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Review Article

Principles of electrosurgery in laparoscopy - A reviewMinakshi Biradar¹ and Pranil Dode^{*2}¹Fellowship Resident in Minimal Access Surgery at Dr. D Y Patil, Medical College, Navi Mumbai, Maharashtra, India²Assistant Professor, Government Medical College Jalgaon, Maharashtra, India**Abstract**

Electrosurgery is widely accepted the application of electrosurgery was considered a stain on the long-standing traditions of the medical profession. Electrosurgery is commonly used in laparoscopic surgeries. It is necessary to understand the techniques to achieve the desired tissue effect and principles of using appropriate electric currents along with complications. An exhaustive literature has been reviewed concerning the incidence of electrosurgical injuries, the principles of electrosurgery, electrosurgical complications and safety measures. Alertness to postoperative warning signs, patient education prior to discharge, and the detection of delayed manifestations with salvage maneuvers may minimize catastrophic complications. Continued research into the area of tissue interaction shows promise in the potential development of novel applications of electrosurgery. In addition to improved electrosurgical cutting and hemostasis, tissue fusion and ablation have seen increasing application in the surgical setting.

Keywords: Electrosurgery, laparoscopy, electrosurgical devices, electrosurgical waveforms.

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1. Introduction

The cutting, coagulation, desiccation and fulguration of tissue using high-frequency electrical current are referred as Electrosurgery [1]. A basic understanding of electricity is needed to safely apply electrosurgical technology for patient care [2]. Although Physicians or surgeon must be knowledgeable about prevention and management of potential complications of electrosurgical procedures. This technique is used in almost all kinds of surgeries to reduce blood loss and surgical time. In addition, they should understand the mechanism of action and how to troubleshoot equipment. Education on the principles of electrosurgery is important [3] as electrosurgical complications are relatively common [4].

Usually, the terms electrocautery, electrosurgery, radiosurgery, diathermy and radiofrequency heating, have all been used to refer to tissue application of radiofrequency electricity to obtain a desired response. This overlapping of definitions can easily confuse those who use these products routinely. The term ‘electrocautery’ is incorrectly used to

describe electrosurgery. Electrocautery refers to direct current (electrons flowing in one direction) whereas electrosurgery uses alternating current. In electrosurgery or diathermy, the patient is included in the circuit and current enters the patient's body. During electrocautery, current does not enter the patient's body. Instead, current flows through a heating element, which burns the tissue by direct transfer of heat. Electrocautery or, more precisely, thermocautery units are usually portable battery powered devices that can be either disposable or reusable [5]. The term radiofrequency is purely descriptive. The frequency of an electrical signal, in simple terms, is the rate at which the signal's voltage rises and falls. Frequency is measured in cycles per second, and the unit of measurement is Hertz. Electrosurgical devices deliver electricity with high frequencies (0.1 MHz and 4 MHz) falling within the radio wave spectrum (0.01 to 300 MHz), that is why it is called radio frequency electricity [6].

Electrosurgical devices stand out as some of the most useful and most used instruments. Although widely accepted today, the application of electrosurgery was considered a stain on the long-standing traditions of the medical profession until relatively recently. In the present review article, the principles of electrosurgical techniques have been elaborated.

2. Historical Overview

The French physicist Becquerel passed direct current through a wire thereby heating it and effectively cauterizing tissue upon contact. Hence the concept of electrocautery was coined during early 19th century. In 1911 Jacobaeus [7] of Stockholm introduced the term laparoscopy during diagnostic visualization of the peritoneal cavity. However, Fervers [8] a general surgeon in 1933 first time reported the use of laparoscopy in combination with electrosurgery during laparoscopic adhesiolysis. Approximately decades later Power and Barnes [9] reported the human performance of laparoscopic electrosurgical procedure using a monopolar instrument. During this period the significant morbidity due to thermal injuries on using monopolar device contributed to the evolution of bipolar devices in around 1970 by Rioux and Cloutier [10] in North America and Frangenheim [11] in Germany. The same technique was further refined by Kleppinger [12] in 1977 and thus invented the still well-known Kleppinger bipolar forceps which were used mostly unchanged until the early

21st century. Amaral [13] in 1993 first described the ultrasonic scalpel for laparoscopy as having the ability to provide both vessel sealing and tissue transection. However it gained practical acceptance only from 2010 onwards.

3. Principle of Electrosurgery

Several properties of electricity must be understood in order to understand electrosurgery. Electrons orbit the nuclei of atoms. Current flow occurs when electrons flow from one atom to the orbit of an adjacent atom. Voltage is the “force” or “push” that provides electrons with the ability to travel from atom to atom. If electrons encounter resistance, heat can be produced. The resistance to electron flow is called impedance. A completed circuit must be present in order for electrons to flow. A completed circuit is an intact pathway through which electrons can travel. Because energy can neither be created nor destroyed, heat is produced as the moving electrons encounter any kind of resistance- so-called resistive heating. This ability of electricity to produce work in the form of heat in living tissue is central to the mechanism of electrosurgery. The surgeon’s goal during the use of electrosurgery is to attain anatomic dissection with hemostasis while causing the least amount of collateral damage and subsequent scar tissue formation [14,15]. Basic terminologies used in electricity are depicted in following flow chart (Figure 1).

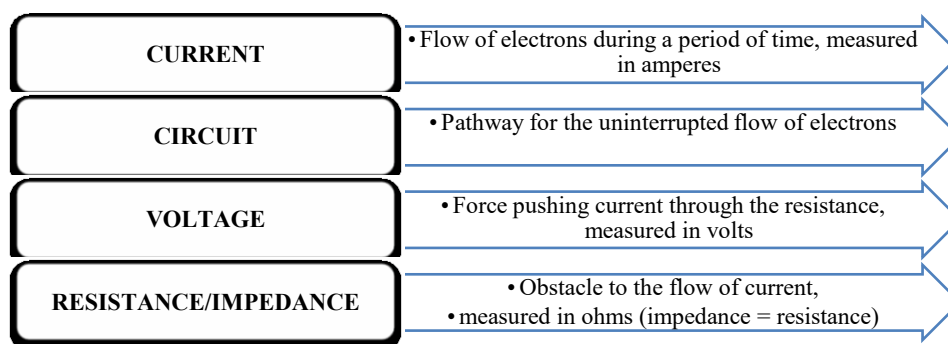


Figure 1: Basic terminology used in Electricity

Electrosurgical units (ESUs) used in operating rooms convert standard electrical frequencies from the wall outlet, which are 50 to 60 Hz, to much higher frequencies, 500,000 to 3,000,000 Hz [16]. This is important to minimize nerve and muscle stimulation, which occurs at

electrical currents below 10,000 Hz [17]. The possible effects of applying electrical current to tissue are fulguration, desiccation/coagulation, or vaporization/ablation. Figure 2 schematically demonstrated application of different current frequencies.

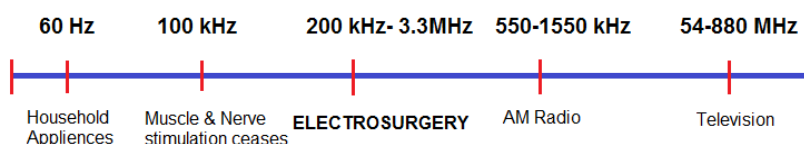


Figure 2: Schematic representation of application of different current frequencies

4. Electrosurgical Waveforms

The typical output settings labeled cut, blend, and coag on the face of conventional electrosurgical generators are simply variations of current and voltage in relation to time, called waveforms. Electrosurgical units produce 3 different waveforms: cut, blend, and coagulation [18].

A pure cut (vaporization) waveform is continuous, unmodulated and undamped. A coagulation waveform is interrupted, modulated, and damped current. [19,20] A blend waveform is a modification of the cutting waveform and is used when hemostasis is needed while cutting. [21,22] This waveform type consists of a combination of both cutting and coagulation waveforms. Higher blend settings translate into more time between bursts of current and greater coagulation, as seen in the following examples: Blend 1 (80% cut, 20% coagulation); Blend 2 (60% cut, 40% coagulation); and Blend 3 (50% cut, 50% coagulation). [18]

The surgeon can use the electrosurgery waveforms in combination with many other factors to achieve numerous tissue effects. The other factors such as power settings (W), the electrode dwell time (the length of exposure or velocity), the volume of tissue treated, the proximity of the tissue to the active electrode, and the current density. Tissue impedance (resistance), which primarily depends on water content, also affects the outcome. Impedance is high in calloused tissues, moderate in adipose tissues, and very low in vascular tissues. Moreover, impedance of tissues is dynamic during electrosurgery. For example, as tissue coagulates and water evaporates, impedance rises-at times to the point that the current is inhibited from flowing through the tissue. If the surgeon increases the power setting (W) and consequently the output voltage (V), the current (I) is more likely to seek an alternate pathway via the least resistance to the ground, which may lead to thermal injury. Therefore, it is advisable to use the lowest power setting to achieve the desired tissue effects. [23]

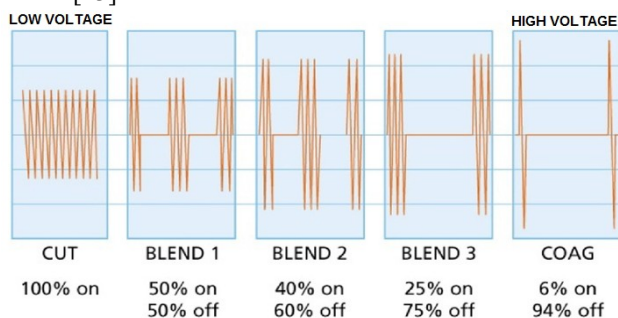


Figure 3: Electrosurgical waveforms with different tissue effects

Fulguration (Spray) is a noncontact coagulation that also utilizes spark gap to mediate tissue effects, which results in heating and necrosis as well as greater thermal

spread. Desiccation (Deep) is another form of coagulation in which direct contact is made with the tissue, resulting in electrical energy being converted into heat within the tissue. The end result is deeper necrosis and greater thermal spread [18].

5. Electrosurgical Procedure

Electrosurgical technology offers essentially two types of devices for energy delivery: monopolar and bipolar. The monopolar instrument, the Bovie being the most common example, delivers current through an active electrode, which then travels through the patient and back to the generator through a conductive adhesive grounding pad applied to the patient before beginning the procedure. Bipolar instruments resemble surgical forceps, with both the active electrode and the return electrode functions being performed at the surgical site. The electrosurgical energy does not travel through the patient but is confined to the tissue between the forceps. Because of this configuration, bipolar delivery of energy clearly offers very little chance for unintended dispersal of current [24].



Figure 4: Figure showing the difference between monopolar and bipolar electrosurgery

5.1 Monopolar Electrosurgery

Monopolar electrosurgery can be used for several modalities including cut, blend, desiccation, and fulguration. Using a pencil instrument, the active electrode is placed in the entry site and can be used to cut tissue and coagulate bleeding. The return electrode pad is attached to the patient, so the electrical current flows from the generator to the electrode through the target tissue, to the patient return pad and back to the generator. Monopolar electrosurgery is the most commonly used because of its versatility and effectiveness.

There is no such a thing as monopolar electrosurgery. However, all modern ESUs are designed to provide power in the so-called “monopolar” and bipolar configuration. The nomenclature regarding monopolar and bipolar configuration of the electrosurgical circuit, although misleading, stems from our forefathers’ logical notion that monopolar had “one” site where the therapeutic effect was desirable and bipolar had “two.” Monopolar implies that there is only a single pole or electrode in the ESU-electrode patient circuit when in fact there must always be 2: 1 high-

power density pole (i.e., the active electrode) and a second low-power density pole (i.e., the dispersive [“return”] electrode at a remote site). A more appropriate rationale to support the designation “monopolar” is that the active electrode in monopolar electrosurgery contains only 1 of the poles in the circuit. In this construct, the patient is the other electrode. An example of this is the hyfrecator described earlier.

In the bipolar configuration, both electrodes are high-density power and are situated across from each other. In the monopolar configuration, electrons travel from the generator through a wire to the tip of the active electrode where the current density is greatest and thus where maximal Joule heating can occur. From the point of contact between the active electrode and the patient’s tissue, electrons disperse throughout the patient’s body. The pattern of dispersion is not uniform and is a function of electrostatic repulsion between electrons and varying tissue resistivities [25]. Finally, the electrons must return to the ESU through the dispersive electrode to close the circuit for the desired clinical effect (Fig. 4). Because body compositions vary across individuals, a generalized model to predict the flow of current would be inaccurate. The displaced charge must travel to a location relatively depleted of electrons to achieve a net neutral charge and a state of lowest entropy. Electrons will always take the path of least resistance to achieve this goal. Because temperature change is a function of the square of current density and this is significantly reduced as electrons disperse, the change in tissue temperatures elsewhere are miniscule. Furthermore, because of the high-frequency nature of the AC used, there is no excitation of nervous or muscle tissues en route. Ideally, electrons will return to the ESU by means of the return/dispersive electrode pad. However, if there is a source of ground (a conductor with sufficient contact with the Earth) in contact with the patient, electrons may preferentially travel to this site, and if current density is sufficiently elevated at any point along this alternate path, a burn may occur. This issue has been addressed in modern ESUs through circuitry that does not reference ground and actively monitor the condition of the return electrode circuit as described earlier.

5.2 Bipolar electrosurgery

Bipolar electrosurgery uses lower voltages so less energy is required. But, because it has limited ability to cut and coagulate large bleeding areas, it is more ideally used for those procedures where tissues can be easily grabbed on both sides by the forceps electrode. Electrosurgical current in the patient is restricted to just the tissue between the arms of the forceps electrode. This gives better control over the area being targeted, and helps prevent damage to other sensitive tissues. With bipolar electrosurgery, the risk of

patient burns is reduced significantly. In the most common techniques, the surgeon uses forceps that are connected to the electrosurgical generator. The current moves through the tissue that is held between the forceps. Because the path of the electrical current is confined to the tissue between the two electrodes, it can be used in patients with implanted devices to prevent electrical current passing through the device causing a short-circuit or misfire. It is always recommended to review the implanted device user manual prior to performing any electrosurgical application, to avoid complications.

Bipolar electrosurgery was devised and applied in gynecologic surgery in 1973 by Canadian gynaecologist Dr. Jacques-Emile Rioux. In fact, he constructed the first laparoscopic bipolar forceps using a coat hanger and broom handle. A nylon version of the prototype was used to perform the first laparoscopic bipolar sterilization on March 12, 1973, and histologically showed significantly less collateral thermal damage when compared with the monopolar technique [26]. Many variations of Rioux’s design have been used for bipolar electrosurgery, of which the most popular was co-engineered by Dr. Richard Kleppinger [27]. Forceps and clamp configurations are the 2 principle bipolar devices. In both cases, the circuit is as such that electrons travel from the ESU to the distal aspect of 1 tine (or active electrode), through grasped tissues, to the sister tine (or return electrode), and back to the generator. In bipolar electrosurgery, electrons do not dissipate throughout the patient’s body because the active and return electrode are in close proximity to each other and only those tissues that are interposed are included in the circuit. Thus, only said tissues and those immediately surrounding are affected by the heat generated. In the bipolar configuration, current is delivered 100% of the time just as in the continuous mode of the monopolar configuration.

Therefore, the bipolar setting is also a high-current/low voltage waveform. The principle of Joule heating applies equally to this modality; the simple difference is the location of the return electrode. Because these devices have similarly sized electrodes, the current density is approximately equivalent at both the active and return electrodes. This produces similar Joule heating and temperature changes at each tine of the instrument and, thus, desiccates target tissues from both sides, simultaneously allowing for lower power settings on the generator. Desiccation is superior to their monopolar counterparts and yields less collateral thermal damage [28].

5.3 Electrosurgery in Laparoscopic Procedures in Endometrial and Cervical Cancer

Conventional and robot-assisted laparoscopic procedures have been used as acceptable alternatives to laparotomy as the traditional surgical approach to

endometrial cancer treatment and staging [29]. These approaches have proved particularly promising in early stages of endometrial cancer; and review of the literature highlights fewer complications, less blood loss, and shorter stay in hospital in those patients undergoing laparoscopic procedures. There is a lack of conclusive evidence on the survival rates, particularly in more advanced stages; however, no significant difference has been reported by the few available studies [30,31]. Moreover, the optimal surgical approach regarding the removal of lymph nodes for staging of endometrial cancer is a matter of ongoing debate in gynecologic literature [32]. Laparoscopic approach and sentinel lymph node mapping has been suggested as an accurate method in early stages of cervical and endometrial cancers [33,34].

The field of minimally invasive surgery and devices used keep on improving and evolving. There have been several advancements in electrosurgical devices used in laparoscopic procedures to manage endometrial cancer. The conventional monopolar and bipolar devices could cause thermal damage, so innovations have been made to address this issue. One of the most active surgical teams in performing laparoscopic radical hysterectomy has developed a pulsed bipolar system. They have reported better surgical outcomes including less complications, operation time, and blood loss. In line with these findings, Lee *et al.* indicated that pulsed bipolar systems could offer advantages in the management of early cervical carcinoma in patients undergoing laparoscopic radical hysterectomy and pelvic lymphadenectomy [35]. Laparoscopic devices including harmonic scalpel and coagulating shears have also been compared to electrosurgical devices in lymph node dissection and laparoscopic hysterectomy. Holub *et al.* reported these devices as more cost-effective alternatives with less thermal injury in lymph node dissection procedures [36]. A randomized trial reported the superiority of a multifunctional instrument that integrates ultrasonic waves and advanced bipolar energy with simultaneous sealing and dissection capabilities. They found that these modified electrosurgical devices could save time and result in less postoperative pain to treat early stages of cervical cancer in patients undergoes laparoscopic radical hysterectomy and lymphadenectomy [37].

6. Newer Vessel Sealing Devices

The latest advance in bipolar electrosurgery is the introduction of three novel ligating cutting devices that minimize thermal damage by delivering electrical energy as high current and low voltage output. These electrosurgical instruments deliver radiofrequency energy to cut, vaporize, coagulate and seal over a wide range of tissue conditions, providing surgeon controlled tissue effects.

The development of laparoscopic vessel sealing devices has revolutionized modern laparoscopy. These devices fall into 2 major categories: advanced bipolar and ultrasonic instruments. These electrosurgical instruments deliver radiofrequency energy to cut, vaporize, coagulate and seal over a wide range of tissue conditions, providing surgeon controlled tissue effects. More recently, ultrasonic energy sources were developed to limit the risks associated with electrosurgery, at the same time providing more efficient vessel sealing and tissue transection. Advanced bipolar technologies were subsequently introduced with optimized vessel compression and the delivery of electrical energy to provide even better vessel sealing capabilities. These new vessel sealing technologies are so successful that they have largely made the need for laparoscopic suturing of vascular pedicles redundant [38].

Both bipolar and ultrasonic devices are effective at sealing vessels up to 5 mm in diameter, but only bipolar devices are approved to seal vessels 6–7 mm in diameter [39-43]. For all laparoscopic energy sources (monopolar [contact mode], bipolar [conventional and advanced], and ultrasonic [vessel sealing mode]), the amount of lateral thermal spread and the risk of collateral tissue damage are proportional to the length of time of activation of the instrument. In summary, there is insufficient evidence for one vessel sealing technology to be considered superior to the other. A detailed critical evaluation of comparative clinical, laboratory and animal studies of all classes of laparoscopic energy sources is available elsewhere [44].

LigaSure™

LigaSure is a bipolar electrosurgical device designed to deliver high current and very low voltage to tissue. It monitors tissue impedance between the jaws of the instrument and continuously adjusts the delivery of energy. The LigaSure Vessel Sealing System allows hemostasis by vessel compression and obliteration through the emission of bipolar energy [38]. LigaSure™ technology delivers a unique combination of pressure and energy to create a consistent seal with each application.

- Provides a combination of pressure and energy to create vessel fusion
- Permanently fuses vessels up to and including 7 mm in diameter and tissue bundles without dissection or isolation
- Average seal cycle is 2 to 4 seconds, when used with the Force Triad™ energy platform
- Seals withstand three times normal systolic blood pressure
- Feedback-controlled response system automatically discontinues energy delivery when the seal cycle is complete, eliminating the guesswork.

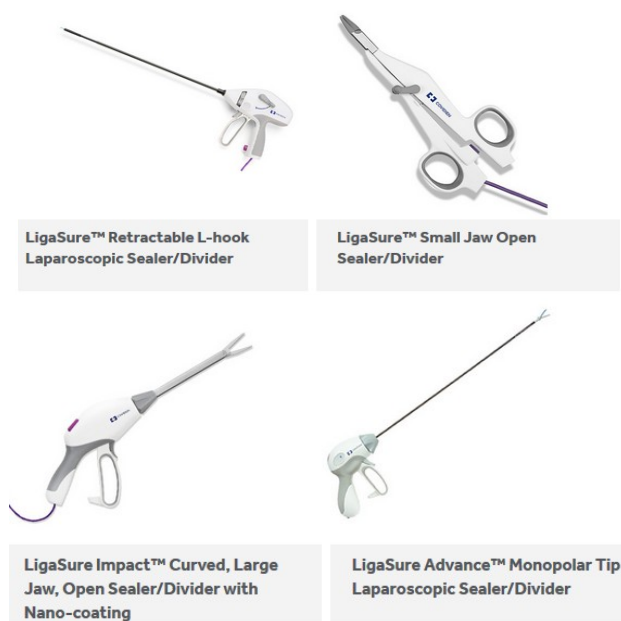


Figure 5: LigaSure™ electrosurgical devices

7. Complications of electrosurgery during laparoscopy

The rate of electrosurgical complications during delivery of energy to the surgical site is estimated to be 25.6% (70/273) and is the second most common laparoscopic complication after a misplacement of trocar or Veress needle, which is 41.8% (114/273). [45]. Although basic and advanced energy-based devices are commonly used, there is no well-defined requirement to demonstrate competency in the skills and knowledge required to use them [46,47]. Electrosurgical injuries may result from the situations such as direct coupling and/or insulation failure, capacitive coupling, return electrode and alternate site burns.

The direct application of the electrosurgical probe can arise either from mistaken targeting or unintended activation can result in injury. The speed of the procedure will result in both less or more coagulation and thermal spread [48]. Direct coupling results from inadvertent contact activation of the generator while the active electrode is in close proximity to another metallic instrument. The former can injure adjacent structures or organs in contact with this secondary instrument out of surgeon's visual field. Proximity between the electrode and the tissue can determine contact (desiccation) or noncontact tissue effect (fulguration) [49]. Insulation defects are not uncommon in laparoscopic instruments, particularly in reusable ones more exposed to damage of the material covering the active electrode. Longer length of instruments, thinner insulation, higher voltages, and narrow trocars increase the risk of this type of injury. Capacitor coupling can be minimized by activating the active electrode only when it is in contact

with target tissues and limiting the time length of high-voltage peaks [48,49].

The most common site of injury is at the patient return electrode in monopolar electrosurgery. The dispersive pad offers the path of low resistance from the patient back to the generator and provides large enough surface area to decrease current density [50]. If the return electrode is not wet or is not completely in contact with the patient's skin, or is not able to disperse the current safely, then the exiting current can have a high enough density to produce an unintended burn [51]. It is important to have good contact between the patient and a dispersive pad [52]. A burn at an alternative site can occur if the dispersive (ground) pad is not well attached to the patient's skin [52]. The quality of contact between the return electrode and the patient's skin can be compromised by excessive hair, adipose tissue, bony prominences, fluid invasion, adhesive failure, scar tissue and many other variables [53]. The best pad site location is on well vascularized muscle tissue.

8. Recent advancement in electrosurgical unit

In an effort to minimize the risks of insulation failure and capacitive coupling, active electrode monitoring systems now exist. When interfaced with electrosurgical units, these systems continuously monitor and shield against the occurrence of stray electrosurgical currents. Tissue response generators are the next step in the evolution of electrosurgical generators. These generators adjust automatically responding to tissue changes maintaining power delivery and minimizing drag. The most recent advancement in electrosurgery has been the introduction of vessel sealing technology. Core to this technology is the use of bipolar electrosurgery that relies on tissue response generators. This advanced electrical current is combined with optimal mechanical pressure delivery by the instruments to fuse vessel walls and create a seal [54,55].

Electrosurgery is being enhanced by the addition of a controlled column of argon gas in the path between the active electrode and the tissue. The flow of argon gas assists in clearing the surgical site of fluid and improves visibility. Many manufacturers have begun to include sophisticated computer-based systems in their ESUs that not only simplify the use of the device but also increase the safety of patient and operator. For instance, in a so-called soft coagulation mode, a special circuit continuously monitors the current between the active electrode and the tissue and turns the ESU output on only after the active electrode has contacted the tissue. Furthermore, the ESU output is turned off automatically, once the current has reached a certain threshold level that is typical for coagulated and desiccated tissue. This feature is also used in a bipolar mode termed autobipolar [55,56].

9. Safety Recommendation during Electrosurgical laparoscopic surgery

Although electrosurgical instruments are commonly used, they are powerful and potentially dangerous, and most surgeons and residents do not receive any formal training in their proper use. The following are some recommended suggestions to avoid injury.

- All connections are carefully checked before the ES unit is put on
- The patient plate used is always one recommended by the manufacturer.
- The patient plate must always be applied by covering the patient with its entire area as best as possible.
- The conductive surface of the patient plate must always be clean and free from corrosion.
- If gelled patient plate are used, it is most important that the gel is evenly applied over the entire conductive area of patient plate
- Prior to use, the patient plate must be checked for damage, especially patient plates made of aluminium foil.
- It is important that the patient plate is applied with the electrically conductive surface to the patient's skin and not with its wrong side.
- The patient plate is applied as close to the operative site as possible.
- Care must be taken that no electrical conductive fluids come between the patient's skin and the patients' plate.
- The patient is insulated against all electrically conductive objects by a thick, dry, electrically insulating sheet, placed between the patient, the operating table and supports. The sheets must not become damp. Areas subject to considerable secretion of sweat, body extremities lying against the trunk or skin-to-skin contacts should be separated by the application of a dry cloth. Drain off urine with catheter.
- The simplest means of avoiding injury is to always use the lowest possible generator setting that will achieve the desired surgical effect and to never exceed the power settings recommended by the manufacturer.
- Frequent cleaning of the electrode tip is recommended. The eschar should be wiped away using a sponge rather than the common scratch pad, because these pads will scratch grooves into the electrode tip, increasing eschar build-up.
- In monopolar electrosurgery, Use the lowest possible power setting, low voltage waveform (cut), brief or intermittent activation, do not activate the electrode in the air when not in use (risk of capacitive current effect) and do not activate the electrode in close proximity or direct contact with another instrument is recommended.

- When using hemostats or a forceps to deliver current to a bleeding vessel from a monopolar electrode ("buzzing the hemostat"), the surgeon should not touch the patient with his free hand.
- During electrosurgery always sparks exist between the active electrode and the patients's tissue. Therefore do not use flammable or explosive substances or gases during electrosurgery. If flammable or explosive substances have been used, these must be completely removed before activating the electrosurgical unit.
- In bipolar electrosurgery, terminate current at the end of vapor phase, apply current in pulsatile fashion, and pay attention to the tip's metallic part is recommended.
- Smoke evacuation can significantly improve visualization in the operation field
- Organize a laparoscopic team (biomedical engineer, perioperative nurses)
- Promote extended education activities and participation in medical conferences

A special precaution to be taken during laparoscopic surgery is that electrosurgery should not be used whenever there is bowel perforation. Bowel contains methane gas, which is released into the peritoneal cavity whenever there is a bowel perforation and if electrosurgery is used at such a circumstance, it may lead to an explosion.

Assuming good surgical technique and good endoscopic instrumentation with intact insulation, correct connection of cables and proper placement of neutral electrode would go a long way in making this efficient tool safe and a boon to the surgeon especially in this era of laparoscopic surgery.

10. Conclusion

Electrosurgery is a continuously evolving field, with active research into new applications. Because the ability to incorporate more sophisticated computer chip technology into electrosurgical generators has grown, the potential for increasing clinical applications has evolved at a dramatic rate. Continued research into the area of tissue interaction shows promise in the potential development of novel applications of electrosurgery. In addition to improved electrosurgical cutting and hemostasis, tissue fusion and ablation have seen increasing application in the surgical setting. A more thorough understanding of the technology is essential to the safe and effective application for improved patient outcomes.

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