length	Water-jet function	Features	Image
Olympus/ FlexKnife	Marking, mucosal incision, submucosal dissection, hemostasis	Other shaped	Yes	2.8 mm	1650 mm	11 mm	No	Adjustable length loop cutting wire Thick distal sheath functions as a stopper to reduce risk of perforation	 104
Olympus/ HookKnife J	Marking, injection, mucosal incision, submucosal dissection	Other shaped	No	2.8 mm	1650 mm, 1950 mm, 2300 mm	4.5 mm	Yes	Rotatable 1.3 mm distal hook to allow manipulation and retraction of tissue during submucosal dissection Focal injection through catheter injection port	 105
Creo/Speedboat UltraSlim	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Bipolar energy	No	2.8 mm	2300 mm	4 mm	Yes	Rotatable knife with focused, bipolar radiofrequency with lower voltage and localized delivery than standard monopolar for clean cutting and high frequency microwave energy for hemostasis Integrated injection needle for lifting Requires its own Chroma Energy platform	 106
Creo/Speedboat Notch	Marking, injection, mucosal incision, submucosal dissection, hemostasis	Bipolar energy	No	2.8 mm	1900 mm, 2300 mm	1.62 mm	Yes	Rotatable knife with focused, bipolar radiofrequency energy and low voltage Designed notch to provide depth perception, tissue retraction, precise dissection and coagulation Integrated injection needle for lifting Requires its own Chroma Energy platform	 107

(continued on the next page)

SUPPLEMENTARY TABLE 1. Continued

Manufacturer and brand name	ESD capabilities	Needle type	Adjustable length	Minimum working channel diameter	Working length	Knife length	Water-jet function	Features	Image
Creo/SpydrBlade Flex	Marking, mucosal incision, submucosal dissection, hemostasis	Bipolar energy/scissor type	No	3.2 mm	1800 mm	4.2 mm and 4.0 mm (inner jaw length), 2.3 mm (outer active jaw length)	No	Rotatable knife with focused, bipolar radiofrequency low voltage energy Radiofrequency energy for cutting delivered between the jaws and at the distal tip for both scissor type and tip cutting Microwave coagulation energy delivered between the open jaws and through both closed jaws Requires its own Chroma Energy platform	

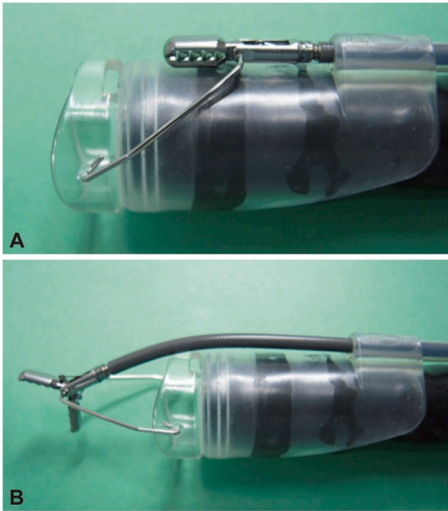
ESD, Endoscopic submucosal dissection.

SUPPLEMENTARY TABLE 2. Off-label and FDA approved submucosal injection fluids

Fluid	Primary content	Dye	Comments
Off label			
Normal saline solution	Normal saline solution	Add in	Dissipates quickly. ProVayBlue (methylene blue) is not compatible with normal saline, so 5% Dextrose solution should be added
2.5% Hydroxypropyl methylcellulose (HPMC)	Hydroxypropyl methylcellulose	Add in	Commercially available as eye drops
Hydroxyethyl starch	Hydroxyethyl starch	Add in	May have limited availability in Hospitals, due to black box warning of its use as an IV fluid
Commercially available			
SIC 8000-Eleview (Medtronic)	Poloxamer 188, polyoxyl-15-hydroxystearate, medium chain triglycerides	Methylene blue	During ESD bubbling has been described that can interfere with visualization
Blueboost (Micro-tech)	Sodium hyaluronate (SH)	Methylene blue	
BlueEye	Sodium hyaluronate (SH)	Not listed	
Everlift (Laborie Medical Technologies)	Hydroxyethyl cellulose and glycerin	Methylene blue	
Endoclot SIS (Olympus)	Absorbable starch polymers	Add in	Comes in powder form and is mixed into solution. Because of its viscosity requires a special spiral syringe
Ascendo (Steris)	Sodium hyaluronate	Methylene blue	
Lift-Up (Ovesco)	Poloxamers, ethylene oxide, propylene oxide	Methylene blue	

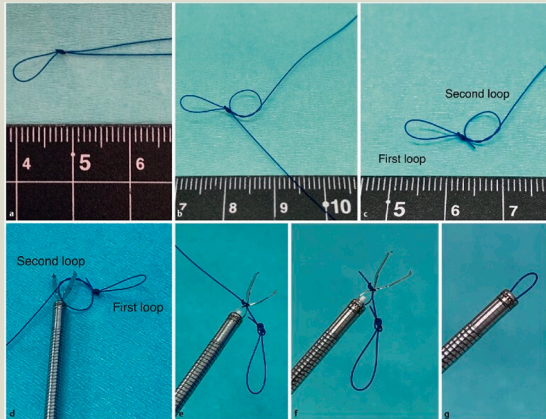
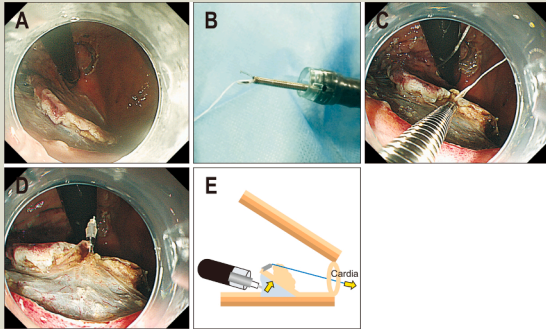
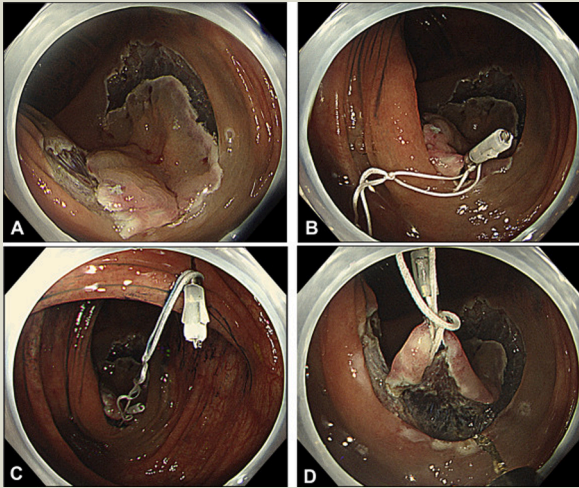
ESD, Endoscopic submucosal dissection; FDA, The U.S. Food and Drug Administration.

SUPPLEMENTARY TABLE 3. Distal attachments for improved visualization during endoscopic submucosal dissection

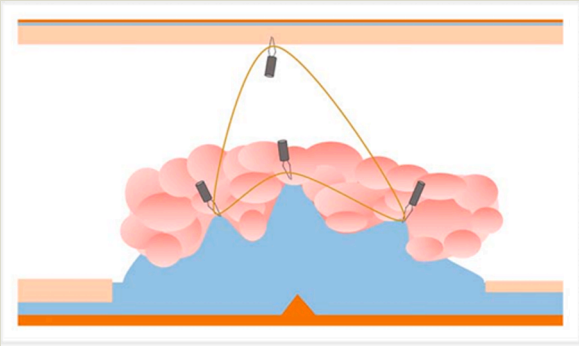
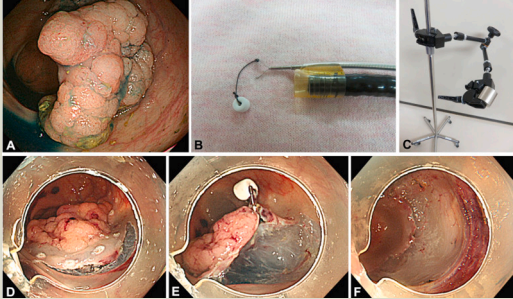
Distal attachments for improved visualization	Figure	Features
Olympus Distal Attachment		• Straight round tip. • 3 mm side hole. • Ten model/size options.
Fuji ST Hood		• Tapered tip for easier access to submucosa. • Two drains. • Three sizes.
Steris Reveal Distal Attachment		• Clear material with straight round tip. • One drain. • Six different diameter options.
Olympus Endolifter®		• Provides counter-traction and acts like an extra hand. • Cube-shaped loop attached to the cap that extends 1.5 cm. • Can rotate as it advances. • Has 2 locks to prevent inadvertent movement.
Ovesco Additional Working Channel or AWC		• Attaches to the scope handle with an adaptor and Luer-lock. • Can rotate 360° on the distal tip of the scope. • Possibility of dropping away during the procedure.

*Not available in the United States.

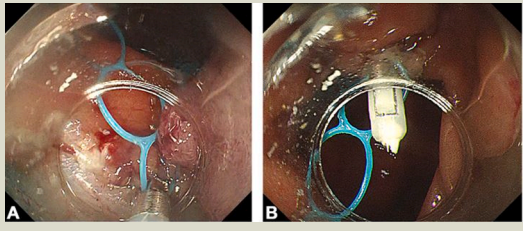
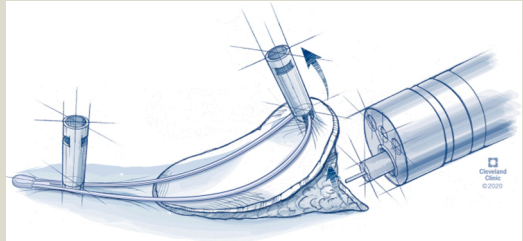
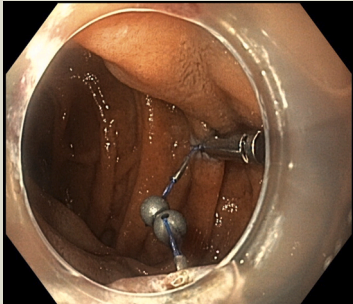
SUPPLEMENTARY TABLE 4. Handmade methods for tissue retraction

System	Comments and QR video code	Image/diagram
Clip-and-loop	Location: Esophagus, stomach, duodenum, and colorectum. ²² QR code for video:  Hyperlink to video	 A, The first loop is made by looping and knotting a nylon suture. B, The second loop is made by looping and keeping in the middle of ligature. C, The unnecessary part of the thread is cut. D, A clip is opened halfway. E, The second loop of the thread is tied tightly to the arm part of the clip. F, The unnecessary part of the thread is cut. G, A completed clip with a looped thread.²²
Clip-with-line	Location: esophagus, stomach, duodenum, colorectum. Line pulled through mouth or anus. ¹⁹ QR code for video:  Hyperlink to video	 A, Circumferential mucosal incision performed for an early gastric cancer measuring 50 mm in the lesser curvature. B, A line was tied to a hemostatic clip outside the patient. C, The hemostatic clip with the line was applied to the distal side of the specimen in retroflexion. D, After pulling the line back proximally, the submucosal plane was well visualized and lifted. E, An illustration of the clip and line traction.²¹
Multiloop with suture	Location: most helpful in segments with large lumen such as the colorectum, especially cecum and rectum by increasing the number of loops. ¹¹⁴  Hyperlink to video	

SUPPLEMENTARY TABLE 4. Continued

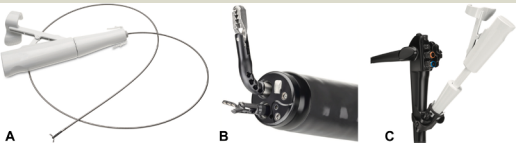
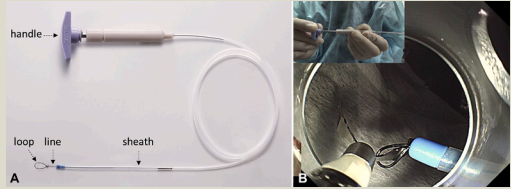
System	Comments and QR video code	Image/diagram
Double clip and rubber band/string	Location: stomach, duodenum, colorectum.²⁷ QR code for video:  Hyperlink to video	 Multitraction with hemostatic clips and a single rubber band.²⁷
Magnetic anchor	Location: stomach, colorectum.³¹ QR code for video:  Hyperlink to video	 A, Lesion in the cecum. B, The magnet attached to a hemostatic clip with thread. C, External magnet with a flexible arm. D, After partial dissection, the magnetic anchor is attached. E, Direct visualization of the submucosal layer by traction using magnetic anchor. F, Defect after dissection.³¹

SUPPLEMENTARY TABLE 5. Proprietary tools and devices for traction

Device	Availability and FDA clearance	Comments	QR video code/Video Hyperlink	Image or diagram
Multiloop Traction Device ³⁵	Available in Japan by Boston Scientific. Not commercially available in the United States. Not FDA approved.	Stomach, duodenum, colorectum		 Hyperlink to video³⁵ Multiloop traction technique. A, The edge of the exfoliated mucosa near the diverticulum was attached to a multiloop traction device. B, Traction was applied by attaching another hemostatic clip to the contralateral colonic wall.³⁵
ProdiGI Traction Wire ³⁶⁻³⁸	Available in the United States by Medtronic. FDA approved.	Stomach, duodenum, colorectum		 Hyperlink to video³⁸  Concept drawing of the traction wire device in use.³⁷
ProdiGI Traction Magnet ⁴²	Available in Europe by Medtronic. Not commercially available in the United States. FDA approved.	Stomach, Duodenum, Colorectum		 Hyperlink to video⁴² The magnet of the second hemostatic clip in normal mucosa adhered to the first magnet on the lesion.⁴²

(continued on the next page)

SUPPLEMENTARY TABLE 5. Continued

Device	Availability and FDA clearance	Comments	QR video code/Video Hyperlink	Image or diagram
TracMotion ⁴⁹	Available in the United States by Fujifilm. FDA approved.	Location: only gastric and rectal because of need for a double channel endoscope.		 A, Hand controller and distal articulating arm and jaw connected by a cable. B, Distal arm with a rotatable grasper. C, Hand controller mounted on the biopsy port.⁴⁹ Hyperlink to video⁴⁹
EndoTrac ⁴⁷	Available in Japan by Top Corporation. Not commercially available in the United States. Not FDA approved.	Location: stomach, duodenum, and rectum.		 The EndoTrac. A, A line with a loop at its tip, a plastic sheath, and a T-shaped handle. B, Pulling the handle advances the sheath forward and tightens the loop around the jaw of the hemostatic clip, tying the EndoTrac to the hemostatic clip.⁴⁷ Hyperlink to video⁴⁷
S-O clip ^{44,45}	Available in Japan by Zeon Medical. Not commercially available in the United States. Not FDA approved.	Location: stomach, duodenum, colorectum.		 Hyperlink to video⁴⁴
SureTrac ¹¹⁵	Available in the United States by Microtech. FDA approved.	Location: gastric, duodenum, colorectum.		 Hyperlink to video¹¹⁶

FDA, The U.S. Food and Drug Administration.

SUPPLEMENTARY TABLE 6. Monopolar energy settings for the Erbe VIO 300D, VIO3

ESD step	Mode	Desired result
Marking	Soft Coag, Forced Coag	White mucosal coagulation mark without penetration of the mucosal layer
Mucosal incision	Endocut I, EndoCut Q, Dry Cut	Incising of mucosa and muscularis mucosa to access the submucosal layer efficiently without significant thermal coagulation effect
Mucosal trimming	EndoCut I, EndoCut Q, Dry Cut, Forced Coag, Swift Coag	Trimming and opening of the submucosal space to allow access to the submucosal space without significant bleeding and without significant drainage of submucosal fluid
Submucosal dissection	EndoCut I, Endocut Q, Dry Cut, Forced Coag, Swift Coag, Spray Coag, PreciseSect	Exposure and dissection of the submucosal plane while limiting tissue desiccation, bleeding, and damage to the lesion and the muscularis propria layer
Hemostasis	Soft Coag, Forced Coag	Coagulation of significant blood vessels without hemorrhage and without significant cutting current

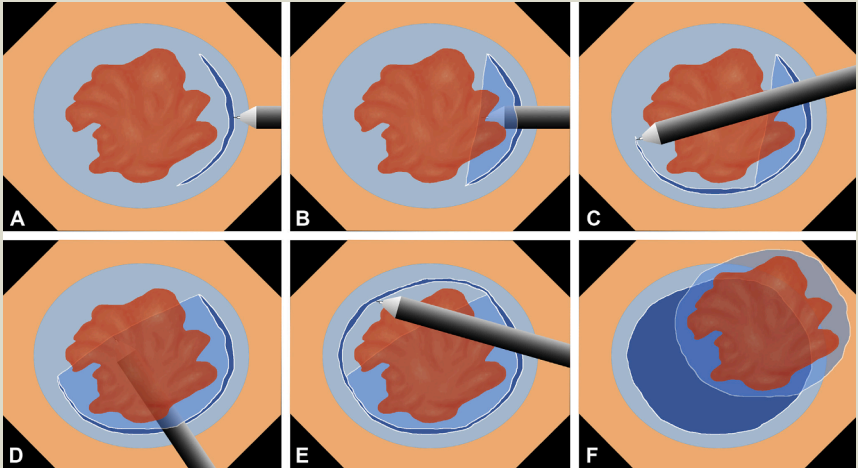
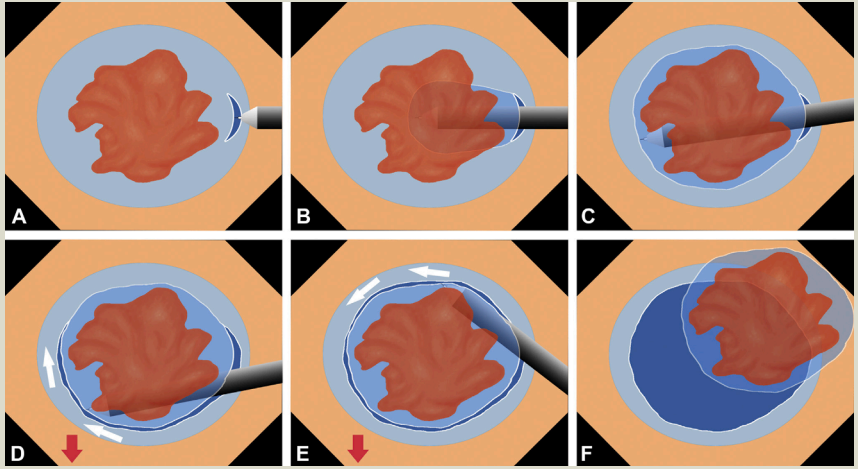
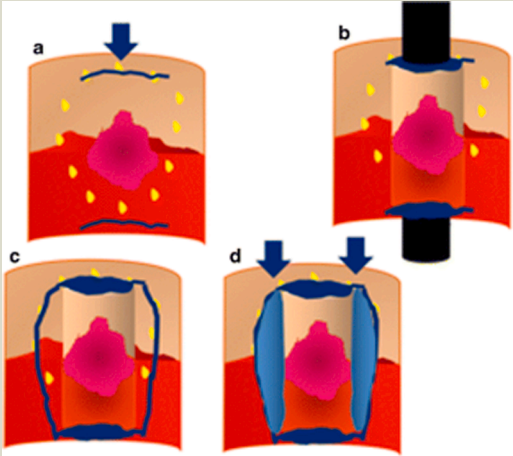
ESD, Endoscopic submucosal dissection.

SUPPLEMENTARY TABLE 7. Bipolar energy settings for the Creo CROMA advanced energy platform

ESD step	Mode	Desired result
Marking	Microwave	White mucosal coagulation mark without penetration of the mucosal layer
Mucosal incision	Bipolar RF	Incising of mucosa and muscularis mucosa to access the submucosal layer efficiently without significant thermal coagulation effect
Submucosal dissection	Bipolar RF	Exposure and dissection of the submucosal plane while limiting tissue desiccation, bleeding, and damage to the lesion and the muscularis propria layer
Hemostasis	Microwave	Coagulation of significant blood vessels without hemorrhage

ESD, Endoscopic submucosal dissection.

SUPPLEMENTARY TABLE 8. Diagrams of various ESD techniques

ESD technique	Image
Conventional ESD	 The diagram illustrates the conventional ESD technique in six steps (A-F). It shows a cross-section of the colon with a polypoid lesion. A mucosal cap is created by dissecting the mucosa from the submucosa. The lesion is then removed within this cap. The steps are: A) Initial dissection, B) Expansion of the cap, C) Further dissection, D) Completion of the cap, E) Removal of the lesion, and F) Final view of the cap and defect.
Pocket creation method	 The diagram illustrates the pocket creation method in six steps (A-F). It shows a cross-section of the colon with a polypoid lesion. A mucosal cap is created by dissecting the mucosa from the submucosa. The lesion is then removed within this cap. The steps are: A) Initial dissection, B) Expansion of the cap, C) Further dissection, D) Completion of the cap, E) Removal of the lesion, and F) Final view of the cap and defect.
Endoscopic submucosal tunnel dissection	 The diagram illustrates the endoscopic submucosal tunnel dissection (ESMT) technique in four steps (a-d). It shows a cross-section of the colon with a polypoid lesion. A mucosal cap is created by dissecting the mucosa from the submucosa. The lesion is then removed within this cap. The steps are: a) Initial dissection, b) Expansion of the cap, c) Further dissection, and d) Completion of the cap.

(continued on the next page)

SUPPLEMENTARY TABLE 8. Continued

ESD technique	Image
Traction ESD	
Water pressure method	
Hybrid ESD	

ESD, Endoscopic submucosal dissection.