

Perspective of Electrosurgical Sources in Minimal Access Surgery

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ABSTRACT

Introduction: There are devices that apply energy to cut, coagulate, and desiccate the tissue with minimal bleeding and by overcoming the hindrance of laparoscopy facilitate minimal access surgery. The inappropriate utilization of electrosurgical devices may expand horrible morbidity and mortality. The present article surveys different electrosurgical sources as far as their basic uses and safe practices.

Objectives: The aim of this review is to discuss about various types of available energy sources, their biophysics, their tissue effects, and complications. It also emphasizes the advantages and disadvantages of these electrosurgical devices and the need for learning required with them.

Materials and methods: With the end goal of this review, a general pursuit was led through NCBI, SpringerLink, and Google. Articles depicting laparoscopic or minimally access surgeries utilizing single or different energy sources were considered, in addition to articles contrasting different marketed energy devices in lab settings. Keywords, such as laparoscopy, vitality, laser, electrosurgery, monopolar, bipolar, harmonic, ultrasonic, and difficulties were utilized as a part of the search.

Results: The authors in this review of the literature likewise accentuate on the unprejudiced learning of all the energy devices before using them. It also shows that the performance of the energy devices depends upon the type of effect needed. There is no accord as to which device is ideal for a given purpose. The specialized expertise level of the specialist and the learning about the device are both critical variables in choosing safe results.

Conclusion: To defeat the deceptions of laparoscopic hemostasis and cutting, electrosurgery has turned out as an imaginative innovation. It has made the life of an expert simple. Be that as it may, everything accompanies its own burdens. Electrosurgery also has its own disadvantages and complexities. The utilization of electrosurgery ought to be constrained just for spots where essential. An expert ought to try to know totally about the device he/she is utilizing and ought not to be driven by marketing companies.

Keywords: Electrosurgery, Energy sources in surgery, Minimally access surgery.

How to cite this article: Lekhi A, Chowhan JS, Mishra RK. Perspective of Electrosurgical Sources in Minimal Access Surgery. World J Lap Surg 2016;9(3):130-137.

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Source of support: Nil

Conflict of interest: None

INTRODUCTION

Minimal access surgery has posed unique challenges with regard to cutting and hemostasis due to visual, tactile, and mechanical limitations. But this has resulted in a variety of creative solutions with their own advantages and disadvantages, electrosurgery being one of them.

The terms “electrocautery” and “electrosurgery” are frequently used interchangeably; however, these terms define two distinctly different modalities. Electrocautery is the use of electricity to heat an object that is then used to burn a specific site – for example, a hot wire – whereas in electrosurgery, the electrical current heats the tissue. The current must pass through the tissue to produce the desired effect.

Today’s specialists are spoilt for decision when it comes to minimal access electrosurgery sources, due to a business sector where there has been noteworthy change in the course of the most recent decade. Moreover, new instruments frequently arrive joined by much ballyhoo and buildup. Shockingly, many of the research facilities and clinical information on new electrosurgery sources are from studies attempted, and also supported, by the producer, and information from randomized trials is unavailable. Regardless, it remains the obligation of the specialist to procure information on the scope of tissue impacts accessible with different laparoscopic electrosurgery sources, how these gadgets give their tissue impacts, and the related advantages and dangers for every gadget. Thus, it is not a simple assignment for specialists to settle on choices about the sources they use for operative laparoscopy.

PRINCIPLES OF ELECTRICITY

Electricity always follows some universal rules. These are that electricity always seeks the ground and invariably seeks the path of least resistance.

There are three variables involved in any electrical circuit. These are voltage (v), impedance or resistance (R), and current (I). The relationship between them is established by the Ohm’s law.

$$I = \frac{V}{R}$$

But the electrosurgical device does not give us the privilege to set the current on our own. They allow us to set the power (W) for application. The relationship of power to above variables is product of voltage and current.

$$W = V \times I$$

For example, as the current flows through the target tissue and coagulates it, the tissue becomes nonconductive and current takes the path of least resistance. Hence, the path of current in living tissue is erratic.

Broadly, there are two types of electrosurgery resources available: Monopolar and bipolar energy sources.

MONOPOLAR ENERGY

All electrosurgery is "bipolar" in light of the fact that the electrical current streams from one electrode on to the other. In monopolar electrosurgery, the active terminal is one electrode in surgeon's hand and the patient return cathode is the other. The primary contrast between monopolar electrosurgery and the other electrosurgery modalities is that electrical current courses through the patient. This distinction benefits the best scope of tissue impacts to monopolar electrosurgery.^{1,2}

The tissue impacts produced with monopolar electrosurgery incorporate vaporization (tissue destruction and cutting), fulguration (tissue destruction and little vessel hemostasis), desiccation (cell wall break and cytoplasm boiling), and coaptation (vessel sealing inferable from denaturation and renaturation of proteins) (Table 1).² These tissue impacts are fundamentally accomplished by using the "cut" or "coag" mode of electrosurgical unit (ESU) while contacting or non contacting the objective tissue (Table 2).³ Varying other parameters are under the specialist's control, such as power setting, length of enactment, and terminal arrangement, can facilitate adjusting the wanted tissue effect.¹⁻³

All energy sources generate tissue temperatures above 45°C, the temperature at which irreversible cell damage

occurs. Monopolar electrosurgery generates tissue temperatures of ~100°C, 100–200°C, and >200°C for desiccation, vaporization, and fulguration respectively. Other laparoscopic energy sources have limited tissue effects of desiccation and coaptation, and they also generate tissue temperatures of ~100°C.^{1,4}

The major disadvantage of monopolar electrosurgery is the unavoidable risk of stray current injury (SCI). These injuries are regularly not seen amid of surgery as they ordinarily happen outside of the specialist's field of vision. They are not attributable to specialist mistake or absence of ability. Rather, it is the physics at fault. When used in contact mode, there is the risk of lateral thermal spread injury to adjacent structures with monopolar electrosurgery, just as for all energy sources that yield tissue effects of desiccation and coaptation. Smoke production during monopolar electrosurgery may be problematic, especially during fulguration.³

There is a risk of capacitative coupling if by mistake the wire gets wrapped around other instrument. So, monopolar electrosurgery is a relatively inexpensive, readily available, and versatile energy source that yields the best range of tissue effects, but despite all this it has a large risk of complications leading to smaller safety margin.

PRINCIPLES OF MONOPOLAR ELECTROSURGERY

Current Pathway

In monopolar electrosurgery, electrical current goes from the ESU to the active electrode, then via the patient to exit by means of a dispersive electrode, at last coming to "electrical ground" (Fig. 1). The potential for SCI emerges in light of the fact that power inside the patient will take whatever pathway it can to come back to ground, including by means of unintended tissue targets.¹⁻⁷

Current Density

The tissue impacts of monopolar current are identified with the current density in the tissue. Consequently, engaged current from the active electrode enters the patient at the site of surgery to yield a tissue impact though current, leaving the patient by means of a dispersive return electrode just results in a clinically inconsequential ascent in tissue temperature due to low current density. Any damage can happen at any part of the circuit in the event where the current density is sufficiently high. For case, blazes have beforehand happened at the patient return electrode inferable from poor contact with the patient's skin, leading to high current density at the current way out point.

Table 1: The main classes of laparoscopic energy sources and their tissue effects²

Energy source	Tissue effects
Monopolar electrosurgery	Vaporization, fulguration, desiccation, coaptation*
Conventional bipolar electrosurgery	Desiccation, coaptation
Advanced bipolar electrosurgery**	Desiccation, coaptation, blade tissue transection
Ultrasonic technology	Desiccation, coaptation, mechanical tissue transection

*Vessel sealing achieved with coagulation and compression.

**Tissue impedance monitoring optimizes activation time.

Table 2: Monopolar electrosurgery tissue effects³

Tissue effect	Surgical effect	Current waveform	Contact with tissue	Characteristics
Vaporization	Cutting	Continuous (cut)	No contact	Low-voltage sparks, moderate smoke
Fulguration	Hemostasis of small vessels (<1 mm)	Interrupted (coag)	No contact	High-voltage sparks, significant smoke and charring
Desiccation	Hemostasis of small vessels (<1 mm)	Continuous (cut) or interrupted (coag)	Contact	Similar action to bipolar electrosurgery, pronounced lateral thermal spread
Coaptation	Sealing of small-to-medium vessels (<2 mm)	Continuous (cut) or interrupted (coag)	Contact and compression of vessel wall	Similar action to bipolar electrosurgery, pronounced lateral thermal spread

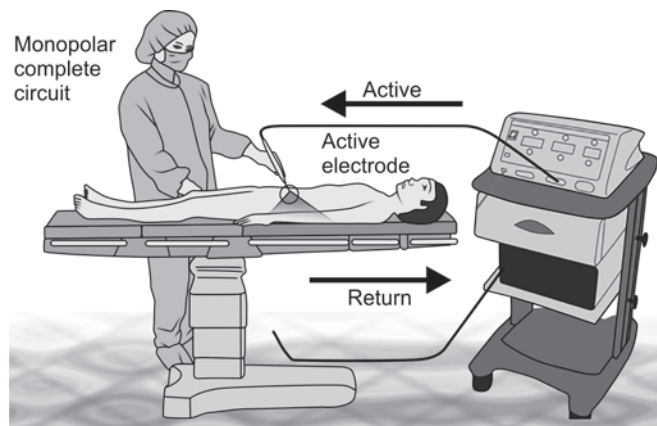


Fig. 1: Pathway of monopolar current

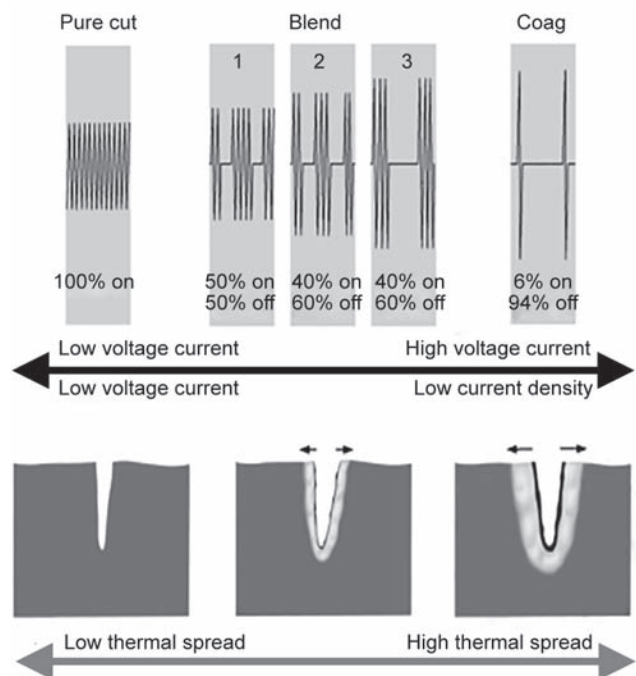


Fig. 2: Waveforms of different monopolar settings

Waveforms

The waveforms in monopolar electrosurgery are “cut,” “coagulation,” and “blend” (Fig. 2). It is important to realize that these waveforms do not imply a particular tissue effect – e.g., the tissue effect is different when cut

waveform is used in either contact or noncontact mode, yielding desiccation or vaporization respectively. Cut waveform is a continuous sinusoidal waveform with current flowing 100% of the time (duty cycle), coagulation waveform is an intermittent or “damped” waveform where the duty cycle is reduced, and blend waveforms are also intermittent waveforms, but with interrupted duty cycle.

Conventional Bipolar Electrosurgery

In bipolar electrosurgery (including advanced bipolar modalities), the active and return electrodes are the two jaws of the energy source placed at the target tissue. In 1974, scientist introduced bipolar electrosurgery as a means of eliminating the risk of complications that had been observed with monopolar electrosurgery, while at the same time a means of sealing larger vessels.⁵

In bipolar electrosurgery, electrical current passes through the tissue held between the jaws of the instrument, not through the patient, and results in tissue desiccation and vessel coaptation. Alternating current is standard output for ESUs, and it is this physical property that results in efficient sealing of vessels with bipolar electrosurgery, via change of direction of current flow through the tissue compressed between the instrument jaws, as orientation of the active and return electrodes rapidly alternates.⁶ A major advantage of conventional bipolar over monopolar electrosurgery is the ability to seal vessels up to ~5 mm in diameter. The dissection capability of the bipolar forceps is good, especially in the grasping configuration. Bipolar electrosurgery is generally available and relatively inexpensive. Disadvantages of bipolar electrosurgery include lateral thermal spread that will continue until device activation is ceased; no audio signal from the ESU to inform the surgeon when desiccation or coaptation is complete, which increases the risk of injury from lateral thermal spread as well as tissue charring and tissue adherence to the instrument jaws; and the need for another instrument, such as a laparoscopic scissor, for tissue cutting.⁶

PRINCIPLES OF BIPOLAR ENERGY

Current Pathway

A high frequency electrical current flows from one tong to the other tong of the surgical pencil, through the intervening tissue (Fig. 3). The tissue within the forceps completes the circuit. An indifferent electrode is not required as the patient is not part of the circuit. So, no risk of SCI is seen.

Current Density

The tissue effects of bipolar energy are identified as desiccation and coaptation depending upon the current

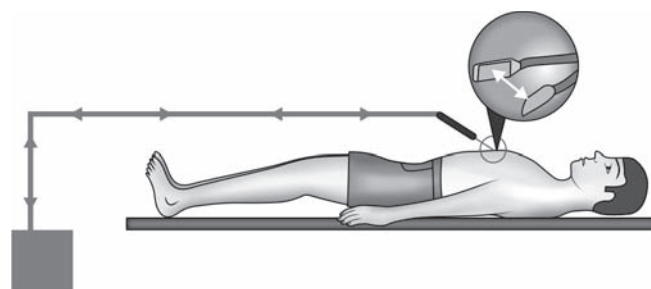


Fig. 3: Pathway of current in bipolar energy

density and pressure applied. As the current density cannot be concentrated at a single focal point in bipolar electrode, it is unable to produce cutting effect. To battle this hindrance, the progressive bipolar devices have a mechanical cut mechanism along in form of blade.

Waveform

The waveform applied is similar to that applied during monopolar “coag” mode. It is a high-voltage interrupted duty cycle current. Best permutation and combinations are incorporated in the device to achieve a high vessel-sealing capacity.

Advanced Bipolar Electrosurgery

In addition to the features of conventional bipolar electrosurgery, advanced bipolar energy sources are progressive in many ways. Main advance is computer-controlled tissue feedback system. Newer products floating in the market are LigaSure (Fig. 4; Covidien), EnSeal (Fig. 5; Ethicon), and Lyons Dissecting Forceps (Fig. 6; Gyrus ACMI). The tissue impedance is monitored with continuous adjustment of the generated voltage and current to maintain the lowest possible power setting to achieve the desired tissue effect, at which time an audio signal alerts the specialist that the terminal point has been achieved. In this way, the risk of lateral thermal spread as well



Fig. 4: LigaSure



Fig. 5: Enseal articulating forceps

as charring of the tissue and adherence of tissue to the device jaws is reduced.³

These energy sources were the first to be endorsed by the US Food and Drug Administration (FDA) to seal vessels up to 7 mm in width inferable from innovative advances, e.g., tissue impedance observing up to 4000 times each second (LigaSure); temperature-delicate material in the gadget jaws that optimizes tissue temperatures at ~100°C (EnSeal); delivery of pulsed energy with nonstop input control to counteract tissue overheating (PK Framework); and jaw outline that advances mechanical pressure to the vascular pedicle (LigaSure, EnSeal).^{2,6} Although the capacity of these more up-to-date devices to seal vessels up to 7 mm in width is unchallenged, the normal minimization of thermal spread attributable to these advancements has yet to be demonstrated in clinical trials. Some devices incorporate a cutting blade into the device jaws (LigaSure, EnSeal) that decreases the need for a laparoscopic scissor.

Hence, the decision to use a particular bipolar device will depend on the specialist need and choice. Albeit progressive bipolar energy sources are costly, they are by far available in all the hospitals.³

Ultrasonic Devices

Previously called the “laparoscopic scalpel”; it has the double usefulness of tissue cutting and vessel sealing.⁶ Ultrasonic energy sources convert electrical energy into ultrasonic energy (vibrations) in the handpiece of the device which then gets converted to the thermal energy at frequencies more than 10000 cycles per second. These vibrations are produced by piezoelectric crystals present in the handpiece that oscillate the nonarticulating jaw of the instrument. Tissue is compressed between the two jaws to achieve the desired tissue effects from combination of thermal and mechanical energy. Desiccation and vessel sealing (coagulation) is achieved at lower setting, and tissue cutting occurs at higher setting. The tissue



Fig. 6: Gyrus plasmakinetic probe

effects are accomplished at temperature of 50 to 60°C due to mechanical effect of vibrations. These are FDA affirmed to seal vessels 5 mm in diameter. The device available is the Harmonic ACE+ (Fig. 7, ethicon), and it has “Adaptive Tissue Technology” that gives a sound sign to the specialist when changes in the objective tissue are sensed – this is an aberrant evaluation and less dependable than the tissue capacitance monitoring utilized by cutting-edge bipolar devices to demonstrate endpoint. More as of late the new up-to-date model have been specifically produced for larger vessel fixing and cutting, this gadget has been evaluated by the FDA to seal vessels up to 7 mm in diameter.³

These tissue impacts are accomplished without the passage of electric current through the patient or the tissue held by the device. Points of interest of ultrasonic devices incorporate less instrument movement, inferable from the blend of vessel-fixing and tissue cutting, and less smoke. The dissection capacity is great, yet not as much as that of monopolar scissors or Maryland bipolar forceps. The detriment is that the obscure harmful tissue gets vaporized in the smoke and can get scattered.



Fig. 7: Harmonic scalpel



Fig. 8: Thunderbeat tip

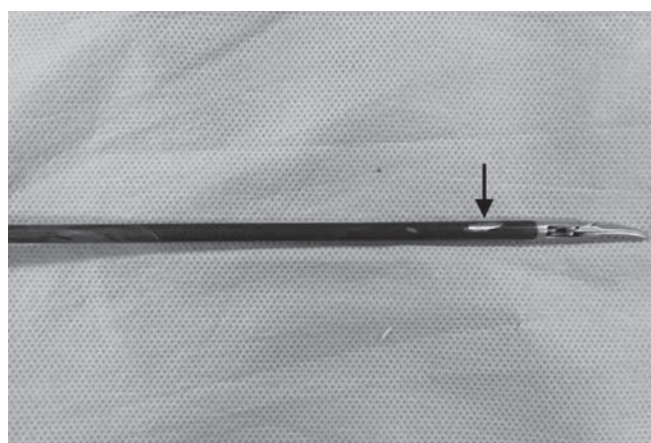


Fig. 9: Break in the insulation of monopolar scissor

Hybrid Devices

Laparoscopic gadgets have as of late been built up that join a few energy source advancements together. These are LigaSure Advance (monopolar and bipolar electro-surgery; Covidien) and Thunderbeat (Fig. 8; ultrasonic and bipolar advancements; Olympus). Joining of different advancements into a solitary device may lessen instrument movement and, furthermore, reduce the general expense, albeit such advantages should be an auxiliary thought if the singular functionalities are bargained in the cross breed setup. Great-quality trials on the adequacy and well-being of the cross-breed devices are lacking.⁶

Complications of Electrosurgery

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).⁸

According to a review by Van der Voort et al,⁸ 61.6% (154/250) of bowel injuries were recognized intraoperatively, and 5.2% (13/250) and 10.4% (26/250) were recognized during early (within the next 48 hours) and late (at least on the 3rd postoperative day or later) postoperative phases respectively. Laparotomy was the most frequently performed procedure to manage laparoscopy induced bowel injury (78.6%). Conservative and laparoscopic treatment were used considerably less often (7.0 and 7.5% respectively).^{8,9}

In a review, conducted by Huang et al¹⁰ they concluded that alertness to postoperative warning signs, patient education prior to discharge, and the detection of delayed manifestations with salvage maneuvers may minimize catastrophic complications.

Vancaillie et al¹¹, in her review of monopolar energy, has stressed upon the use active electrode monitoring system for detecting insulation failures.

Direct Application

Damage by direct utilization of the electrosurgical probe can emerge either from mixed up focusing on or unintended initiation. The pace of the system will bring about either less or more coagulation and thermal spread. The stay time decides the measure of tissue impact. Drawn out enactment will deliver more extensive and more profound tissue harm more than the expected sought tissue effect.¹²

Stray Current

A stray current emerging from blemished insulation can harm the neighboring structure (Figs 9 and 10). A cautious preoperative and after use assessment of gear is the best method for distinguishing imperfect insulation.¹³ The two noteworthy reasons for insulation failure incorporate the utilization of high voltage streams and the regular reesterilization of instruments, which can debilitate and break the insulation.¹⁴

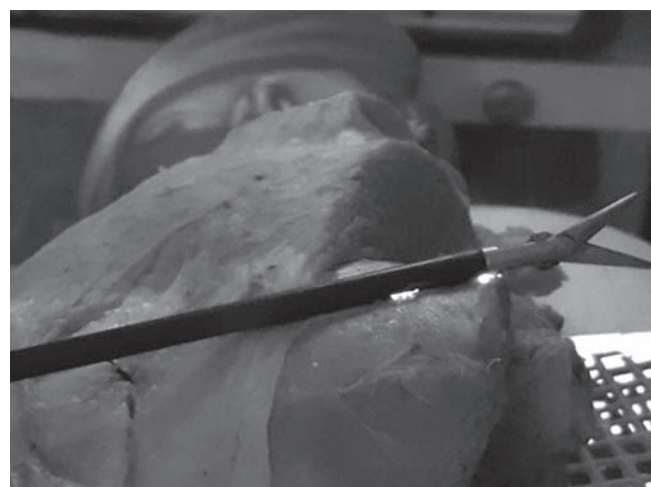


Fig. 10: Current getting dispersed from the insulation failure site and causing burning of tissue

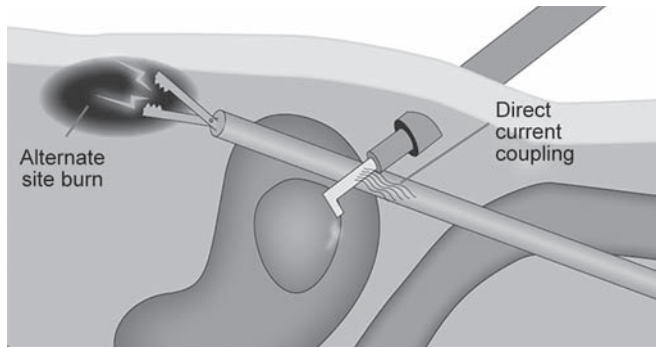


Fig. 11: Direct coupling

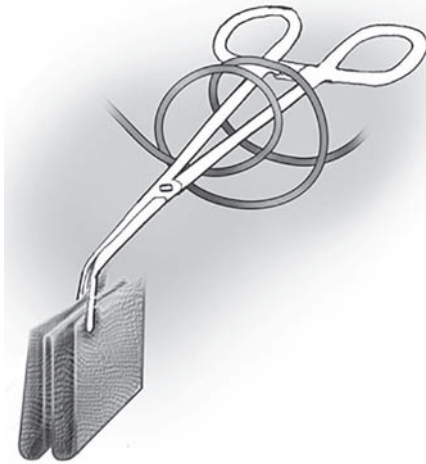


Fig. 13: Capacitance due to wrapping of monopolar code around artery forceps

Direct Coupling

Direct coupling happens when the active terminal is unintentionally enacted or is in close nearness to another metal instrument inside the pelvis, e.g., laparoscope or metal grasper forceps¹⁴ (Fig. 11). Direct coupling can be prevented by keeping the electrode in vision and keeping away from whatever other conductive instruments before enacting the electrode.^{13,15}

Capacitive Coupling

Capacitive coupling happens when the electric current is exchanged from one conductor (the dynamic terminal), through in-place insulation, into nearby conductive materials (e.g., bowel) without direct contact (Fig. 12). Longer length of instruments, thinner protection, higher voltages, and different conductivity instruments, such as unknown wrapping of electro-surgical codes (Fig. 13) and thin trocars build the danger of this kind of injury.¹⁶ Capacitor coupling can be minimized by enacting the active electrode just when it is in contact with target tissues and restricting the time length of high-voltage peaks.^{12,17}

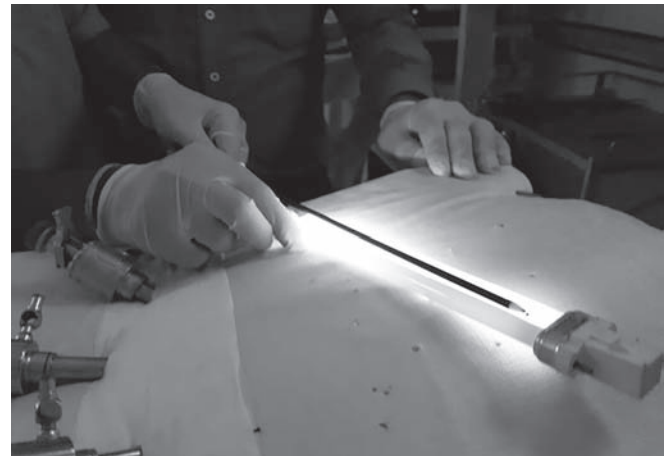


Fig. 12: Glowing of bulb due to capacitance coupling from monopolar hook

Return Electrode or Alternative Site Burns

If the return electrode 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.¹⁴ It is important to have good contact between the patient and a dispersive pad.¹³ The minimum size of return electrode should be 100 cm².

RESULTS

The author in this review of the literature likewise accentuates on the unprejudiced learning of all the energy devices before using them. It also shows that the performance of the energy devices depends upon the type of effect needed. There is no accord as to which device is ideal for a given purpose (Table 3). Wang and Advincula¹⁴ have stressed on a careful comprehension of the upsides and downsides of the innovative technical advances can enhance the operative experience for both specialist and patient. The specialized expertise level of the specialist and the learning about the device are both critical variables in choosing safe results.

Holloran-Schwartz et al,¹⁸ in a randomized control trial of 46 laparoscopic hysterectomy patients, compared

Table 3: Comparison of various energy sources

Device	Skill	Risk of			Reusable
		stray current	Cutting	Coagulation	
Monopolar hook	✓	✓	✓	✓	✓
Bipolar dissector	✓	✗	✗	✓	✓
Ligasure	✓	✗	✓	✓	✗
Enseal	✓	✗	✓	✓	✗
Gyrus	✓	✗	✓	✓	✗
Harmonic	✓	✗	✓	✓	✗
Thunderbeat	✓	✗	✓	✓	✗

the efficacy of single use energy devices with standard methods and found them to be significantly beneficial.

Aytan et al,¹⁹ in their randomized trial of 45 laparoscopic hysterectomy patients, compared the adequacy of advanced bipolar devices. But none of the three devices was found to be superior to other.

CONCLUSION

To defeat the deceptions of laparoscopic hemostasis and cutting, electrosurgery has turned out as an imaginative innovation. It has made the life of an expert simple. Be that as it may, everything accompanies its own burdens. Electrosurgery also has its own danger and complexities. The utilization of electrosurgery ought to be constrained just for spots where essential. The expert ought to try to know totally about the device he is utilizing and ought not to be driven by marketing companies.

ACKNOWLEDGMENT

Author would acknowledge the efforts of my husband Dr Navin Bhatia in my work, my inspiration, and my support. I would like to thank my parents, Dr Ajay and Dr Neelam Lekhi, and also my critics, friends, and my teachers Dr JS Chowhan, Dr RK Mishra, and Dr Rahul Manchanda.

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