



# Bipolar Electrosurgery: Convention and Innovation

ANDREW I. BRILL, MD

*Department of Obstetrics and Gynecology, California Pacific Medical Center, San Francisco, California*

**Abstract:** Bipolar electrosurgery is part of the customary gynecologic surgical armamentarium providing isolated thermal effects and blood vessel occlusion. However, end points are not always predictable as hemostasis may require contiguous applications and thermal damage can significantly expand beyond the target zone. Unintentional transection of a patent vessel cannot be entirely reduced. Recent advances in bipolar technology provide more predictable vessel occlusion with less thermal damage. To date, there are 3 novel bipolar platforms, using either impedance feedback from the operative site to moderate output as pulsed current with lower voltage or by local regulation using nanotechnology within the jaws.

**Key words:** bipolar, electrosurgery, hemostasis, En-Seal, LigaSure, PK technology

## Introduction

Bipolar electrosurgery has been part of the customary gynecologic surgical arma-

mentarium for decades. Principally borne by unfounded concerns that monopolar electrosurgery for laparoscopic tubal sterilization posed certain risks for thermal injury to the viscera, the development of an ergonomic and presumably safer delivery device quickly catapulted the use of bipolar electrosurgery as the principle method for nonmechanical laparoscopic tubal sterilization.<sup>1</sup> Its essential role in operative laparoscopic surgery was firmly established after demonstration that it could be used as a reliable and safe method to secure major vascular pedicles for the whole gamut of conventional laparoscopic operations.<sup>2</sup> Most gynecologic surgeons are inherently more comfortable and apt to use bipolar rather than monopolar electrosurgery. Nonetheless, certain key electrosurgical techniques, such as cutting or vaporization, are not possible with conventional instrumentation.<sup>3</sup> To date, there is no evidence to support significant advantage of bipolar over monopolar electrosurgery for operative dissection.

*Correspondence:* Andrew I. Brill, MD, Department of Obstetrics and Gynecology, California Pacific Medical Center, 3700 California Street, Suite No. G322, San Francisco, CA 94118. E-mail: [brilla@suterhealth.org](mailto:brilla@suterhealth.org)

*Sources of support:* Consultant to SurgRx (Palo Alto, CA), Gyrus ACMI (Maple Grove, MA), Covidien (Boulder, Colorado).



## ***Principles of Electrosurgery***

Electrosurgery is achieved by the delivery of high-frequency alternating current from an electrosurgical generator into living tissue by an active electrode, which is then conducted via low resistance pathways to a return electrode. The flow of electrons or electrical current ( $I$ ) is set in motion and sustained by electromotive force termed voltage ( $V$ ) to complete the circuit across the difference in electrical potential between the 2 electrodes.<sup>2,4,5</sup> Because voltage is the force that drives the transit of charged particles across a potential difference, greater voltage has the propensity to produce greater thermal necrosis.<sup>6</sup>

The ability of electricity to produce work in the form of heat in living tissue is termed resistive heating. Thermal injury is related to the maximum tissue temperature, total volume of heated tissue, rate of temperature rise, and duration of temperature elevation. As living tissue is slowly heated above 50°C for a sufficient duration of time, irreversible damage occurs; cellular water completely evaporates at 90°C (desiccation); cell walls rupture at 100°C (vaporization); and tissue begins to carbonize and char at 250°C.<sup>4,5</sup> The temporal relationship between tissue temperature and thermal injury is nonlinear owing to the complex effects of conduction and convection on the entire process. Practically speaking, thermal effects can be moderated by altering the power setting, the type of output current (cut vs. blend vs. coag), the electrode dwell time, the proximity of the tissue to the active electrode, and the current density (ie, electrode surface area).<sup>6</sup>

The behavior of electricity in living tissue is generally governed by Ohm's law:  $V = I \times R$ . Derivatively,  $I$  is directly proportional to  $V$  and inversely proportional to resistance ( $R$ ). To complete a circuit, greater  $R$  requires greater force or voltage. Power keyed into a conventional electrosurgical generation as watts ( $W$ ) corresponds to the rate of work being

performed. The relationship between voltage and resistance is restated by the derivation of power,  $W = I \times V$ , and by using Ohm's law,  $W = I^2 \times R$  and  $W = V^2/R$ ; at any particular power setting ( $W$ ) using a conventional electrosurgery generator, higher  $R$  as with desiccation, fat, or char will drive higher output  $V$  to maintain the desired tissue end point.<sup>4,5,7</sup>

## ***Fundaments of Bipolar Electrosurgery***

Bipolar electrosurgery consolidates an active electrode and return electrode into an instrument, which are separated by a small distance. Dissimilar from monopolar electrosurgery, the intervening tissue is part of the electrical circuit rather than the patient. This obviates the need for high power and the return electrode, as current returns to the generator directly back up the electrode. The low voltage "cut" waveform is the default output current during bipolar electrosurgery.<sup>2-5</sup> The bi-directional flow of current eliminates the risk of direct and capacitive coupling associated with laparoscopic monopolar electrosurgery.<sup>8</sup>

The ability to coaptively heat tissue between 2 electrodes provides a number benefits of including the ability to limit the volume of affected tissue, a reliable method to occlude and seal blood vessels, and the capacity to effectively heat tissue that is immersed in fluid.<sup>5</sup> Because saline-rich blood can readily conduct electricity and thereby significantly reduce current density, mechanical tamponade to obliterate the pulse pressure is an essential component to achieve effective coaptive hemostasis.<sup>5,6</sup>

Despite the isolation of tissue between the bipolar electrodes, thermal damage may occur well beyond their confines. Tissue desiccation percolates heated intracellular water into adjacent tissues. The



unabated application of current can propagate a thermal bloom that disruptively bubbles steam through the surrounding parenchyma, damaging tissue at some distance from the target site.<sup>9</sup> Further application can carbonize tissue and cause a sticky amalgam.<sup>4,5,7</sup> Unwanted thermal injury is reduced by terminating current on tissue whitening and when water vapor can no longer be seen to emanate from the heated tissue. Despite its usefulness to determine the tissue end point for bipolar tubal sterilization, use of an in-line ammeter, which meters the flow of current between the tissue and the jaws of the bipolar grasper, tends to promote excessive thermal damage.<sup>9</sup> Because larger coapted tissue pedicles generate greater heat, bleeders are best managed using the sides or tips of a slightly open bipolar device to tamponade and then desiccate.<sup>10</sup> Despite the many technical advantages, tissue end points using bipolar electrosurgery are not always predictable; hemostasis often requires a number of contiguous applications, application duration per coaptation is entirely subjective, and thermal spread can significantly grow beyond the tissue pedicle. And finally, despite the surgeon's judgment that coagulation has been reached, unintentional transection of a patent vascular core cannot be entirely eliminated. Opposed to the security of a suture ligature, coaptive hemostasis using conventional bipolar electrosurgery is accomplished by blood vessel shrinkage along with a proximal thrombus.<sup>11</sup>

## ***Innovations in Bipolar Electrosurgery***

Responding to inherent limitations of conventional bipolar electrosurgery, recent advances in bipolar instrumentation provide more consistent and reliable hemostasis with significantly less collateral thermal damage. Hinged on smart generator technology that integrates impe-

dance (ie, tissue resistance) feedback from a surgical delivery device, 2 novel platforms moderate output using highly pulsed or continuous current paired with as little as one tenth the output voltage from conventional systems. Pulsing, the rapid on-and-off cycling of energy delivery, serves to allow for interval tissue cooling and provides time for the generator to make control decisions on the basis of the impedance reading made during or after the pulse. This new breed of generators is paired with a variety of conventional and novel ligating-cutting devices that provide continuous feedback about tissue impedance at the treatment site. By near instantaneous response to changes in tissue resistance, total energy delivery is much less than conventional bipolar systems. Once audible feedback from the generator signals complete coagulation, the tissue pedicle is secure and can be conventionally divided or transected by advancing a centrally set mechanical blade.

Using nanotechnology to autoregulate the output between the jaws, a third system similarly provides high current with low voltage output. With all of these new platforms, tissue carbonization, sticking, plume, and the zone of thermal damage are reduced when compared with conventional bipolar electrosurgery. As a general rule, low voltage bipolar coaptive desiccation/coagulation is most reliably achieved using broad tissue contact under reduced tissue tension. All of these new platforms can reliably seal blood vessels up to 7 mm in diameter and have instrumentation that variably dissect, grasp, manipulate, and transect tissue.

## ***LigaSure Vessel Sealing System***

True vessel wall fusion can be achieved using a combination of pressure and pulsed energy to denature collagen and elastin in tissue bundles, vessel walls,



and lymphatics to reform into a permanent plasticlike seal that resists deformation with tensile strength up to 3 times normal systolic pressure. The LigaSure single use vessel sealer/divider (Covidien, Boulder, CO) is equipped with optional hand-switching and comes in a variety of configurations including 5 and 10-mm laparoscopic instruments (Fig. 1), and a 20-cm device for laparotomic or vaginal surgery; and an instrument line that seals tissue for laparotomic or vaginal surgery, which comes as Heaney-style and angled clamps (Fig. 1). The tissue to be sealed is grasped in the jaws of the instrument, and a calibrated force is applied to the tissue while temperature generation is minimized. Using proprietary generator technology, the type of tissue held in the forceps is diagnosed, and the appropriate amount of energy is delivered to seal the tissue. When used with the most recent generator (Force Triad, Covidien, Boulder, CO) and software version (TissueFect, Covidien, Boulder, CO), the tissue effect is achieved

by responding 3333 times/s to impedance feedback.

### ***PlasmaKinetic Technology***

The PlasmaKinetic (PK) technology device platform (Gyrus ACMI, Maple Grove, MN) uses advanced solid-state generator software to deliver pulsed energy (VaporPulse) with continuous feedback control. It is the only technology with a true bipolar cut. The PK generator constantly takes tissue impedance readings during coagulation and a tissue impedance status is displayed in real time on the generator. As low impedance unsealed tissue is modified by the flow of bipolar current across it, the generator reduces power delivery. This technology consists of a proprietary PK generator (Gyrus ACMI, Maple Grove, MA), and a variety of dedicated instruments designed as a system. The basic PK armamentarium includes a laparoscopic line consisting of 5 or 10-mm laparoscopic coagulation/cutting forceps with a jaw ratchet (Fig. 2) and a 5-mm rotatable scissors,

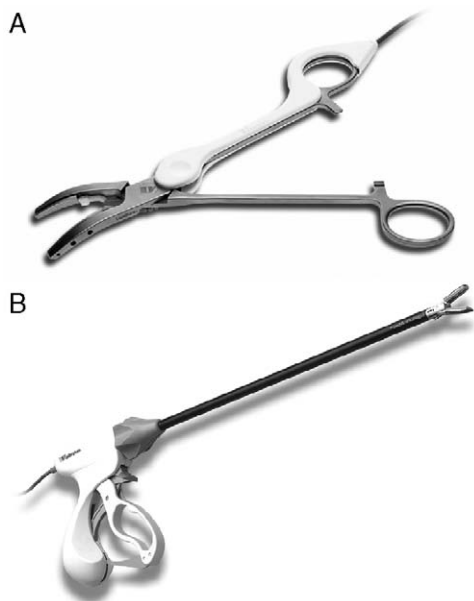


**FIGURE 1.** LigaSure. A, Max handpiece. B, Atlas 10-mm laparoscopic handpiece (courtesy of Covidien, Boulder, CO).

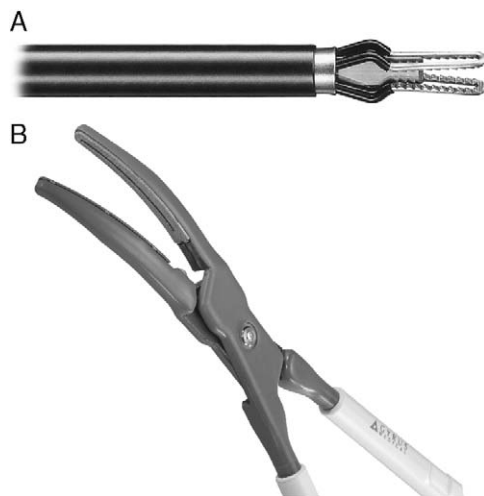


**FIGURE 2.** A, PK cutting forceps. B, PK plasma seal (courtesy of Gyrus-ACMI, Maple Grove, MA).



l hook with irrigator port, fine tipped and rotatable dissecting forceps, rotatable coagulating forceps (3 mm as well), and an adjustable cutting needle; and Heaney-style or angled tissue sealing forceps with nonconductive outer jaw surfaces for laparotomy or vaginal surgery.

The latest advancement in PK technology, called Plasmacision (Gyrus ACMI, Maple Grove, MA), provides devices able to both coagulate and cut using adaptive bipolar energy. The key technical enhancements enable a high-intensity electric field to form an unstable plasma cloud so current flows using the moisture from the tissue during cut and coagulation cycles. This plasma breaks down the cellular structure of the tissue giving an effective hemostatic cut with minimal thermal spread. Plasmacision instrumentation include the Trisector (Gyrus ACMI, Maple Grove, MA) for mechanical coaptation with hemostatic bipolar cutting (Fig. 2), the J-Hook for rapid hemostatic cut and coagulation, the Plasmaspatula (Gyrus ACMI, Maple Grove, MA) for spot coagulation and rapid cutting, and the Plasmaseal (Gyrus ACMI, Maple Grove, MA) open Pean-type forceps (Fig. 2) for sealing vessels and hemostatic bipolar cutting.

### ***EnSeal***

The EnSeal Laparoscopic Vessel Fusion System (SurgRx, Inc, Palo Alto, CA), uses a set of plastic jaws embedded with nanometer-sized spheres of nickel that conduct a locally regulated current. The temperature of the tissue pedicle is predetermined by the local conductivity of the heated nickel-laden plastic jaws. A patented material uses a carbon crystalline matrix to limit tissue temperature along the seal line to approximately 100°C. It is the first and only system that controls energy deposition at the electrode-tissue interface. Using trigger activated power in the handle, coagulation is facilitated by simultaneously advancing a mechanical blade that both



**FIGURE 3.** The SurgRx EnSeal PTC system.

cuts and squeezes the tissue bundle to eliminate tissue water. This reduces the propensity for steam to propagate the zone of lateral thermal injury. Once audible feedback from the generator signals complete coagulation, the pedicle is secure and can be transected by advancing a centrally set truncated blade (I-Blade, SurgRx, Inc, Palo Alto, CA). The combination of locally controlled heat deposition and high-jaw compression (forces up to 7500 psi) is designed into a 5-mm disposable device for both open and laparoscopic procedures and comes with a dedicated electrosurgical generator (Fig. 3).

### ***Evaluating New Bipolar Devices***

The clinical evaluation of new bipolar devices should reach well beyond their



capacity to simply desiccate/coagulate and cut tissue. Other pivotal considerations include the relative responsiveness to variable tissue content, tissue tension, and efficacy in fat as well as the propensity for smoke production and tissue sticking. Each instrument should also be evaluated as an operative instrument including the relative ability to grasp, elevate, dissect, and coapt tissues of variable densities and girth.

### ***Measures to Reduce Risk***

The ultimate aim of energy-assisted surgery is the attainment of anatomic dissection and hemostasis with the least amount of collateral damage and subsequent scar tissue formation. Ideally, the surgeon's final view of the operative field should accurately approximate the topography discoverable after postoperative healing. Despite the continued innovation of products borne to reduce thermal damage and then marketed as being comparatively safer, it is the hands and mind of the surgeon that serve to preserve tissue integrity by reducing the burden of delayed thermal necrosis and taking steps to prevent excessive devitalization of tissue. Regardless of the chosen modality, the inseparable elements of time and the quantity of delivered energy must be integrated while purposefully moderating to attain the desired tissue effect. Ultimately, the reduction of unwanted thermal injury is inherently linked to good surgical judgment and technique, a sound comprehension of the applied energy modality, and the surgeon's ability to recognize anatomic structures within the field of surgical dissection and those within the zone of significant thermal change.

During the use of any energy-based device for hemostasis, out of sight must never mean out of mind. If the bowel, bladder, or ureter is in close proximity to a bleeder, they should be sufficiently mobilized before applying energy. Thermal energy should always be withheld until

an orderly sequence of anatomic triage is carried out. Whenever a vital structure cannot be adequately mobilized, hemorrhage is preferentially controlled by using mechanical tamponade or suture ligation.

### ***References***

1. Soderstrom RM. Electrosurgical injuries during laparoscopy: prevention and management. *Current Opinion in Obstet and Gynecol.* 1994;6:248–250.
2. Odell RC. Physics and clinical application of electrosurgery. In: Liu CY, ed. *Laparoscopic Hysterectomy and Pelvic Floor Reconstruction.* Boston, MA: Blackwell Science; 1996.
3. Tucker RD, Benda JA, Sievert CE, et al. The effect of bipolar electrosurgical coagulation waveform on a rat uterine model of fallopian tube sterilization. *J Gynecol Surg.* 1992;8:235–241.
4. Luciano A, Soderstrom R, Martin D. Essential principles of electrosurgery in operative laparoscopy. *J Am Assoc Gynecol Laparosc.* 1994;1:189–195.
5. Brill AI. Energy systems for operative laparoscopy. *J Am Assoc Gynecol Laparosc.* 1998;5:333–349.
6. Wu MP, Ou CS, Chen SL, et al. Complications and recommended practices for electrosurgery in laparoscopy. *Am J Surg.* 2000;179:67–73.
7. Vaincaillie TG. Electrosurgery at laparoscopy: guidelines to avoid complication. *Gynaecol Endosc.* 1994;3:143–150.
8. Odell RC. Pearls, pitfalls, and advancement in the delivery of electrosurgical energy during laparoscopy. *Probl Gen Sur.* 2002;19:5–17.
9. Phipps JH. Thermometry studies with bipolar diathermy during hysterectomy. *Gynaecol Laparosc.* 1994;3:5–7.
10. Ryder RM, Hulka JF. Bladder and bowel injury after electrodissection with Kleppinger bipolar forceps: a clinicopathologic study. *J Reprod Med.* 1993;3: 595–598.
11. Sigel B, Dunn MR. The mechanism of blood vessel closure by high frequency electrocoagulation. *Surg Gynecol Obstet.* 1965;121:823–831.