Article published online: 2024-05-31

Electrosurgery in Gastrointestinal Endoscopy: Bench to Bedside

Zaheer Nabi[1] Priscilla Lopez[2] D. Nageshwar Reddy[1]

[1] Department of Gastroenterology, Asian Institute of Gastroenterology, Hyderabad, Telangana, India
[2] Department of Endoscopic Surgery, Instituto Chileno - Japonés, Clínica Las Condes, Santiago, Chile

Address for correspondence Zaheer Nabi, MD, DNB, FASGE, FISG, FSGEI, Department of Gastroenterology, 6-3-661, Asian Institute of Gastroenterology, Hyderabad, Telangana 500082, India (e-mail: zaheernabi1978@gmail.com).

J Digest Endosc 2024;15:116–124.

Abstract

Electrosurgical generator units (ESUs) are instrumental in modern therapeutic gastrointestinal (GI) endoscopy, converting household alternating current into high-frequency current to generate thermal energy within tissues. This review elucidates the essentials of electrosurgery, exploring the thermal effects on tissue, current resistance, voltage, current density, duty cycle, crest factor, and the distinctions between monopolar and bipolar circuitry. The concept of duty cycle, the proportion of time electrical current is delivered, and crest factor, the ratio of peak to root mean square voltage, are essential while comparing differently named modes across various commercially available ESUs. This article discusses the practical applications of electrosurgery in therapeutic GI endoscopy procedures, including endoscopic sphincterotomy, polypectomy, endoscopic mucosal resection, endoscopic submucosal dissection, and peroral endoscopic myotomy. It outlines recommended modes and settings for ESUs across various procedures, emphasizing the balance between cutting and coagulation to achieve optimal outcomes while minimizing adverse effects. The review further addresses special considerations for the use of grounding pads and the management of patients with implanted cardiac devices during electrosurgical procedures. This article concludes with a call for a deeper understanding of electrosurgical principles and their application in GI endoscopy to ensure patient safety and procedural success, backed by references to relevant literature and detailed tables summarizing electrosurgical modes and settings for various therapeutic interventions.

Keywords
- electrosurgery
- endoscopy
- cutting
- coagulation
- polypectomy
- endoscopic resection

Introduction

Electrosurgical generator units (ESUs) convert the household alternating current (50 Hz) into high-frequency current (200 to 1 million kHz) which is then transformed into thermal energy within the tissue. Generation of high-frequency current is important to prevent shock and neuromuscular stimulation to the patient. ESUs are capable of producing a variety of electrical waveforms which impact the corresponding effect on the tissues. Pure cutting currents have a constant waveform, generate heat very rapidly, and vaporize or cut the tissue. On the other hand, intermittent waveforms produce less heat leading to the formation of a coagulum instead of vaporization. It is important to note that the final effect (cut or coagulation) is dependent on the rapidity of heat production. The modulation of these waveforms by ESUs from different manufacturers is meant to give different effects on the tissue, that is, predominant cutting or predominant coagulation. Since a variety of names are provided by different manufacturers, users must learn about the particular waveforms available with each generator.

article published online
May 31, 2024

DOI https://doi.org/10.1055/s-0044-1787128.
ISSN 0976-5042.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

In this review, we discuss the fundamentals of electrosurgery and its practical applications for various therapeutic gastrointestinal (GI) endoscopy procedures.

Basics of Electrosurgery

Thermal Effect on Tissue

The thermal effect of heat on tissue initiates at ≥ 40°C. At this temperature the effects include initial tissue damage, edema formation, and, depending on the duration of application, the tissue can recover or die (devitalization). At ≥ 60°C, devitalization (destruction) of the cells, shrinkage of the connective tissue through denaturation occurs. The coagulation effect is produced when the tissue is heated more gently (> 60°C to < 100°C). Cutting effect is produced when the tissue is rapidly heated beyond 100°C resulting in rapid vaporization of the fluid and disruption of the cell structures. Even higher temperatures result in either carbonization (about 150°C) or vaporization of the tissue (about 300°C) (►**Fig. 1**).

Current, Resistance, and Voltage

Current (I) refers to the movement of electric charge (specifically, electrons) within a circuit over a given time period.

Resistance (R) or impedance represents the degree to which the flow of current is hindered. Resistance is significantly affected by the content of water and electrolytes in the tissue. For example, tissues that contain a high amount of water, such as blood vessels, offer lower resistance compared to those that are less hydrated, such as bone and fat. As a result, cutting through a fatty lesion using a snare proves to be more challenging than cutting through a nonfatty polyp under the same electrosurgical conditions. Furthermore, the presence of fibrosis and scars can elevate the impedance of tissue, potentially requiring modifications to the power and/or the waveform of the current to achieve the intended outcome. The accumulation of char on the knife's tip can also obstruct the flow of current, highlighting the importance of regularly cleaning the electrodes during a procedure to ensure effective contact coagulation.

Voltage (V) is the force that pushes a current through a resistance and is measured in volts. Therefore, higher voltages potentially increase the depth of thermal effect (desired or undesired). Caution is advised while using modes with very high voltages like forced coagulation, swift coagulation, and spray coagulation.

Current density is the amount of electrical current per unit area of cross-section. Small areas of contact with the electrode (e.g., snare, sphincterotome, needle knife) produce higher current density resulting in a rapid and sharp cut. No wonder, precut papillotomy is still considered dangerous by some experts. While a clean cut without much coagulation is the desired effect during endoscopic sphincterotomy (EST) to minimize thermal injury to the pancreatic sphincter, the same may be counterproductive during other procedures like endoscopic submucosal dissection (ESD) and polypectomy where hemostasis is equally important. The bulbous tip of the commonly used electrosurgical knives for ESD and braided nature of polypectomy snares ensure a broad area of contact with the tissue balancing the speed of cut while maintaining hemostasis due to slow and controlled cutting. Another practical example of current density is that during endoscopic cutting or resection the current is very concentrated along the device (knife tip or snare wire) but dispersed over the much larger area of the grounding pad when it exits the patient's body. Therefore, while cutting or coagulation occurs at the resection site, the same amount of current produces no noticeable rise in skin temperature.

Duty cycle refers to the percentage of total time that electrical current is actually delivered. A duty cycle of 100% implies that the current is delivered continuously for the entire activation period without any pauses. The ultimate effect on the tissue in pure waveforms is determined by peak voltage (Vp). While a peak voltage of > 200 Vp produces pure cutting effect, a peak voltage of ≤ 200 Vp produces pure coagulation effect. In clinical practice, the pure waveforms are modulated by introducing interruptions or pauses in the waveform to achieve both the effects, that is, cut as well as coagulation. During the pauses, the target tissue has more opportunity to cool which in turn promotes greater degrees of tissue coagulation over cutting effect. In general, lower is the duty cycle (longer pause) more is the coagulation effect. Therefore, ESU modes with predominant coagulation effects

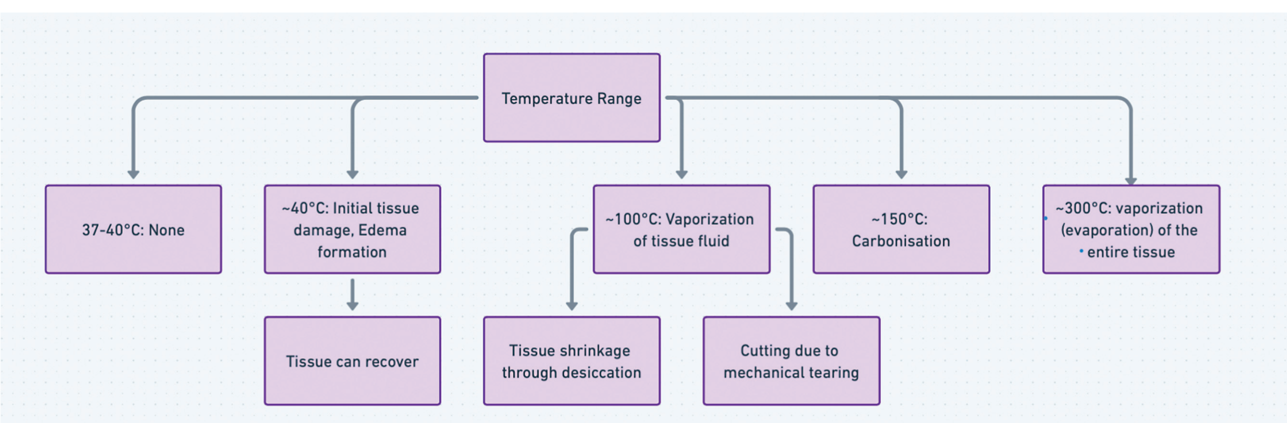

Fig. 1 Thermal effects on biological tissue at different temperatures.

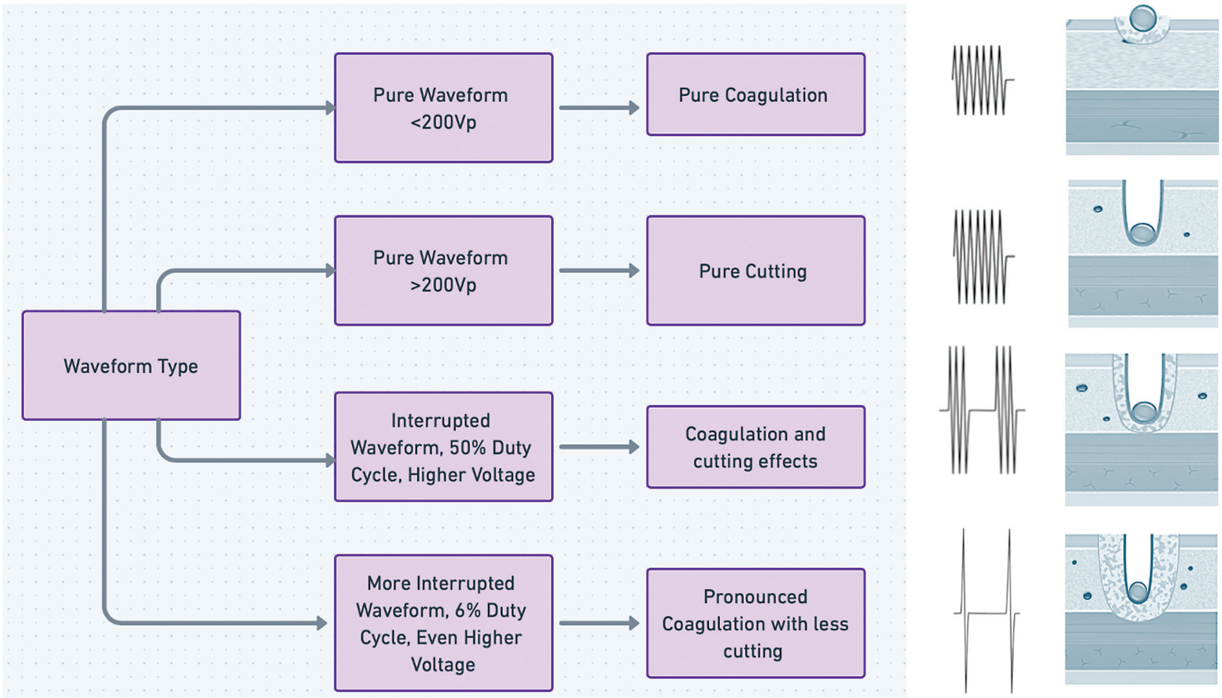

Fig. 2 Different types of waveforms and their impact on the tissue.

(*Forced Coag*, *Spray Coag*, *Swift Coag*) have low duty cycles ranging from 4 to 8% and higher voltages (> 650–4,300 Vp). On the other hand, modes with relatively high duty cycle (30–100%) like *EndoCut*, *PulseCut*, and *DryCut* produce mainly cutting effects with less intense coagulation. Duty cycle or nature of waveform is a simple way to compare modes named differently across various ESUs (►**Fig. 2**; ►**Table 1**).

Crest factor is the ratio of peak to root mean square voltage. Pure sinus current waveforms have a crest factor of 1.4, whereas modulated current waveforms have a crest factor ranging from 1.5 to 8. In general, crest factor is proportional to the intensity of coagulation provided by that particular waveform or mode on ESU. Crest factor is useful to compare different modes across various ESUs (►**Table 1**).

Monopolar and Bipolar Circuitry

In monopolar mode, the electrical current passes from the active electrode to the target tissue, through the patient's body, to finally exit the patient through a large dispersive neutral electrode (also called a patient plate or return electrode). The vast majority of devices used in therapeutic GI endoscopy are monopolar including electrosurgical knives, coagulation forceps, polypectomy snares, sphincterotome, etc.

In bipolar mode, the endoscopic device contains both the active and the neutral electrodes in close proximity to each other. The electrical current passes directly from one electrode to the other through a small amount of tissue in contact with both electrodes. The current does not pass through the rest of the patient's body and no patient plate is required. Only a few commercially available devices are bipolar in nature like the SpeedBoat device (Creo Medical), heater probe or Gold Probe (Boston Scientific), coagulation forceps (Hemostat Y, Pentax), and radiofrequency ablation probes. The advantage of bipolar instruments is that they use less power to achieve similar effects. Consequently, bipolar devices are associated with less tissue damage,

Table 1 Basic characteristics of various electrosurgical modes

ERBE VIO 300D				ESG-300		
Setting	Voltage	Duty cycle	Crest factor	Setting	Voltage	Duty cycle
Soft Coag	55–199	100%	1.4	Soft Coag	221	100%
EndoCut Q and I	0–770	100%	1.4	PulseCut (slow/fast)	770	100%
DryCut	650–1450	30%	3.0	Blend Cut	1400	50%
Swift Coag	660–2500	8%	5.4	Power Coag	2500	8%
Forced Coag	880–1800	8%	6.0	Forced Coag	2000	8%
Spray Coag	3800–4300	4%	7.4	Spray Coag	4300	4%

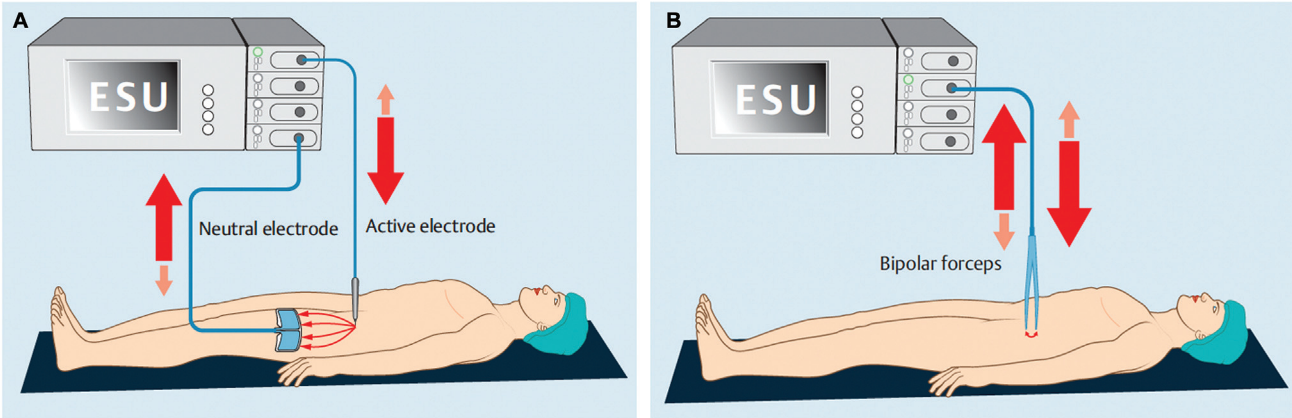

Fig. 3 Diagrammatic representation of monopolar (**A**) and bipolar (**B**) electrosurgery. (With permission from: Rey J F, Beilenhoff U, Neumann C S, Dumonceau J M. European Society of Gastrointestinal Endoscopy (ESGE) guideline: the use of electrosurgical units. Endoscopy 2010;42(9):764-72.)[2]

with decreased risk of collateral thermal injury and perforation when compared to monopolar devices.[1] Since the current does pass through the patient's body, bipolar instruments are less likely to interfere with the implanted cardiac devices (ICDs). However, these bipolar devices are not widely available, in part due to their more complex design and manufacturing costs relative to their monopolar counterparts[2] (►**Fig. 3**).

Major Modes in GI Endoscopy

There are two main electrosurgical effects on the tissue, that is, cut and coagulation. In clinical practice, majority of the electrosurgical modes possess both the properties, that is, cut and coagulation (►**Fig. 4**).

Cutting Modes

Cutting modes commonly used during therapeutic GI endoscopy procedures include *EndoCut* Q and I (Erbe) and *PulseCut* slow or fast (Olympus). Although the nomenclature suggests a pure cutting effect, these modes have blended effects (both cutting and coagulation) on the target tissue. Examples of pure cut modes include *AutoCut* and *HighCut* (Erbe Vio 300D). The common indications for blended (EndoCut and PulseCut) modes include snare polypectomy, endoscopic mucosal resection (EMR), EST, and mucosal incision during ESD. The modifiable parameters on ESUs while using these modes include effect (intensity of coagulation), duration (amount of tissue cut in one go), and interval (duration between two cut cycles). Duration and interval determine the speed of cutting, that is,

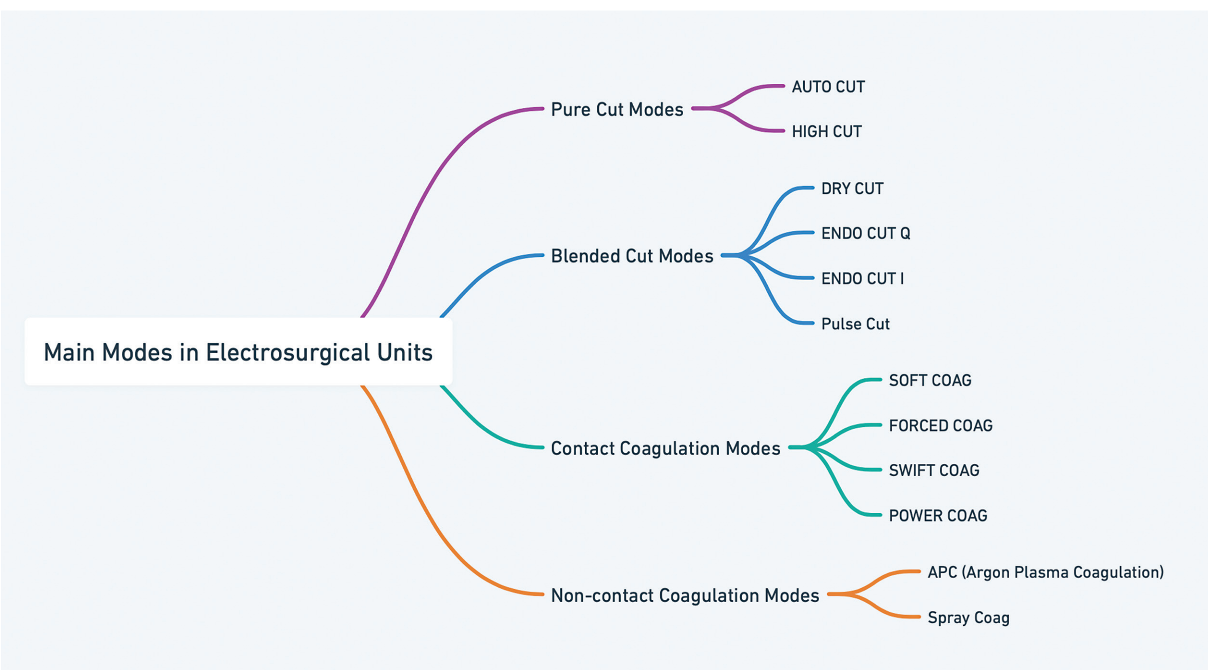

Fig. 4 Common electrosurgical modes used in therapeutic gastrointestinal (GI) endoscopy.

higher duration and lower interval result in faster cutting. On the counter side, the risk of intraprocedural bleeding may be higher with faster cutting as there is little time for the coagulation to occur. Similarly, higher effect results in better coagulation with the downside of increased risk of thermal injury. Therefore, the settings on ESU are governed by several factors like vascularity of the tissue, wall thickness, and the accessory used.

DryCut mode, when compared to *EndoCut*, has better coagulation capability owing to its lower duty cycle and higher peak voltage. Therefore, this mode is often utilized for mucosal incision especially in regions with high vascularity like large rectal polyps.

Coagulation Modes

Coagulation modes in the commercially available ESUs include *Forced Coag* (Erbe and Olympus), *Swift Coag* (Erbe), *Spray Coag* (Erbe and Olympus), *Soft Coag* (Erbe and Olympus), and *Power Coag* (Olympus). Among these modes, *Soft Coag* has the lowest peak voltage ($\leq$ 200 V) with no cutting capacity (pure waveform, 100% duty cycle), and therefore, intended to be used only for preemptive coagulation or achieving hemostasis during active bleeding. Other coagulation modes have intense coagulation capacity along with some tissue cutting capability. These modes are utilized during ESD and third space endoscopy procedures. The modifiable factors in these modes include power and effect. Lower settings (power and effect) are desirable in thin-walled regions of GI tract like the duodenum and right colon. On the other hand, higher settings may be preferred in regions with relatively thicker walls like the stomach and rectum (►**Fig. 5**).

Newer Modes

Several newer electrosurgical modes have been introduced to enhance the safety and efficacy of endoscopic dissection procedures. One of these modes, preciseSECT, responds very quickly and precisely to different tissue impedances by dynamically adjusting the current curve. This mode has been proposed for precise submucosal dissection and pronounced hemostasis with little thermal damage. The high impedance given by a small contact surface (i.e., tip of the knife) enhances the dissecting effect. Conversely, an effective coagulation effect can be achieved through lower impedance with the preciseSECT mode. This sealing of the vessel is achieved by applying the instrument tip to blood vessels in a more planar manner (large contact surface). Although several advantages have been proposed, high-quality trials are required to evaluate the real-world impact of this novel mode for ESD procedures.

Practical Applications of Electrosurgery

This section outlines the recommended modes and settings on ESUs for different therapeutic GI endoscopy procedures. It is crucial to understand that these recommendations depend on several factors, including the operator's personal preference, the specific tools used (such as the type of knife), the ESU brand, the lesion's location, and the thermal sensitivity of the GI tract being treated. As such, these recommendations should be applied with careful consideration of the specific clinical situation and not adhered to without thoughtful adaptation to the context (►**Table 2**).

Endoscopic Retrograde Cholangiopancreatography (Sphincterotomy)

Several cutting currents have been utilized for EST including (1) pure cut, (2) coagulation, (3) blended (cutting and coagulation), and (4) proprietary currents (*EndoCut*) which are characterized by an automatically controlled cut system.[3] These currents have been compared for main adverse events associated with EST, that is, bleeding and perforation. Overall, the data suggest that mild bleeding is higher with pure cutting modes. Whereas there is no major impact of the mode on perforation, pancreatitis, and significant bleeding.[4] Although EST can be carried out safely with any of the aforementioned modes, cutting modes capable of automatic control (*EndoCut* mode) are commonly used in clinical practice to reduce the risk of mild bleeding and unexpected

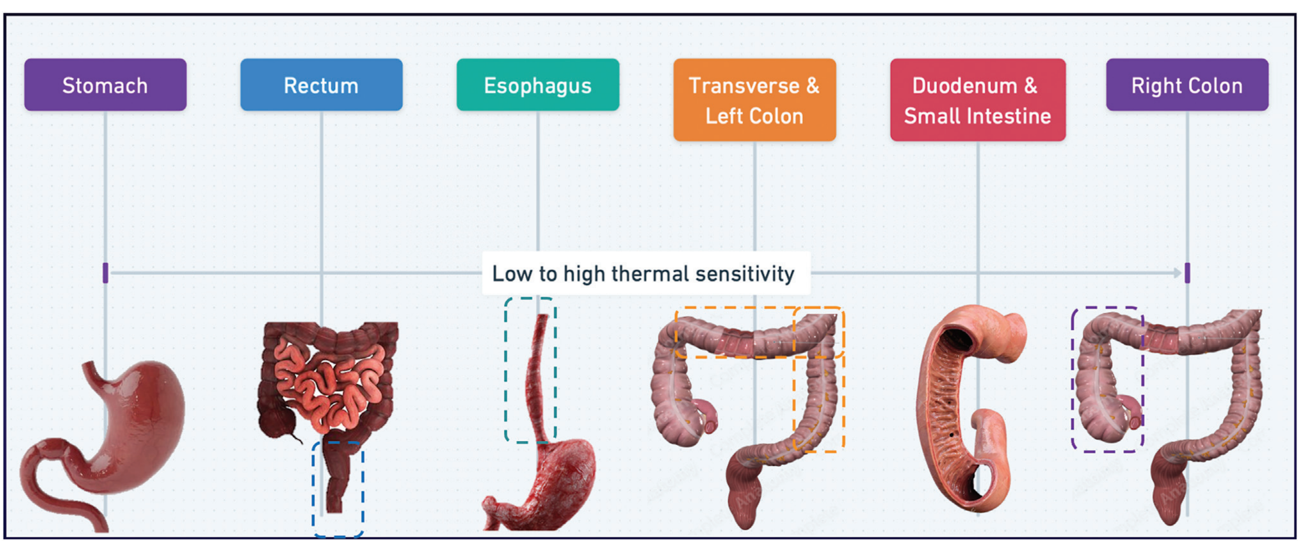

Fig. 5 Thermal sensitivity across different locations in the gastrointestinal (GI) tract.

Table 2 Electrosurgical modes and settings on the electrosurgical generator for various therapeutic interventions

Intervention	VIO 200/300 (ERBE)	ESG-300 (Olympus)
Polypectomy and EMR	EndoCut Q (E3, D1, I 4-6)	PulseCut Slow (E2, 120 W)
Large pedunculated/rectal polyps	EndoCut Q (E4, D1, I 6)	Forced Coag (E4, 120 W)
Right colon polypectomy	EndoCut Q (E1-2, D1, I 4-6)	PulseCut Slow (E2, 120 W)
Ablation to reduce recurrence (snare tip soft coagulation)	Soft Coag (E4, 80 W)	Soft Coag (E3, 50 W)
Endoscopic sphincterotomy	EndoCut I (E2, D3, I3)	PulseCut Fast (E2, 120 W)
Precut papillotomy	EndoCut I (E2, D3, I3)	NA
Endoscopic submucosal dissection[a]		
Marking	Forced Coag (E2, 20 W), Soft Coag (E4, 50–80 W)	Forced Coag (E2, 20 W) or Soft Coag (E3, 50 W)
Mucosal incision	EndoCut I (E2, D3, I 1), DryCut (E2-3, 30 W)	PulseCut Fast (E2, 120 W)
Submucosal dissection	Swift Coag (E4, 30–40 W)	Power Coag (E2, 30 W)
Hemostasis (small vessels)	Swift Coag (E4, 30–40 W)	Power Coag (E2, 30 W)
Hemostasis (large vessels)	Soft Coag (E4-5, 60–80 W)	Soft Coag (E3, 50 W)
Peroral endoscopic myotomy[b]		
Mucosal incision	EndoCut I (E2, D2, I 2)	PulseCut Fast (E2, 120 W)
Submucosal tunneling	Spray Coag (E2, 50 W)	Spray Coag (E2, 40 W)
Myotomy	Spray Coag (E2, 50 W), EndoCut I (E2, D2, I 2)	PulseCut Fast (E2, 120 W)
Hemostasis	Soft Coag (E4-5, 60–80 W)	Soft Coag (E3, 50 W)
Device-assisted EFTR		
Marking	Forced Coag (E2, 20 W) or Soft Coag (E4, 80 W)	Forced Coag (E2, 20 W) or Soft Coag (E3, 50 W)
Cutting	High Cut (E4, 200 W), AutoCut (E5, 180 W)	Pure Cut (E1, 120 W)

Abbreviations: D, duration; E, effect; EFTR, endoscopic full-thickness resection; EMR, endoscopic mucosal resection; I, interval; NA, not available.
[a]While using Dual knife from Olympus.
[b]While using Triangular tip knife from Olympus.

zipper cuts.[3] The recommended settings on the commonly used ESU are as follows: *EndoCut* I (Vio 300D: E2, D3, I3) and *PulseCut* Fast (ESG 300: E2, 20 W). Active bleeding during sphincterotomy is controlled using sphincterotome by pressing the blue paddle and activating *Forced Coag* (E2, 60 W).

Polypectomy and EMR

Polypectomy and EMR are among the most common therapeutic procedures performed in a GI endoscopy unit. The settings and modes are essentially similar for both polypectomy and EMR. *EndoCut* (Erbe) and *PulseCut* (Olympus) modes are frequently utilized for both the procedures. The effect can be modulated according to the presumed vascularity of the polyp as well as the location in GI tract. Since EMR in cases with laterally spreading polyps involves larger areas of resection (vs. polypectomy in pedunculated polyps), the closure of snare should be fast and complete to prevent deep thermal injury to the muscle bed. In contrast, gradual closure of snare while the foot paddle is continuously activated is recommended when resecting thick stalked polyps. Some experts prefer coagulation mode (*Forced Coag*) for performing polypectomies. In a well-conducted randomized trial including 928 patients with nonpedunculated colorectal polyps 20 mm or larger, *EndoCut* and *Forced Coag* modes were comparable with regards to serious adverse events, complete resection rate, or polyp recurrence.[5] Therefore, electrosurgical settings can be selected based on the endoscopist's expertise and preference. The settings for the commonly available ESUs in India have been outlined in ►**Table 2**

Endoscopic Submucosal Dissection and Per-oral Endoscopic Myotomy

ESD and peroral endoscopic myotomy (POEM) procedures involve several steps each requiring different modes and settings on ESU. It is important to note that the settings vary according to the manufacturer of the ESU, location of the lesion, and the type of device used. In addition, the use of a particular mode differs according to the preference of the operator performing the procedure. In general, lower settings are preferred at locations were the luminal wall is thin (like the duodenum and right colon). Conversely, higher settings are required at locations with high vascularity and thick mucosa (rectum and stomach).

Endoscopic Submucosal Dissection

ESD involves several steps including marking, mucosal incision, and submucosal dissection. The decision to mark around the lesion is at the discretion of the endoscopist. In general, marking is performed for lesions located in the esophagus and stomach, and avoided in the colon mainly due to clear and discernible margins of colonic polyps. Marking should be done using the same knife with lower settings in one of the coagulation modes (e.g., *Forced Coag* E1, 20 W). Alternatively, argon plasma coagulation (APC) can also be used for marking around the lesion. Care should be taken to avoid deep mucosal burns during marking as it may lead to leakage of submucosal cushion fluid. Mucosal incision is performed using one of the cutting currents (*EndoCut* or *DryCut*). Coagulation currents (*Forced Coag* or *Swift Coag*) are utilized for the subsequent steps, that is, precutting and submucosal dissection. Some experts prefer cutting modes (*EndoCut* or *DryCut*) for submucosal dissection to minimize charring. Small intervening vessels are coagulated with the same mode, whereas soft coagulation is preferred in cases with more than mild bleeding or failure to achieve hemostasis with the previous coagulation modes. It is important to note that the settings on ESU differ according to the manufacturer as well as the accessory used for the procedure. Therefore, it is crucial to recognize the type of knife and the recommendations from the manufacturer before implementing similar settings for the procedure.

Peroral Endoscopic Myotomy

POEM procedure involves several steps including mucosal incision, submucosal tunneling, and myotomy. In contrast to ESD for polyps, mucosa is preserved and muscle is severed during POEM. In general, the modes and settings on ESU are similar to those utilized during ESD. Some experts prefer spray coagulation mode for submucosal tunneling for rapid dissection. Since spray coagulation mode is a noncontact mode with very high peak voltage ($\sim$4000 V) and strong coagulation effect, caution should be exercised especially during dissection close to the gastroesophageal junction where the mucosa and muscle layer are in close proximity to each other.

The authors of this article utilize the following settings while using triangular tip knife and Erbe Vio 300D: mucosal incision (*EndoCut*, E2, D2, I2), submucosal tunneling (*Spray Coag* E2, 50 W), and myotomy (*EndoCut* or *Spray Coag* with similar settings).

Hemostasis

Various endoscopic instruments designed for hemostasis include heater probe (Olympus and Boston Scientific), coagulation forceps, and APC probe.

Heater probe (e.g., BiCOAG Bipolar Probe, Olympus) and Gold Probe (Boston Scientific Inc., Natick, Massachusetts, United States) are bipolar devices which achieve hemostasis by mechanical compression (coaptive coagulation) and application of coagulation current in short bursts (5–10 s). It is mainly used for bleeding peptic ulcers.

Preemptive coagulation and minor bleeding episodes during dissection can be managed using the dissection knife. Low power settings are used for preemptive coagulation (*Forced Coag*, effect 1, 10 W; *Spray Coag*, effect 1, 7 W; VIO300D). Conversely, for vessels with diameters $\geq$ 2 mm or for patients at an increased risk of hemorrhage, hemostatic forceps is preferred to ensure complete hemostasis by thermocoagulation in the soft coagulation mode (effect 4–5, 80 W; VIO300D).[6] After grasping with the forceps, it is important to gently pull back the vessel to avoid transmission of current in the deeper layers of the GI wall. Since the colonic walls are thinner as compared to the gastric wall, a smaller coagulation forceps with lower opening width (4 vs. 5 and 6.5 mm) is preferred. Soft coagulation is preferred over other coagulation modes for hemostasis due to its several properties including slow and deep coagulation, low tissue sticking, and low carbonization. Other coagulation modes (*Swift Coag*, *Forced Coag*, and *Spray Coag*) produce rapid heating and early charring which hinders subsequent transmission of the current. As a result, the coagulation may be ineffective. In addition, these modes have additional cutting properties which may be counterproductive.

During APC, the electrical energy is transferred from the APC probe to the tissue via ionized, electrically conductive argon gas, that is, plasma. The main advantage of APC is limited tissue penetration, that is, $\leq$ 5 mm. APC is mainly used in circumstances of diffuse bleeding, such as angiodysplasia, gastric antral vascular ectasia, radiation proctitis, and bleeding ulcers. Another use of APC is ablation of large tumor masses (debulking) for which higher power settings with longer activation times are required. In recent studies, APC has also been utilized to ablate the margins after EMR in cases with colorectal polyps in order to prevent recurrences[7–9] (►**Table 3**).

Other Procedures

Ampullectomy

The main adverse events associated with endoscopic ampullectomy include bleeding, pancreatitis, and perforation. Settings with high coagulation capacity are likely to be associated with lower bleeding, but greater risk of postprocedure pancreatitis as a result of thermal injury to the pancreatic orifice. On the other hand, pure cutting modes (e.g., *AutoCut*) may be associated with less thermal injury to the pancreatic sphincter but higher risk of procedural bleeding. A randomized trial comparing pure cut (*AutoCut*, Erbe) and endocut modes for endoscopic papillectomy concluded no difference in the incidences of delayed bleeding and pancreatitis, but higher rate of crush artifacts and lower rate of immediate bleeding in the *EndoCut* group especially in tumors greater than 14 mm in diameter.[10] A recent systematic review concluded that both pure cut and blended endocut modes are associated with high incidence of adverse events. Therefore, there is an unmet need to establish a standard method of endoscopic papillectomy, including the electrosurgical cutting mode.[11] In order to answer this question, Yamamoto et al conducted an elegant study in animals followed by a small clinical study.[12] The authors concluded that the ideal settings while using Erbe ESUs are *EndoCUT*-I mode (effect 1, duration 4, interval 1) and a thinner snare wire (0.40 mm Snare Master, Olympus or 0.48 mm Captivator, Boston Scientific). The authors

Table 3 Practical application of argon plasma coagulation in gastrointestinal tract

Mode	Properties	Clinical application	Settings[a]
Forced APC	Continuous beam with steady power output, fast and effective, large area of hemostasis; provides effective coagulation and devitalization; used for tumor debulking and coagulation of acute ulcer bleeding	Tumor ablation Tumor bleeding Dieulafoy's ulcer Stent trimming Bleeding ulcer	> 60 W, 20–50 W 30–60 W 30–60 W 30–60 W 30–60 W
Pulsed APC	Intermittent power output, more controlled effect on tissue; suitable for hemostasis of diffuse and widespread bleeding (GAVE, angiodysplasias) and for ablation Barrett's esophagus	Barrett's esophagus, residual adenomas, radiation proctitis, hemostasis stomach/colon, stent ingrowth/overgrowth	30–50 W (Barrett's), Effect 2 10–30 W, Effect 1 or 2 (others including left colon and rectum)
Smart/ precise APC	Automatic power adjustment according to distance from tissue; works in the lower energy range, suitable for treating angiodysplasias in the right colon, cecum, and small bowel	Hemostasis duodenum and right colon	Effect 4–5, 10–30 W

Abbreviations: APC, argon plasma coagulation; GAVE, gastric antral vascular ectasia.
[a]Flow rate recommended according to the site is: esophagus, stomach, rectum: 1.4 l/m; sigmoid to transverse colon, small bowel: 1–1.4 l/m; cecum and right colon: 0.5 l/m.

of this manuscript advocate similar settings for endoscopic papillectomy.

EUS drainage and Endoscopic full thickness resection

Endoscopic ultrasound-guided drainage using electrocautery enhanced stents (e.g., Hot Axios, Boston Scientific) is performed using pure cut mode (80–120 W).

Device-assisted endoscopic full-thickness resection (FTRD, Ovesco, Germany) is used for full-thickness resection of mucosal as well as submucosal lesions in colon and upper GI tract. This is one of the few procedures where a pure cutting current is utilized, that is, *AutoCut* or *HighCut* (E4, 180–200 W). Since the clip is deployed before resection, the risk of bleeding is minimal in this scenario while using a pure cutting current.

Special Considerations

Neutral or Return Electrode

In the current era, "split or dual sensing" grounding pads are used to avoid the issue of overheating with the older generation grounding pads when placed inappropriately. The new "neutral electrodes" are equipped with an equipotential ring requiring no particular plate orientation.[2] Moreover, the newer generation ESUs include pad safety and tissue sensing technology in their design. As such, the grounding pads are able to communicate with the generator's computer and alarm system and produce both a visual and audible warning to the operator that the pad is sensing an impedance situation that, if not corrected, could result in a temperature rise on the patient's skin under the pad. The best practices for the use of grounding pads are as follows.[13] The pads should be placed in the most suitable position that is muscular, well vascularized, and close to the treatment site (e.g., flank and upper thigh). Pad should not be placed over tattoos, implants, metal, bony protuberances, broken skin, or scar tissue. Although the pad can be placed on the upper arm, this location should be avoided if the patient has an ICD.

Implanted Cardiac Devices

ICDs such as pacemakers and cardioverter defibrillators are meant to sense electric signals from the heart. However, noncardiac signals such as those from ESU may interfere in the functionality of ICD. The response to this interference may be in the form of temporary inhibition, inappropriate programming, reversion to asynchronous pacing mode, and triggering an unintended shock to the patient. Therefore, caution is advised while using electrosurgery in these patients. Although newer pacemakers are resistant to electric interference, it is advisable to check the manufacturer's recommendation for all the ICDs. It is especially important to identify patients who are dependent on their pacemaker for moment-to-moment maintenance of adequate rhythm and hemodynamics. The use of bipolar devices is preferred while performing therapeutic GI procedures in these patients because the energy travels only the short distance between electrodes and is less likely to pass near the implanted device. Alternatively, use of minimal effective settings (low power and voltage) and avoidance of continuous activation of the current for prolonged periods is recommended while using monopolar devices. The active electrode should be at least 6 inches away from the cardiac device and its lead system.[13]

Newer Electrosurgical Units

The new generation ESUs are equipped with microprocessor that controls the voltage to a constant level to achieve a uniform, even incision and coagulation by detecting discharge at approximately 350 times per second for the ICC (Integrated Cutting and Coagulation) and 1,000 times per second for the VIO300D. A new ESU (VIO3, Erbe) is available commercially which detects discharge at 25,000,000 times per second for the VIO3.[12] This new system is equipped with an unparalleled discharge detection function, enabling highly accurate voltage control. In the authors' experience, the performance (dissection and coagulation) of this newly available ESU is distinctly better than the previous versions.

Summary

ESUs play a crucial role in modern therapeutic GI endoscopy. ESUs produce various electrical waveforms that dictate their impact on tissues—ranging from pure cutting with rapid heat generation to intermittent waveforms that lead to coagulation. The fundamental understanding of electrosurgery, including the thermal effects on tissue, current resistance, voltage, current density, duty cycle, and crest factor, is vital for the safe and effective application of ESUs in procedures such as EST, polypectomy, EMR, ESD, and POEM.

Funding
None.

Conflict of interest
None declared.

References

1 Shinmura K, Ikematsu H, Kojima M, et al. Safety of endoscopic procedures with monopolar versus bipolar instruments in an ex vivo porcine model. BMC Gastroenterol 2020;20(01):27
2 Rey JF, Beilenhoff U, Neumann CS, Dumonceau JMEuropean Society of Gastrointestinal Endoscopy (ESGE) European Society of Gastrointestinal Endoscopy (ESGE) guideline: the use of electrosurgical units. Endoscopy 2010;42(09):764–772
3 Ryozawa S, Itoi T, Katanuma A, et al. Japan Gastroenterological Endoscopy Society guidelines for endoscopic sphincterotomy. Dig Endosc 2018;30(02):149–173
4 Hedjoudje A, Cheurfa C, Farha J, et al. Safety of different electrocautery modes for endoscopic sphincterotomy: a Bayesian network meta-analysis. Ther Adv Gastrointest Endosc 2021; 14:26317745211062983
5 Pohl H, Grimm IS, Moyer MT, et al. Effects of blended (yellow) vs forced coagulation (blue) currents on adverse events, complete resection, or polyp recurrence after polypectomy in a large randomized trial. Gastroenterology 2020;159(01):119–128.e2
6 Horikawa Y, Fushimi S, Sato S. Hemorrhage control during gastric endoscopic submucosal dissection: techniques using uncovered knives. JGH Open 2019;4(01):4–10
7 Motchum L, Levenick JM, Djinbachian R, et al. EMR combined with hybrid argon plasma coagulation to prevent recurrence of large nonpedunculated colorectal polyps (with videos). Gastrointest Endosc 2022;96(05):840–848.e2
8 Motz VL, Lester C, Moyer MT, Maranki JL, Levenick JM. Hybrid argon plasma coagulation-assisted endoscopic mucosal resection for large sessile colon polyps to reduce local recurrence: a prospective pilot study. Endoscopy 2022;54(06):580–584
9 Rex DK, Haber GB, Khashab M, et al. Snare tip soft coagulation vs argon plasma coagulation vs no margin treatment after large nonpedunculated colorectal polyp resection: a randomized trial. Clin Gastroenterol Hepatol 2024;22(03):552–561.e4
10 Iwasaki E, Minami K, Itoi T, et al. Impact of electrical pulse cut mode during endoscopic papillectomy: pilot randomized clinical trial. Dig Endosc 2020;32(01):127–135
11 Minami K, Iwasaki E, Fukuhara S, et al. Electric endocut and autocut resection for endoscopic papillectomy: a systematic review. Intern Med 2019;58(19):2767–2772
12 Yamamoto K, Itoi T, Nagata N, et al. Optimal mode and power output of electrosurgical units for endoscopic papillectomy based on animal experiments and a preliminary clinical study (with videos). Gastrointest Endosc 2022;95(04):760–776
13 Nelson G, Morris ML. Electrosurgery in the gastrointestinal suite: knowledge is power. Gastroenterol Nurs 2015;38(06):430–439