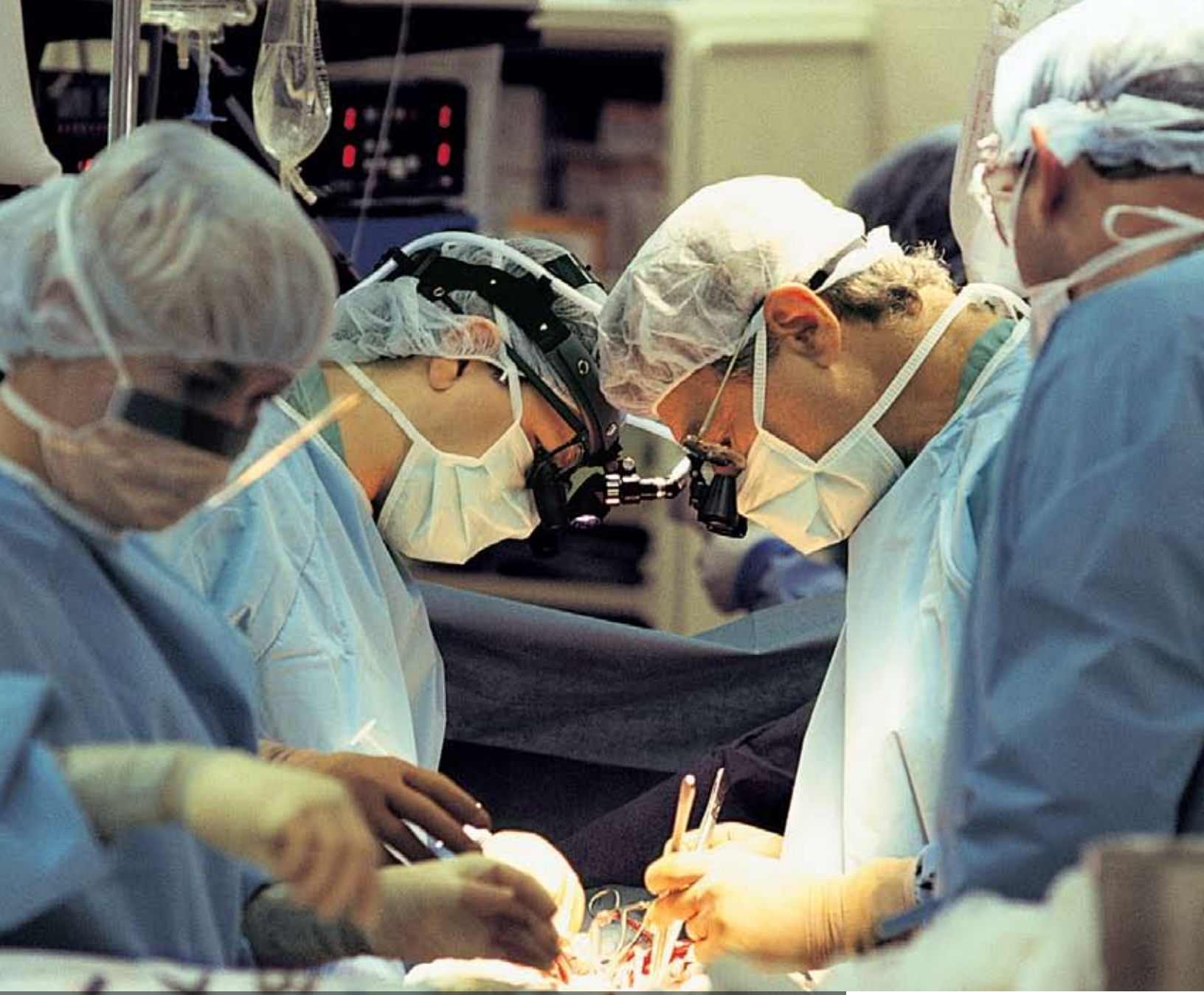

Electrosurgery Self-Study Guide

COVIDIEN

ELECTROSURGERY SELF-STUDY GUIDE

September, 2009

Intended Audience: A self-study guide to assist surgeons, perioperative nurses and other health-care team members to provide safe and effective patient care during electrosurgery procedures.

By

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OBJECTIVES

Upon completion of this activity the participant will be able to:

- Relate the properties of electricity to the clinical applications of electrosurgery.
- Review four of the variables the surgeon controls that impact surgical effect.
- Discuss the relationship between current concentration and tissue effect.
- Identify potential patient injuries related to electrosurgery and technological advances designed to eliminate these problems.

KEY CONCEPTS

Electricity may be hazardous. It is important that clinicians understand how electricity behaves and relates to electrosurgical function and applications can contribute to its safe use.

Many types of electrosurgical technologies are in use in settings where surgery and invasive procedures are performed including ORs, doctors' offices, ambulatory surgery units and endoscopy suites. The surgeon, perioperative nurse and other health-care team members must be aware of the implications for use for each technology in order to ensure safe patient care.

Knowledge of the preoperative, intraoperative and postoperative medical and nursing considerations and interventions can impact positive patient outcomes.

OVERVIEW

Electrosurgery came into wide use because of the urgent need to control bleeding in operative procedures. There have always been safety concerns when electricity is used in a therapeutic manner. This module will cover the fundamentals of electricity, principles of electrosurgery, clinical applications, technologies, recommended practices and nursing care during electrosurgery.

Note: The terms listed in the glossary are printed in bold in the body of the text of the self-study guide.

Figure 1. Edwin Smith Papyrus

THE HISTORICAL DEVELOPMENT OF AN ESSENTIAL TOOL

Throughout the history of medicine and surgery, the need to control bleeding has always been a concern. The earliest known surgical records describing the therapeutic use of **cautery** are in papyrus documents from Egypt dated as early as 3000 B.C. The Edwin Smith papyrus is a hieroglyphics description of procedures by one of the earliest physicians—Imhotep (Figure 1). Edwin Smith was an Egyptologist who acquired the papyrus in 1862 (Breasted, 1930). **Cautery** is described in the treatment of a tumor. It was called a fire drill—a device which when turned rapidly produced heat along the shaft that was then used as a **cautery** (Wicker, 1990).

It is reasonable to assume that throughout the centuries **cautery** continued to be used to treat disease processes and control bleeding. Hippocrates (460-377 B.C.), the Father of Medicine, in ancient Greece described the use of **cautery** to treat hemorrhoids (Lifshutz, 2004). A fellow Greek, Thales (the Father of Science) first described the frictional properties of amber. Thales noted that when amber is rubbed an attraction to other materials is created. The Greek word for amber is "Elecktron," the root of electricity (Greenwood, 1931).

Cautery was used throughout the Middle Ages. Its use was promoted by one of the greatest surgeons of that age—Albucasis, the Father of Modern Surgery. He lived and worked in Spain from about 1013-1106 (Goodrich, 2004). Albucasis wrote a 32-volume medical encyclopedia in which he described in-depth procedures that he performed, as well as instruments and devices he designed. He advocated using **cautery,** and because his writings were translated into many languages, many European surgeons were trained using his methods (Zahoor, 2006).

During the 16th Century the use of **cautery** began to decline. Ambroise Paré (1510-1590) was a French surgeon who gained his experience and reputation from treating battlefield wounds. Paré had used **cautery**, but in 1552 is said to have used ligature rather than hot irons to amputate a leg. He stated that the wound healed better and with much less pain than when it was burned using **cautery**. Paré later recommended the use of ligature exclusively. The prevailing wisdom of the time seems to have been the use of suture required greater skill than simply applying **cautery**, and that wounds healed better than after the tissue damage that resulted when **cautery** was used (Harvey, 1929).

William Gilbert (1540-1603), was one of the researchers whose work laid the foundation for the development of modern day generators. He lived in England, and was a court physician to Queen Elizabeth. He was interested in magnetism, and was the first to use the term "electricity" (Kelly, 1932). Gilbert published his work in a book entitled, "De Magnete" in 1600. In Book II he describes his experimentation with electricity in which he studied amber's frictional, or static electrical, properties. His work earned him the title of the Father of Electrotherapy (Greenwood, 1931).

During the 17th Century experiments with electricity heightened interest in the benefits of electrotherapy worldwide. Advances in the natural sciences occurred in Europe and America, sometimes at the same time. Each discovery served as a building-block for the next. Goldwyn (1979) and Vender (2005) suggest that the progression of knowledge in electrotherapeutics occurred during three eras. The first era involves experiments before 1786 with static electricity; the second era encompasses discoveries between 1786-1831 with muscle spasm and galvanization; and the third era spans from 1831 to modern times.

The discoveries related to static electricity were the first that looked at natural explanations for the phenomenon. It is called static electricity because the charge accumulates on an object—there is no **current** flow. Even though the **current** does not flow, the charge can jump from one object to another (Kurtus, 2006). The most common example is walking across a carpet and then getting shocked when the charge jumps to another object, such as a light switch or another person. Many researchers experimented with static electricity. Undoubtedly the most famous of these was Benjamin Franklin (1706-1790). As early as 1749 Franklin noted similarities between static electric sparks and lightning. Those deductions led to his renowned kite experiment where he induced lightning to flow from the kite. He was able to collect lightning in a Leyden jar, and proved both lightning and static electricity had the same properties. Benjamin Franklin's work led to the installation of lightning rods on buildings to direct the charge to **ground** and prevent damage and fires (Walter, 2003).

The second era in electrotherapy began with Luigi Galvani

(1737-1798) and the muscle spasms he observed in a frog's leg when touched with an electrical charge. He was able to reproduce the spasms in severed frog legs with his work, giving birth to electrophysiology (Corrosion Doctors, 2006). While working in the same area, Alessandro Volta (1745-1827) determined that metal contained electrical properties, as had Galvani. Volta constructed what he called the "voltaic pile," or the first battery. He made two stacks of different types of metal, separated by cardboard and soaked in an acidic solution. The voltaic pile could send out sustained electrical **current**. Today's wet cell batteries operate on the same principle. The **volt**, which is a measure of electrical energy, was named for Volta (Corrosion Doctors, 2006).

The third era in the development of **electrosurgery** started in 1831 with Joseph Henry in the United States and Michael Faraday in England. Both were conducting research on the relationship between magnetism and electricity. Both concluded that a moving magnet could induce an electrical **current**. The discoveries surrounding electromagnetism led to improved electromedical devices and to the development of the telegraph and the telephone (Goldwyn, 1979).

The late 1800s saw a dramatic increase in the knowledge related to the therapeutic use of electricity. In 1881 William J. Morton discovered that **current** in the 100 kHz range did not produce the pain and shock associated with **current** in the lower **frequency** ranges. By 1891 Arsenne d'Arsonval of France proved that **alternating current** frequency could be lowered to 100 kHz without producing a neuromuscular effect (Pearce, 1986).

By the early 1900s researchers were able to modify high **frequency current** to produce variations in the wave forms and tissue effects. The names that the researchers used to describe the tissue effects are still in use today. Walter deKeating-Hart and Simon Pozze in 1907 used "**fulguration**" from the Latin word for lightning "fulgur," to describe superficial tissue carbonization. In 1909 Doyen described **coagulation**, which means "to curdle" in Latin. Doyen was the first to report using a second electrode, which he called bipolar, to improve electrical performance. This would later become the **patient return electrode**, and was referred to as the indifferent electrode (Pollack, 2000). The term desiccate was introduced by William Clark in the Journal of the American Medical Association in 1914. He describes the effect to be between hyperemia and carbonization with just enough heat to destroy the tissue. Desiccate is from the Latin "desiccare" which means to dry out (Clark, 1914).

Joseph A. Riviere, a French surgeon, is credited with the first clinical use of **electrosurgery**. He used a spark to treat an ulcer on a musician's hand, and noted that repeated treatments resulted in the ulcer healing. His results were reported at the First International Congress of Medical Electrology and Radiology in Paris in 1900 (Kelly, 1932). In 1910 Edwin Beer, M.D. of New York, published his treatment of bladder tumors in Journal of the American Medical Association. He outlines his treatment methods, equipment used, tissue effect and outcomes from using high **frequency current** (Beer, 1910). After reading of Beer's success, A. Raymond Stevens, M.D. of New York reported on two cases in 1913 using high frequency **current**, stating that ease of use and efficiency as contributing to his successful outcomes (Stevens, 1913). In 1917 H. G. Bugbee, M.D. published his results of treating urological obstructions in Urologic and Cutaneous Review (Bugbee, 1917). Early reports of the successful use of high **frequency** electrical **current** paint a picture of a technology that evolved over time because of the efforts of many scientists and clinicians. There were, likewise, many **electrosurgery** devices that were developed. Lee DeForest filed the first patent for an electrosurgical **generator** on February 10, 1907. He described it as being specifically designed to be used on patients during surgery (Geddes, 2003).

The historical development of **electrosurgery** tells us that many men have contributed to its advancement over a long period of time. Despite the efforts of so many, the technology is most closely associated with William T. Bovie and Harvey Cushing. The individual genius of each and the collective genius of the partnership greatly contributed to their success at promoting and prompting the use of **electrosurgery** worldwide.

William T. Bovie was born in Augusta, Michigan on September 11, 1882. He studied botany, and then went to Harvard to study for a doctorate in plant physiology. He stayed on to work at the Harvard Cancer Commission (O'Connor, 1995). It was there that he became interested in **electrosurgery**. His work included treating cancer patients with radium. He came to believe that the **cautery** effect achieved from radium emanation could also be achieved using high **frequency current**. It was for this use that his generators were first developed. His work with Harvey Cushing, however, resulted in a **generator** that was better suited for the operating room than some that preceded it. Bovie and Cushing also worked with Liebel-Flarsheim to manufacture a commercial unit. Sale of **electrosurgery** units was not profitable for many years because of low demand and constantly changing improvements. Whenever Bovie or Cushing developed improvements in the technology, the previous machines were reportedly scrapped. The Bovie

originally sold for $2,000, but by 1932 the price had dropped to $1,250. Bovie never benefited financially from his invention. He sold his patent to Leibal-Flarsheim for $1 (Goldwyn, 1979).

Harvey Williams Cushing was born in Cleveland, Ohio on April 8, 1869. He entered Yale College in 1887, Harvard Medical School in 1891. In 1896 he began his residency with William Halsted at Johns Hopkins in Baltimore. He completed his residency there in 1900. He returned to Boston in 1901 to Peter Bent Brigham Hospital. It was in Boston that Cushing's collaboration began with William T. Bovie (Fulton, 1946).

Blood control during surgery had always been a concern for Cushing. In a 1911 paper, "The Control of Bleeding in Operations for Brain Tumor," Cushing gives an account of the methods he used to achieve hemostasis including wax, pledgets and silver clips (Cushing, 2002). Despite the variety of methods to achieve hemostasis, there were still patients considered inoperable because of the fear of bleeding.

It is reported that Cushing first contemplated the use of **electrosurgery** during a medical conference in 1925. Two of Cushing's residents were watching an **electrosurgery** demonstration when Cushing walked up to them. One suggested that Cushing use the machine on the brain. Cushing paused and looked thoughtfully at the demonstration in progress (Voorhees, 2005). He later visited Bovie at Harvard. Their collaboration began with Cushing making arrangements with Bovie to use his device in the operating room. The two men worked together over the next two years using the machine on patients, and making changes and refinements to the machine and its accessories. A 1928 paper reported on their success (Cushing, 1928), which has stood the test of time.

FUNDAMENTALS OF ELECTRICITY

Electricity is a natural phenomenon arising from the existence of positively and negatively charged particles that make up matter. All matter is made up of atoms. Atoms are comprised of electrons (negatively charged), protons (positively charged) and neutrons (neutral) particles. Atoms that contain equal numbers of electrons and protons are charge neutral. When forces are introduced that cause electrons to move from their base atoms to other atoms, the charge is changed. Atoms with fewer electrons than protons become positively charged; those with more electrons than protons become negatively charged. During movement like charges repel and unlike charges attract. Electron movement is termed electricity. There are two constant properties of electricity that can impact patient care. Electricity, which moves at nearly the speed of light, (1) always follows the path of least **resistance**, and (2) always seeks to return to **ground** (Columbia Encyclopedia, 2006).

ELECTRICITY VARIABLES

There are variables associated with electricity that must be considered when using it in a therapeutic manner. Knowledge of the role of each variable and the consequence of changing variables makes it possible to increase the level of patient safety whenever **electrosurgery** is used.

CURRENT

Electrical **current** is the flow of electrons, and it is measured in amperes or amps. The two types of **current** that are used in the operating room are **direct current** (DC) and **alternating current** (AC). **Direct current** uses a simple **circuit,** and electrons only flow in one direction. Batteries are usually part of these simple circuits. Energy flows from one terminal on the battery and must return to the other terminal to complete the **circuit**.

Alternating current (AC) switches, or alternates, direction of electron flow. The **frequency** of the alterations is measured in cycles per second or **Hertz** (Hz). One **Hertz** is equal to one cycle per second. Household **current** alternates at 60 cycles per second, as does much of the electrical equipment used in operating rooms. **Alternating current** at 60 Hz causes tissue reaction and damage. Neuromuscular stimulation ceases at about 100,000 Hz (100 kHz), as the **alternating current** moves into the **radio frequency** (**RF**) range (Hutchisson, 1998).

IMPEDANCE/RESISTANCE

Impedance/resistance is the opposition to the flow of **current**. Although the terms are sometimes used interchangeably, **impedance** refers to the opposition to the flow of **alternating current**; the term **resistance** refers to the opposition to flow of **direct current**. **Impedance/resistance** is measured in ohms. During use of **electrosurgery** one source of **impedance** is the patient.

VOLTAGE

Voltage, measured in volts, is the force that causes **current** to flow through an electrical field. One volt causes one amp to flow through one **ohm** of **impedance** or **resistance**. The **voltage** in an electrosurgical **generator** provides the electromotive force that pushes electrons through the **circuit**.

POWER

Power is the rate that energy is produced. The power is measured in **watts**. On electrosurgical generators the power

setting used by the surgeon is either displayed on a screen in **watts**, or a percentage of the total available wattage as indicated on a numerical dial setting (Lister, 1984).

PRINCIPLES OF ELECTROSURGERY

ELECTROCAUTERY

The electrocautery device is the simplest electrical system used in the operating room. It uses battery power to generate a simple **direct current** (DC). The **current** never leaves the instrument to travel through the patient's tissue. An example is the small hand-held eye **cautery** (Figure 2). The battery heats up a wire loop at the end of the device. It is most often used in ophthalmic surgery and other minor procedures where very little bleeding is encountered. Its use is limited because it cannot cut tissue or coagulate large bleeders. It is further limited because tissue can stick to the wire electrode. The term "electrocautery," or "cautery" is often, and incorrectly, used to describe all types of electrosurgical devices. Its use is only appropriate to describe the simple direct current cautery device.

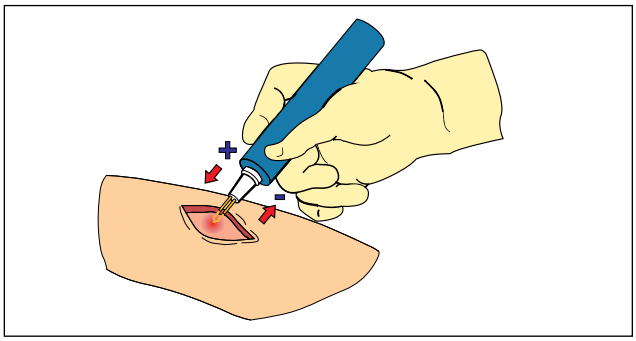


Figure 2 – Hand-Held Cautery

ELECTROSURGERY AND RADIO FREQUENCY CURRENT

Why do electrosurgery generators not shock patients is a common question. The answer is because of the higher frequencies at which electrosurgery generators operate. Electrosurgery generators take 60 Hz current and ramp it up to the radiofrequency range. Radiofrequency **current** alternates so rapidly between the positive and negative poles that cells do not depolarize, or react to the **current**. Neuromuscular stimulation ceases at about 100,000 Hz. AM radio stations operate in the 550 to 1500 kilohertz (kHz) range. Electrosurgery generators typically operate in the 200 kHz to 3.3 megahertz (MHz) range (Figure 3). That is well above the range where neuromuscular stimulation or electrocution could occur (Harris, 1978).

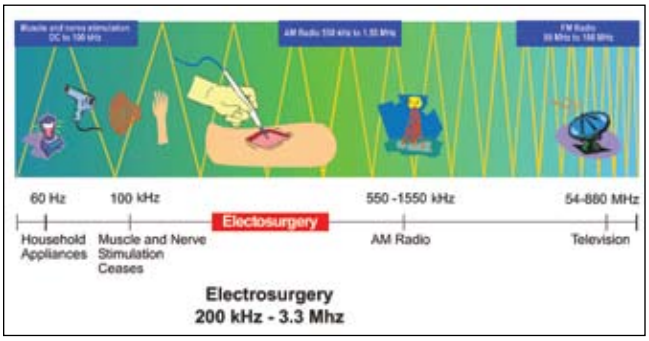


Figure 3 – Frequency Spectrum

BIPOLAR ELECTROSURGERY

Bipolar electrosurgery is the use of alternating electrical **current** in which the **circuit** is confined within an instrument using two adjacent poles—one positive and one negative—located in close proximity to one another. **Current** flow is restricted between the two poles (Tucker, 1998). A variety of **bipolar instrument** configurations are available including forceps, scissors or graspers. Because the positive and negative poles are so close together, lower **voltages** are used to achieve tissue effect. Most bipolar units use a low **voltage waveform** that achieves hemostasis without unnecessary charring. A **patient return electrode** is not needed when bipolar is used because **current** flow is confined to the tissue between the poles of the instrument (Figure 4).

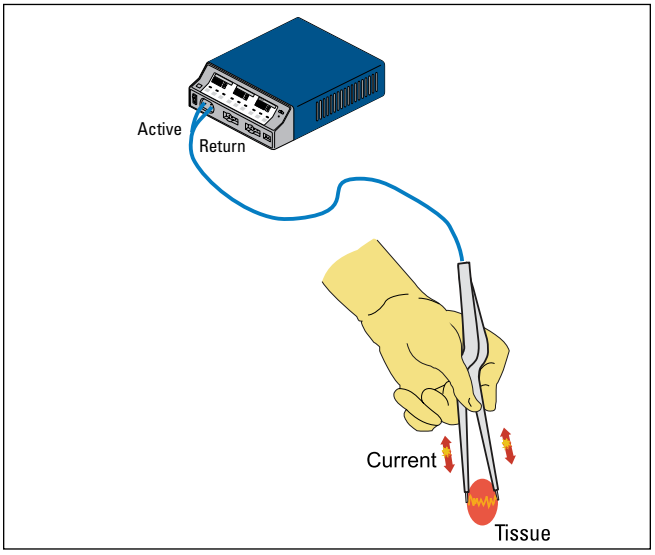


Figure 4 – Bipolar Circuit

Bipolar is a very safe **electrosurgery** technology. There are some disadvantages to the use of bipolar. Bipolar cannot spark to tissue, and the low **voltages** make it less effective on large bleeders (Mitchell, 1978). There are, however, newer bipolar generators that incorporate a "macro" or bipolar "cut" mode that has higher **voltage** and is designed for use with newer

generations of bipolar cutting instruments.

Bipolar is widely used in neurosurgery and gynecologic surgery. It is also safer to use when there is a question about the efficacy of using more powerful monopolar electrosurgical units (e.g., with pacemakers and implantable cardioverter/difibrillators).

MONOPOLAR ELECTROSURGERY

The most frequently used method of delivering **electrosurgery** is monopolar because it has a greater range of tissue effects and it is more powerful. When using **monopolar electrosurgery** the **generator** produces the **current**, which travels through an **active electrode** into patient tissue. The **current** then passes through the patient's body to a **patient return electrode** that collects the **current** and carries it safely back to the **generator** (Figure 5). That is the intended pathway for the electrical **current** flow. The type of monopolar **generator** used, along with appropriate surgeon and perioperative nursing interventions, can help insure that this is the path the **current** takes.

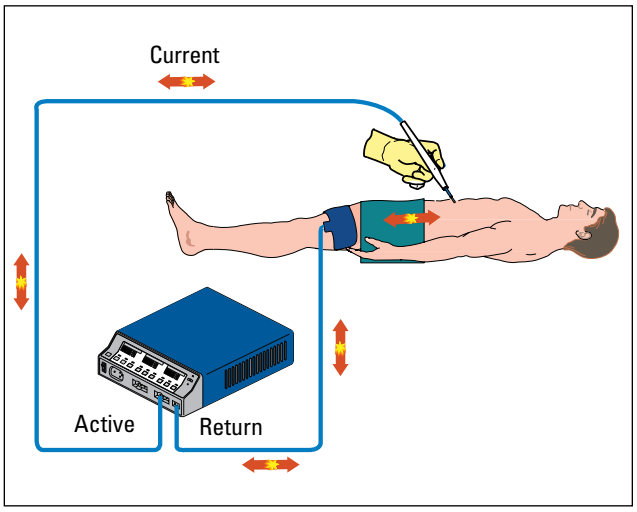


Figure 5– Monopolar Circuit

CURRENT CONCENTRATION/DENSITY

The reason for using **electrosurgery** is to produce high-frequency electrical **current** that will create the desired clinical effect (Massarweh, et. al., 2006). Heat is produced when high-frequency **current** is concentrated. The amount of heat produced determines the extent of the tissue effect. **Current** concentration or density depends on the size of the area through which the **current** flows. A small area that concentrates the **current** produces more **impedance/resistance** and will require more force to push the **current** through the limited space. The combination of greater force through a smaller space produces more heat. A large area that spreads out the **current** has less **impedance/resistance** to the flow of the **current**, which reduces the amount of heat produced (Figure 6).

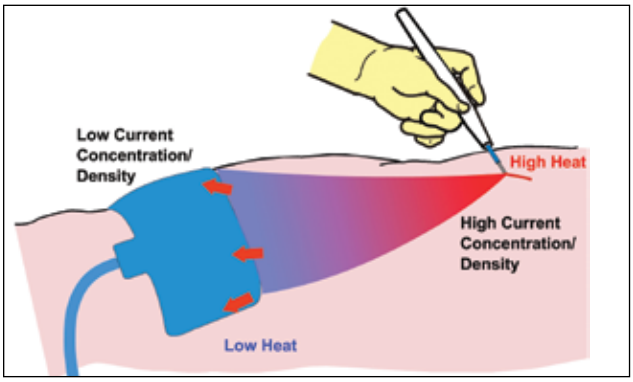


Figure 6 – Current Concentration/Density

ELECTROSURGICAL MODE DIFFERENTIATION

As noted in the historical development of high-frequency **electrosurgery**, researchers determined that the output of the generators could be modulated to deliver different **waveforms** or electrosurgical modes. The basic **waveforms** or modes are **cut** (vaporization), **coagulation** (**fulguration**) and **blend**. Any mode can be used to desiccate tissue. The variable is how the **current** is applied to the tissue.

ELECTROSURGERY CUT (VAPORIZATION)

The electrosurgical mode referred to as cut is a continuous sinusoidal **waveform** (Figure 7). Because the delivery of the **current** from the **generator** is continuous, lower **voltage** is needed to achieve tissue vaporization. The correct method to achieve the cutting effect in tissue is to hold the tip of the **active electrode** in close proximity to, but not touching, patient tissue. When used in this manner the **current** creates higher tissue temperatures in a shorter time, leading to rapid expansion of intracellular fluids and cell explosion or vaporization (Munro, 1995). This type of cell vaporization provides a clean tissue division (Figure 8). The cut mode is also a good choice for **coagulation** of tissue through **desiccation**.

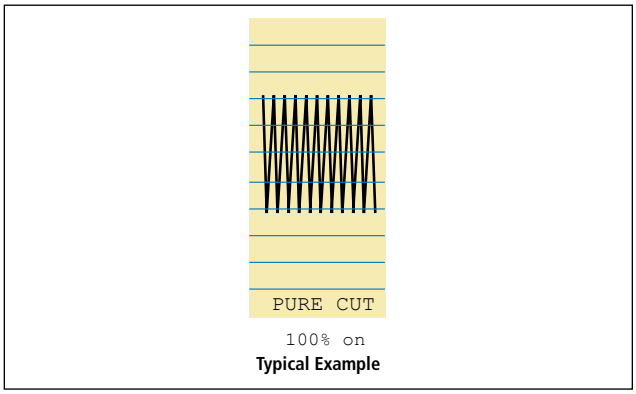


Figure 7 – Cut Waveform

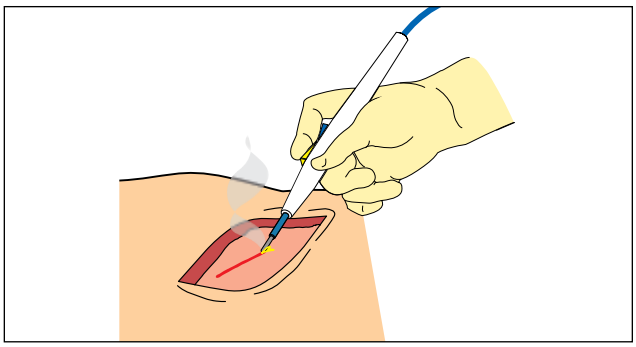


Figure 8 – Vaporization or Cut Waveform

FULGURATION

The electrosurgical mode referred to as **coagulation** or coag is an interrupted or dampened method of **current** delivery. When using this mode **current** is only being delivered to tissue about 6 percent of the time (Figure 9). This is referred to as the duty cycle. The **coagulation** current produces spikes of **voltage** as high as 9,000-10,000 volts peak to peak. The tissue is heated when the **waveform** spikes and cools down in between **voltage** spikes thus producing **coagulation** of the cell during the 94 percent off-cycle of the **waveform**. To achieve **fulguration** the electrosurgery **active electrode** tip should be held slightly above the tissue that is to be coagulated (Figure 10).

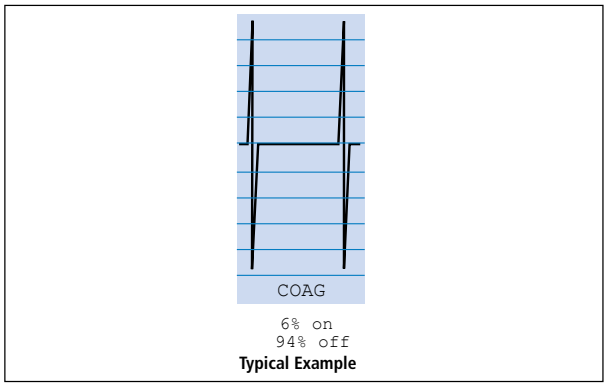


Figure 9 – Coagulation Waveform

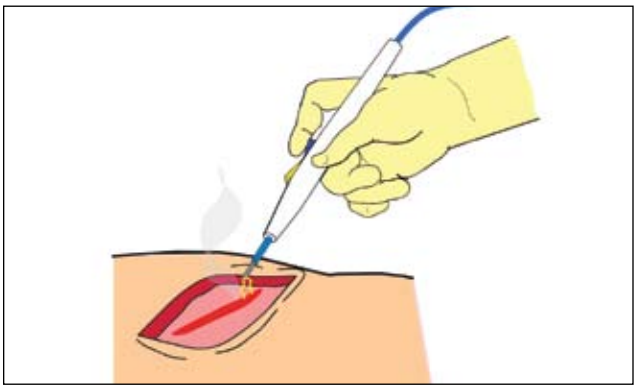


Figure 10 – Fulguration

BLENDED MODE

Electrosurgical generators also offer a **blend** mode of **current** delivery. **Blend** modes are a function of the cut waveform (typically the yellow side of the **generator**) whereby **current** delivery is modified producing varying degrees of cutting and hemostasis (Tucker, 1998). Generators can produce several **blend** waveforms that provide varying degrees of **coagulation** and cutting **current** delivery by modifying the duty (on/off) cycle (Figure 11). Examples of **blend** waveforms available in electrosurgery generators are:

Blend 1 = 50% on/50% off

Blend 2 = 40% on/60% off

Blend 3 = 25% on/75% off

Variations of cut to **coagulation** blends may vary among manufacturers. Generally, however, a higher blend number means a higher degree of **coagulation**.

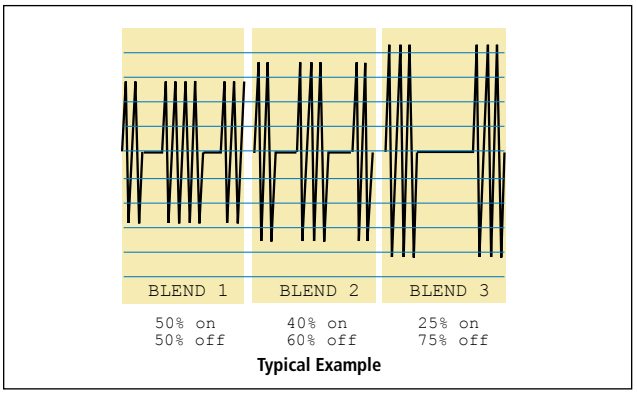


Figure 11 – Blended Waveforms

DESICCATION

Desiccation or the drying out of tissue can be achieved when using either the cut or **coagulation** mode. Whenever the tip of the **active electrode** is in direct contact with tissue, the tissue is being desiccated (Figure 12). The choice then becomes

whether to use the cut or the **coagulation** waveform. The cut waveform is a better choice when desiccating tissue because less **voltage** is used to achieve the desired tissue effect.

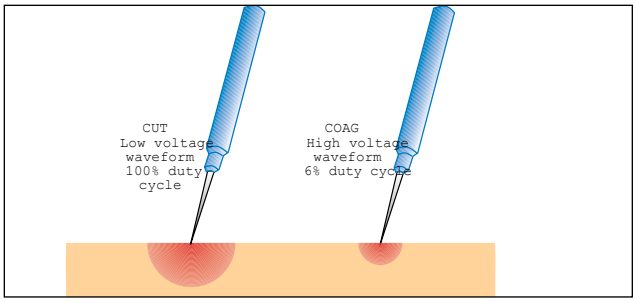


Figure 12 – Desiccation

OTHER VARIABLES THAT IMPACT TISSUE EFFECT

An important factor in achieving hemostasis is the **waveform** the surgeon elects to use—cut, coag or **blend**. Equally important is how the **active electrode** is used; if the **active electrode** is in direct contact with the tissue or not. There are also other variables that alter the outcome of the electrosurgical tissue effect:

Power – The power setting used during surgery will have a definite impact on tissue effect. The lowest possible power setting that achieves the desired tissue effect should always be used. Power settings will vary from patient to patient and for every surgical procedure. Muscular patients of weight and height in proper portions require lower power settings than obese or emaciated patients. One of the most important considerations is the location of the **patient return electrode**. The **patient return electrode** should always be as close to the surgical site as possible on a large muscle mass. When the **patient return electrode** is close to the surgical site, the surgeon can use lower power settings because the **current** does not have to travel as far as when the **patient return electrode** is a greater distance away from the **active electrode**. The tissue mass (**impedance/resistance**) between the two sites is less.

Time – The length of time the surgeon activates the **generator** also determines the amount of tissue effect. Activations that are too long will produce wider and deeper tissue damage. Too short an activation time will result in a less than optimal tissue effect.

Active Electrode – The size of the **active electrode** influences the tissue effect of the **generator**. A large **active electrode** will require a higher power setting than a smaller electrode to achieve the same tissue effect because the **current** is dispersed over a wider surface area (Figure 13).

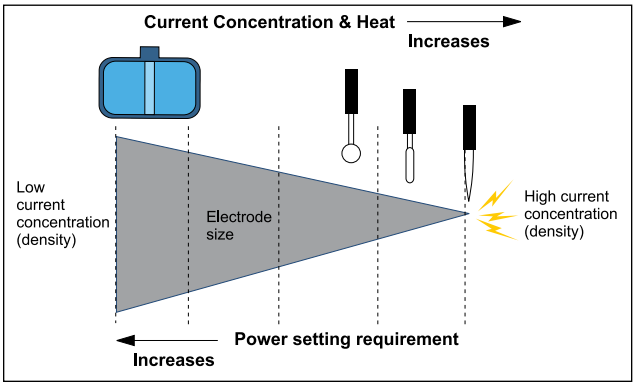


Figure 13 – Current Concentration Effect on Power Settings

A clean **active electrode** tip will require less **power** to do the same work than a dirty one because eschar buildup has higher **impedance/resistance** that hampers the flow of electrical **current**. When stainless steel blades are used and continuously cleaned using a "scratch pad" eschar can build up in the resulting grooves making cleaning difficult (Figure 14).

Figure 14 – Grooved Stainless Steel Blade Coated with Eschar

Eschar buildup can be reduced by using a coated electrode that can be cleaned with a wet sponge. Electrode tips can be coated with Teflon® (PTFE) or an elastomeric silicone coating (Figure 15). Because coated electrodes wipe clean with a wet sponge, use of a "scratch pad" can be eliminated.

Careful evaluation of **active electrode** tips should be conducted because some will enable the surgeon to use lower power settings, reducing the potential for thermal spread. In addition, some coated electrodes are bendable, have a nonflake coating and retain their cleaning properties longer than others.

Figure 15 – Coated Active Electrodes

Tissue – Patient tissue has an impact on the effectiveness of the **generator**. The physical characteristics of the patient's body determine the amount of **impedance** to the electrosurgical **current** flow as it attempts to complete the **circuit** through the return electrode back to the **generator**. A lean, muscular patient conducts the electrical **current** much better than a patient who is obese or emaciated.

ELECTROSURGICAL TECHNOLOGIES

The electrosurgery unit is one of the most widely used tools available to surgeons. As the sophistication of surgical procedures has evolved over time, so too have **electrosurgery** technologies. Meeting the challenge of improved patient care is but one of the goals of the medical manufacturing partner within the health-care arena. Providing education and information on emerging technology is another. Both the surgeon and the perioperative nurse must be familiar with older technologies and with current innovations so that the safest and most effective care is available to patients wherever surgery and invasive procedures are performed.

GROUND-REFERENCED GENERATORS

The late 1800s and early 1900s ushered in the use of radiofrequency electrosurgery generators during surgical procedures. Early electrosurgery generators, such as Bovie's original unit, were **ground** referenced. It was the **ground**, or earth, that completed the **circuit**. The spark-gap systems were high output and high performance, and were a favorite device among surgeons for many years (Massarweh, 2006). The major hazard associated with **ground**-referenced technology is that **current division** can occur. If the electrical **current** finds an easier (lower **impedance/resistance**) or faster pathway to return to **ground** and the **current** is sufficiently concentrated, the patient could be burned at any point where the **current** exits the patient's body (Figure 16).

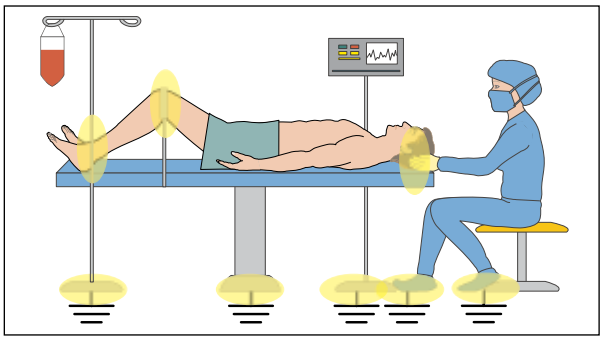


Figure 16 – Current Division

This could be where the patient's hand touches the side of the OR bed, a knee touches a stirrup or any number of possible alternate exit sites (Figure 17). In early models of ground-referenced generators, the surgeon could use **electrosurgery** regardless of whether a **patient return electrode** was placed on the patient. This resulted in patient burns. Later models offered a cord fault alarm, which sounded an alarm if the **patient return electrode** was not plugged into the **generator**. The disadvantage was that **electrosurgery** could be used if the cord was plugged into the **generator** even if the **patient return electrode** was not on the patient. Burns could also occur at the patient return electrode site when the return electrode was on the patient.

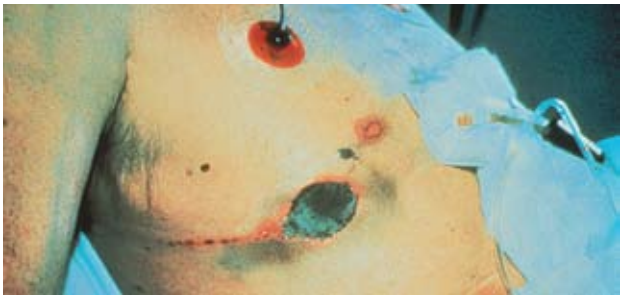


Figure 17 – Alternate Site Burn

SOLID-STATE GENERATORS

The first innovation in radiofrequency **electrosurgery** occurred in 1968 with the introduction of solid-state generators. A scientist from the aerospace industry developed a small, compact **generator** that employed isolated circuitry. This was a huge advance in patient safety since the electrical **current** was referenced to the **generator,** and ignored any grounded object that inadvertently came in contact with the patient other than the **patient return electrode**. Isolated generators prevent **current division** because if the electrical **current** cannot return to the **generator**, it will not work. **Current division** and the possibility of alternate site burns was dramatically reduced (Figure 18).

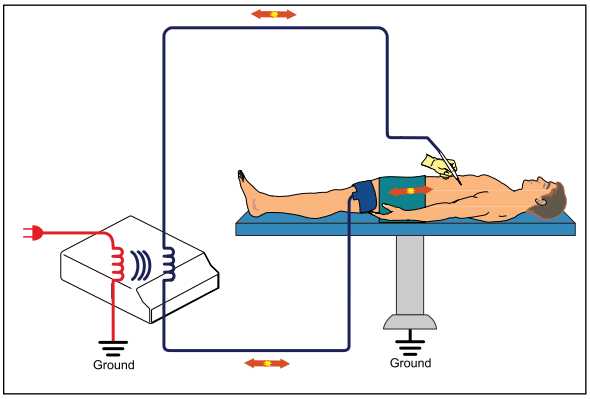


Figure 18 – Isolated Circuit

An isolated **generator** will not work unless the **patient**

return electrode is applied to the patient. However, without additional safety features, the **generator** cannot determine the status of the contact at the **pad**/patient interface. Should the **patient return electrode** be compromised in the quality or quantity of the **pad**/patient interface during surgery, a return electrode burn could occur (Figure 19). The perioperative nurse must ensure throughout the procedure that the **patient return electrode** is in good contact with the patient.

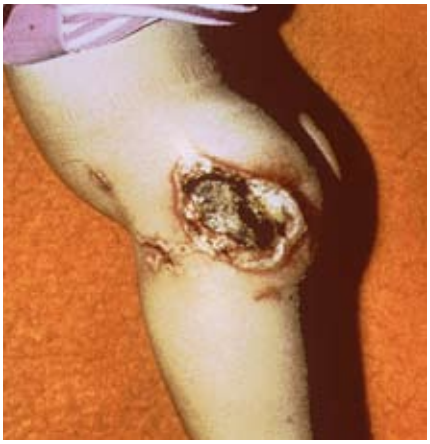


Figure 19 – Pad Site Burn

CONTACT QUALITY MONITORING

The next major innovation in **electrosurgery** came about in 1981 when an interrogation **circuit** was added to the **patient return electrode**. The interrogation **circuit** in a **contact quality monitoring patient return electrode** continuously monitors the quality/quantity of the contact area between the **pad** and the patient (Figure 20).

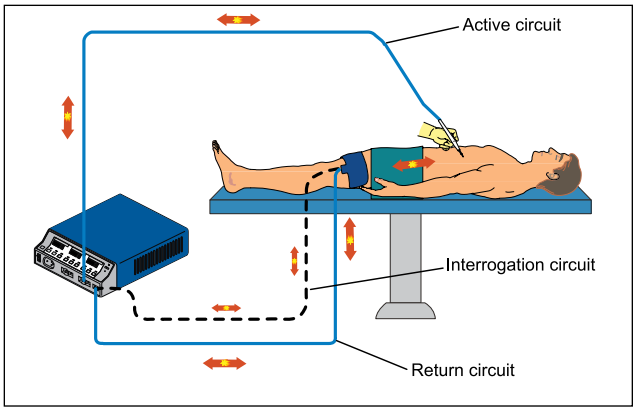


Figure 20 – Return Electrode Monitoring System

The contact quality monitoring system is designed to inactivate the generator while giving audible and visual feedback before a patient burn can occur due to a contact quality issue. Return electrode monitoring is a major safety device for patients since return electrode burns due to a reduction in the quality or quantity of contact area used to account for a majority of patient burns during **electrosurgery**. This technological breakthrough was the first time since the development of **electrosurgery** that the patient's own tissue status was taken into consideration as part of a feedback mechanism. According to ECRI, many **electrosurgery** burns could be eliminated by a **patient return electrode contact quality monitoring system** (ECRI, 1999).

ARGON-ENHANCED ELECTROSURGERY

In the late 1980's an argon delivery system was combined with the electrosurgery **generator** to create argon-enhanced **electrosurgery**. This **electrosurgery** technology should not be confused or compared to a laser. Argon is an inert, nonreactive gas that is heavier than air and easily ionized. The argon shrouds the electrosurgery **current** in a stream of ionized gas that delivers the spark to tissue in a beamlike fashion (Figure 21). Because the beam concentrates the electrosurgical **current**, a smoother, more pliable eschar is produced. At the same time, the argon gas disperses the blood, improving visualization. Because the heavier argon displaces some of the oxygen at the surgical site, less smoke is produced. When used during surgery, argon-enhanced electrosurgery can reduce blood loss and surgical time (Rothrock, 1999).

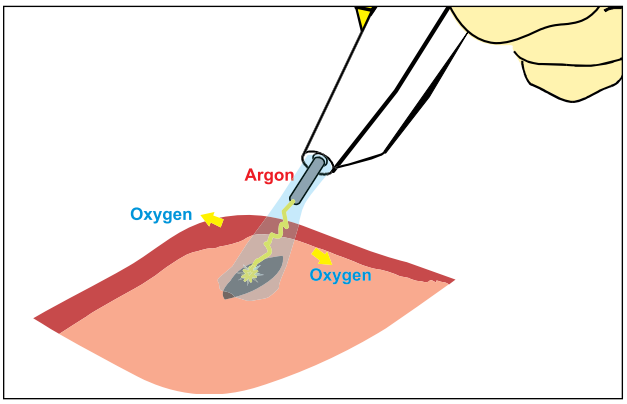


Figure 21 – Argon-Enhanced Electrosurgery

TISSUE DENSITY FEEDBACK TECHNOLOGY

During the mid-1990s electrosurgery generators were introduced that incorporated computer-controlled feedback systems. Referred to as **tissue response**, or tissue effect generators, the instant response technology could sense tissue **impedance/resistance**. The feedback system provided the surgeon with consistent clinical effect through all tissue types in the cut or vaporization mode. Generators equipped with the feedback mechanism rapidly sense tissue **resistance** and automatically adjust output **voltage** to maintain constant generator effect (Figure 22). What that means to the surgeon is that if 40 watts is selected as the desired power setting, the

generator will deliver 40 watts through tissues of varying ohms of **resistance**. The constant **power** output has an added advantage in that perioperative staff is not required to frequently adjust generator power settings, and **voltages** are kept as low as possible. Instant generator response to changing patient tissues represented a "first" in patient safety in which the electrosurgery **generator** used information from the patient throughout the procedure. While a major advance in generator technology, only surgeons who made use of the cut or vaporization mode could take full advantage of **generator** capabilities (Eggleston, 1997).

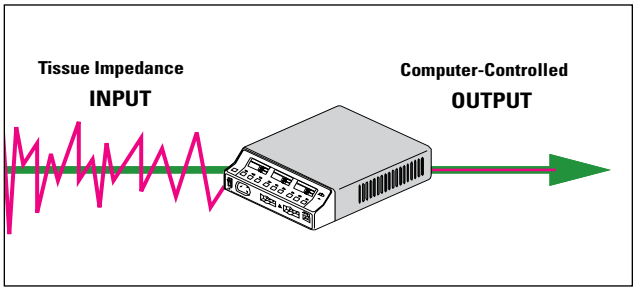


Figure 22 – Tissue Response Technology

TISSUE FUSION TECHNOLOGY

In 1999 a technology was developed that gave surgeons a new way to achieve hemostasis. The specialized generator/instrument system reliably seals vessels and tissue bundles in both laparoscopic and open surgery applications. It applies a unique form of bipolar-type energy in combination with pressure to fuse vessel walls and create a permanent seal (Figure 23).

Figure 23 – Tissue Fusion Technology

The output of the **generator** is computer-feedback-controlled so that a reliable seal is achieved in minimal time when the tissue is held between the tines of specially designed instruments. The result is a reliable seal on vessels up to and including 7 mm in diameter and tissue bundles in a single **generator** activation. The seal is strong and permanent, and has been shown to withstand three times normal systolic pressure. Thermal spread is reduced when compared to traditional bipolar, and is comparable to ultrasonic **coagulation**. The site has a translucent appearance that is the reformed collagen and elastin that actually changes the nature of the tissue to form the permanent seal. An important consideration is the bipolar-type nature of this technology. The electrical **current** only travels between the tines of the forceps and never goes through the patient's body making it a very safe treatment option for patients for whom **monopolar electrosurgery** might be contraindicated, such as those with pacemakers (Prokopakis, 2005).

The specifications of tissue fusion technology make it unique among surgery hemostatic devices. There is no other **generator** or instrument equivalent (Figure 24):

Bipolar-type Generator

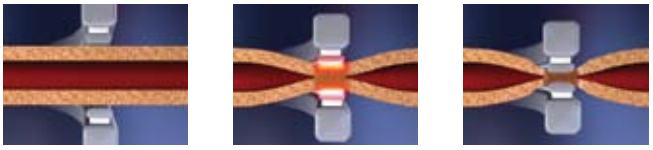
- Low voltage – 120 V
- High peak amperage – 4 A (minimum)
- Patient tissue responsive
- Closed loop feedback circuitry

Instruments

- Precisely calibrated
- High pressure
- Open and laparoscopic

System Operation

- Applies controlled pressure to vessels, tissue bundles and lymphatics
- Delivers precise energy cycle:
  - Measures initial impedance/resistance of tissue and automatically chooses appropriate energy settings
  - Delivers continuous controlled power
  - Senses that tissue response is complete and stops cycle



Step 1 Step 2 Step 3

Figure 24 – Tissue Fusion Technology Operation

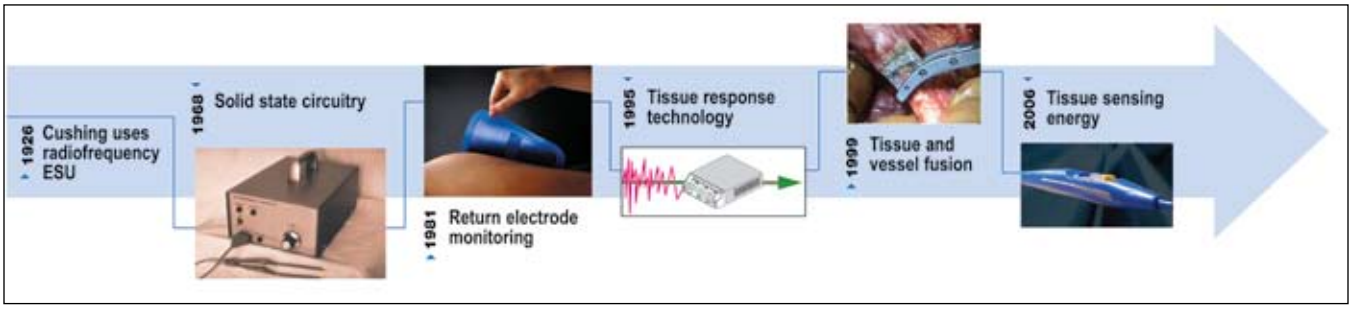


Figure 25 – Progression of Technology

CLOSED-LOOP COAGULATION TECHNOLOGY

The steady increase in electrosurgery **generator** improvement culminated with the engineering breakthrough that created closed-loop controlled **coagulation** in 2006 (Figure 25).

The introduction of closed-loop controlled **coagulation** allowed the development of a radiofrequency electrosurgery **generator** capable of including tissue feedback data in every mode available on the **generator**. The tissue sensing energy platform is a computer controlled system that senses **resistance** in patient tissues and adjusts output **voltage**, electrical **current** and generator **power** 3,333 times per second. As with **tissue response** in the cut mode of earlier generators, this provides consistent electrosurgical effect across a wide range of varying patient tissue **resistance/impedance** (Figure 26).

Figure 26 – Tissue Sensing Energy Platform

The dramatic differences between the tissue sensing capabilities of closed-loop controlled **coagulation** are most obvious when comparing actual oscilloscope printouts of traditional **coagulation** and closed-loop controlled **coagulation** (Figure 27). In the **coagulation** mode, without closed loop control, the positive and negative poles of the duty cycle are unequal. When the peak to peak **voltage** is controlled, **voltage** is similar in both the positive and negative poles of the duty cycle, which gives a more consistent generator tissue effect. The ability of the tissue sensing **generator** to include tissue information during each activation is another huge advance in patient safety and makes each and every surgical procedure specific to each and every patient.

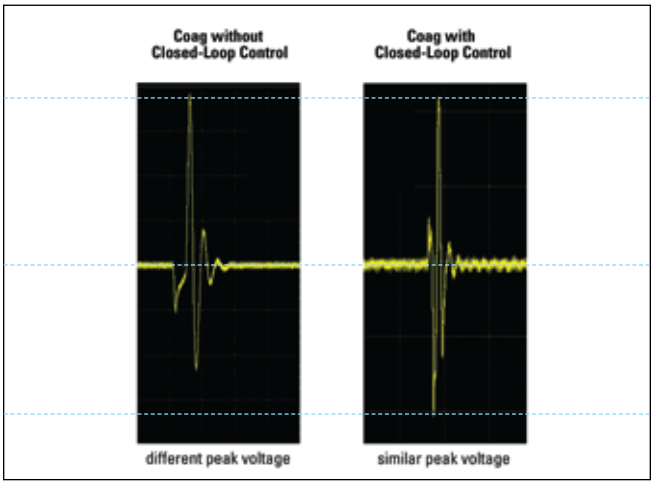


Figure 27 – Closed-Loop Control Comparison

SMOKE EVACUATION

In 1994 AORN (the Association of Perioperative Registered Nurses) first published a recommended practice stating that patients and perioperative personnel should be protected from inhaling the smoke generated during the use of **electrosurgery**. The recommendation to evacuate and appropriately filter surgical smoke has remained a standard supported by AORN since that time (AORN, 2006). The recommended practice is applicable whenever a smoke plume is produced whether it is from laser, **electrosurgery** or any other surgical device that aerosolizes human tissue. Toxic fumes and carcinogens have been isolated from surgical smoke (Ulmer, 1997). Formaldehyde and benzene are two of the long list of substances that are contained in smoke. Acrylonitrile and hydrogen cyanide are toxic, colorless gases present in smoke that are easily absorbed through the skin and lungs.

Acrylonitrile exerts its toxicity by liberating the cyanide, while the cyanide combines with other substances to impair tissue oxygenation (Barrett, 2004).

Air in hospitals and operating rooms has been described as a "chemical soup" that can cause symptoms such as shortness of breath, eye and respiratory irritation, rhinitis, contact dermatitis, headaches, joint pain, memory problems and difficulty concentrating, to name a few (Wilburn, 1999). There has been no quantitative way to measure the long-term effects on health-care workers, but as with cigarette smoking, the effects of inhaling surgical smoke is cumulative. In September 1996 the National Institute for Occupational Safety and Health (NIOSH) issued a hazard alert through the Centers for Disease Control's (CDC) health-care facility network. The alert recommended that laser and electrosurgical smoke be evacuated and filtered to protect health-care workers. The alert still appears as a recommendation on the NIOSH Web site (CDC/NIOSH, 2006).

Patients, as well as surgical staff, can be exposed to surgical smoke during laparoscopic procedures. There is a high concentration of carbon monoxide in surgical smoke. Carbon monoxide can cause symptoms that include headache, nausea, fatigue, vomiting, cardiac dysrhythmias, lactic acidosis and syncope, based on the level of exposure (Vremen, 1995). When carbon monoxide is absorbed through the peritoneal membrane during laparoscopic surgery elevated levels of methemoglobin and carboxyhemoglobin are produced in the patient's bloodstream. This can pose a potential risk to patients during surgery (Ott, 1997).

Surgeons and perioperative scrubbed staff are also at increased risk from inhaling surgical smoke during laparoscopic procedures due to a surge of concentrated smoke being released from the cannula system. It is recommended that a smoke evacuation laparoscopic handpiece be used to maintain visualization throughout the procedure through metered smoke evacuation. Any air that is released from the cannula should be collected by a smoke evacuator (Healthstream, 2004).

A list of the chemicals contained in surgical smoke is reason enough to institute a policy that all smoke be evacuated and filtered (Figure 28).

Acetylene	Ethane	4-Methy phenol
Acroloin	Ethene	2-Methyl propanol (aldehyde)
Acrylonitrile	Ethylene	Methyl prazine
Alkyl benzene	Ethyl benzene	Phenol
Benzaldehyde	Ethynyl benzene	Propene
Benzene	Formaldehyde	2-Propylene nitrile
Butadiene	Furfural (aldehyde)	Pyridine
Butene	Hexadeconic acid	Pyrrole (amine)
3-Butenenitrile	Hydrogen cyanide	Styrene
Carbon monoxide	Indole (amine)	Toluene (hydrocarbon)
Creosol	Isobutene	1-Undecene (hydrocarbon)
1-Decene (hydrocarbon)	Methane	Xylene
2,3-Dihydro indene (hydrocarbon)	3-Methyl butenal (adlehyde)	
	6-Methyl indole (amine)	

Figure 28 – Chemicals Contained in Surgical Smoke

Before the procedure, the perioperative nurse should determine the volume of smoke that will be produced and select the appropriate smoke evacuation system. The vacuum source should be portable, easy to set up and use. A filtration system with a triple filter offers the greatest protection. The systems consists of a prefilter to filter out large particles, an ULPA (Ultra Low Penetrating Air) filter to capture microscopic particles and a charcoal filter to adsorb or bind to toxic gases produced during the procedure (Figure 29).

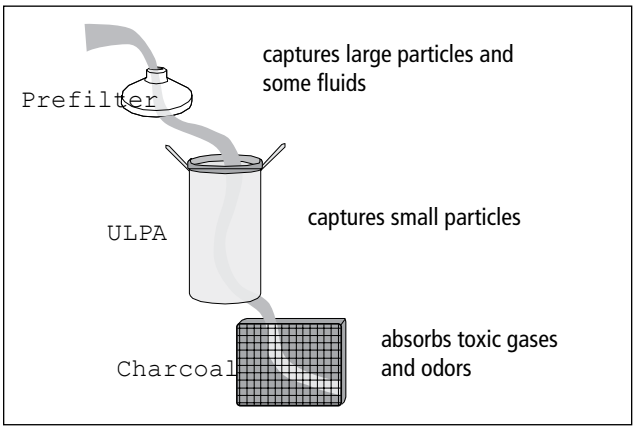


Figure 29 – Triple Filter System

The vacuum source should be able to adequately pull sufficient air through the system to capture the smoke, about 50 cubic feet per minute of air. A system powerful enough to handle the amount of smoke produced is the most effective evacuator, and offers the perioperative nurse the flexibility to select the appropriate capture device. A smoke evacuator which has variable power settings will be of most use in a wide variety of surgical procedures (Figure 30).

Figure 30 – Smoke Evacuator System

There are also different capture devices that can be attached to the smoke evacuator. The most convenient is the smoke carriage that attaches to the electrosurgical pencil (Figure 31). This has the advantage of being in direct proximity to where the smoke originates, which is the recommended location to most efficiently capture smoke. For larger volumes of smoke, the larger capture tubing may be needed. The most efficient and effective system configuration should be selected for every surgical procedure in which smoke is produced.

Figure 31 – Electrosurgical Pencil with Smoke Evacuation Attachment

MINIMALLY INVASIVE SURGERY:

POTENTIAL MONOPOLAR ELECTROSURGICAL HAZARDS

Since the 1980s the number and type of minimally invasive surgery (MIS) procedures has steadily increased, and that trend is expected to continue (Figure 32). The surgery suite and outpatient surgery department are not the only places where MIS procedures are done. Endoscopy suites as well as radiology have seen a rise in the number of cases, and the complexity of procedures done in a minimally invasive manner. As the number of MIS procedures has increased so too have patient safety issues related to the use of **monopolar electrosurgery**. There have been reports of severe illness and death following laparoscopy in which radiofrequency **current** was implicated (ECRI, 1995). There are hazardous situations that may develop as a result of the endoscopic use of **electrosurgery**. Some of these are:

- Direct coupling
- Insulation failure
- Capacitive coupling
- Residual heat injuries
- Endosurgical smoke
- Electromagnetic interference

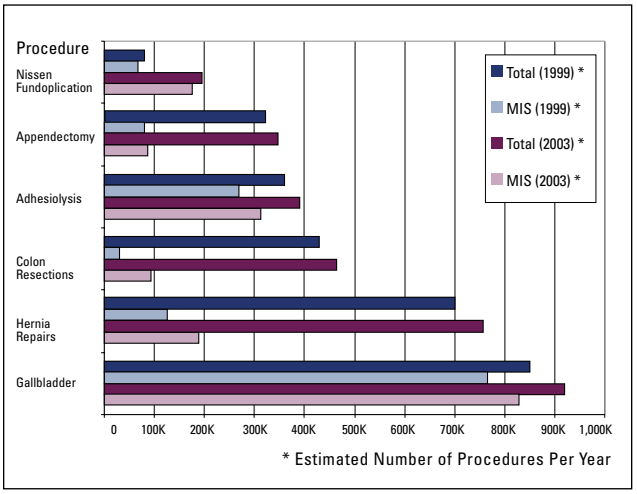


Figure 32 – Growth of Laparoscopic Surgery Procedures (From BioMaterials & Surgery 1999)

Each of these can cause adverse patient outcomes that may result in injury. Perioperative practitioners should be aware of how and when these factors occur and how to reduce the risk to the patient. In determining the root cause of potential hazards it is useful to divide the **active electrode** and cannula system into four zones (Figure 33):

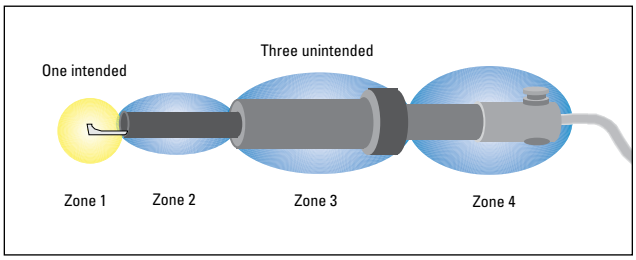


Figure 19 – Four Zones of Injury

- Zone 1 – The small area at the tip of the **active electrode**, and the only area in direct view of the surgeon
- Zone 2 – The area just beyond the **active electrode** tip to the end of the cannula, outside the surgeon's view
- Zone 3 – The area of the **active electrode** covered by the cannula system, also outside the view of the surgeon
- Zone 4 – The portion of the **active electrode** and cannula that is outside the patient's body

The greatest concern and potential patient hazard is the incidence of unseen stray radiofrequency **current** in Zones 2 and 3, outside the surgeon's view, due to stray **current** from **insulation failure**, **direct coupling** or **capacitive coupling** (Wu, 2000).

Direct coupling occurs when the **active electrode** is activated in close proximity or in direct contact with other conductive instruments within the patient's body. **Direct coupling** can occur in Zones 1, 2 or 3. If **direct coupling** occurs outside the field of vision of the surgeon and the **current** is sufficiently concentrated, patient injury can occur.

Insulation failure occurs when the insulating coating on the **active electrode** is compromised. This can happen in multiple ways that range from instrument damage due to rough handling to an insulation defect that results from using a high **voltage** electrosurgical **current**, such as **coagulation**. Insulation damage can occur during instrument cleaning, but it can also develop during surgery from repeated insertions into the cannula system. High **voltage** radiofrequency **current** can be powerful enough to blow a hole through intact **active electrode** insulation. The **voltage** can be as high as 8,000 to 10,000 volts of electricity, depending on how the surgeon uses the **active electrode**. There is also concern that some **active electrodes** may not meet the standards for electrosurgical devices set by the Association for the Advancement of Medical Instrumentation (AAMI). Integrity of insulation coating may vary among manufacturers. **Insulation failure** that occurs in Zones 2 or 3 could escape detection by the surgeon and cause injury to adjacent body structures if the **current** is delivered in a concentrated manner (Figure 34).

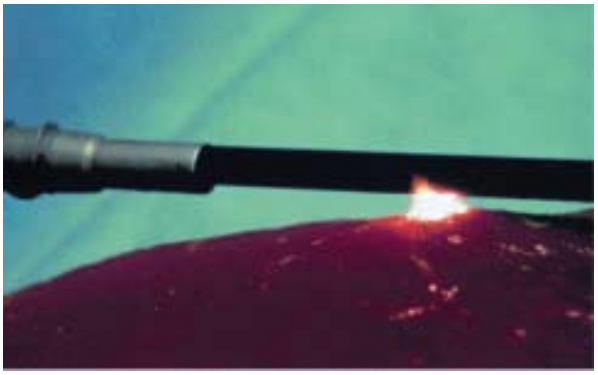


Figure 34 – Insulation Failure

Capacitive coupling is perhaps the least understood of the potential endoscopic electrosurgical hazards. The definition of a capacitor is two conductors separated by an insulator. Laparoscopically a capacitor is created by inserting an **active electrode**, surrounded by its insulation, into a metal cannula (Figure 35).

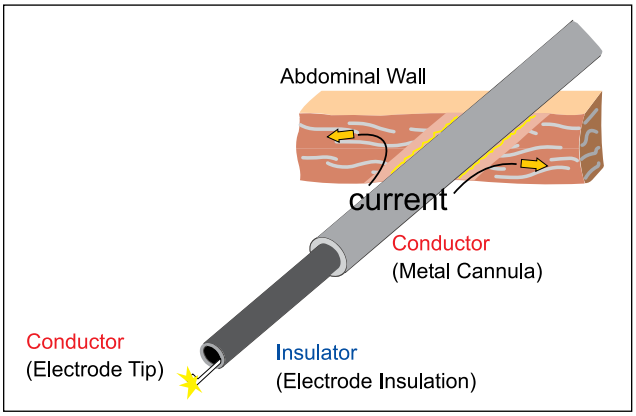


Figure 35 – Capacitor Active Electrode/Cannula

When the **active electrode** is activated by the surgeon, capacitively coupled electrical **current** can be induced from the **active electrode** into the conductive metal cannula. Should the cannula then come in contact with body structures, the energy can be discharged into adjacent structures and cause injury (Munro, 2004). When using an all-metal cannula any electrical energy stored in the cannula will tend to disperse into the patient through the relatively large contact area between the cannula and the muscular abdominal wall. The large area of contact serves to disperse the electrical energy, which is far less dangerous than areas of higher concentration. For this reason, it is unwise to use plastic anchors to secure the cannula because the plastic anchors isolate the electrical **current** from the abdominal wall and increase the likelihood that it could accumulate on other areas of the cannula. There are some steps perioperative personnel and surgeons can take

to reduce the risk of patient injury during laparoscopic use of **electrosurgery**:

- Inspect insulation carefully.
- Use the lowest possible power setting.
- Use the low voltage (cut) waveform (Munro, 2004).
- Use brief intermittent activations versus prolonged activations of the **active electrode.**
- Do not open **circuit** activate the **active electrode.**
- Do not activate the **active electrode** in close proximity or in direct contact with metal or conductive objects in the abdomen.
- Use **bipolar electrosurgery** when possible.
- In the **active electrode** operative channe.l
  - Select an all-metal cannula system as the best choice to disperse electrical buildup along the cannula.
  - Do not use hybrid systems (metal and plastic components).

One of the most important ways to increase patient safety during laparoscopy is to take advantage of improvements in technology. Advancements in technology most often exist to solve problems that were present in older generations of devices, and the improvements make surgery safer for patients and practitioners alike. Technological improvements include:

- Tissue response generators to reduce **capacitive coupling** in the low voltage waveform.
- Tissue sensing generators to reduce **capacitive coupling** in both the cut and **coagulation** waveforms.
- Vessel sealing generators to take advantage of the full capabilities of bipolar-type instruments.
- **Active electrode monitoring** to minimize concerns about insulation failure and **capacitive coupling**:
  - Risks posed to the patient by insulation failure and **capacitive coupling** can be reduced by using an **active electrode monitoring** (AEM) system. The **active electrode monitoring** system is used with an electrosurgical generator (Figure 36). The system continuously monitors and actively shields against stray electrosurgical current. The **active electrode monitoring** system is one of the most effective means to minimize the potential patient injuries due to insulation failure or **capacitive coupling** (Dennis, 2005).

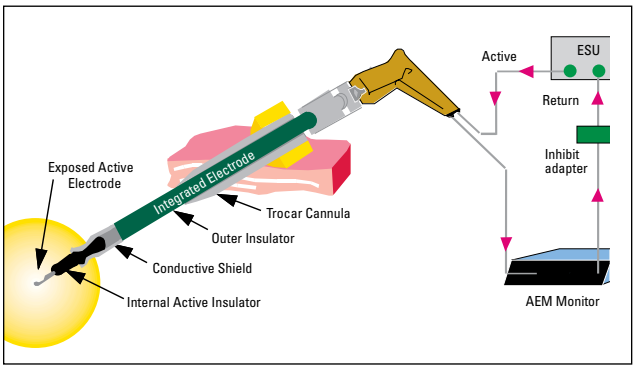


Figure 36 – Active Electrode Monitoring

ELECTROSURGICAL ACCESSORIES

Electrosurgical generators are only part of the electrosurgical system. The generators are only 25 percent of the electrosurgical equation. The other 75 percent of the system are the pencil, the **patient return electrode** and the user. "These three have much higher problem rates than does the **generator**" (Harrington, 1994). Perioperative practitioners should be knowledgeable about electrosurgical accessories, including their safe and effective use.

ACTIVE ELECTRODES

The **active electrode** is the component of the electrosurgical system that delivers concentrated electrical **current** to patient tissues. There is a wide assortment of **active electrodes** that can be used with both bipolar and **monopolar electrosurgery**. **Active electrode** pencils or forceps may be controlled by hand switches on the pencil or by foot pedals. Pencils tips are available in a wide variety of configurations—needles, blades, balls and loops, to name a few (Figure (37). There are many **active electrodes** available for laparoscopic use. Some **active electrodes** offer a combination of suction and **coagulation** in the same handpiece. **Active electrodes** are available as disposable and reusable products, and some are what is referred to as "reposable." Reposable products are used for a certain number of times and then discarded.

Figure 37 – Active Electrodes

One of the potential hazards associated with **active electrode** tips is buildup of eschar on the tip. Eschar buildup greatly increases the **impedance** or **resistance** of the tip, and, it can represent a fire hazard. With sufficient heating, eschar can become a glowing ember and can pose a fire hazard both as an ignition source and a fuel source. If eschar is on the **active electrode** tip, the scrub person should remove it according to the manufacturer's recommendations. Scratch pads can be used to remove the eschar, but with each scratch microgrooves are left behind. As the eschar builds up in the groves, it becomes impossible to remove and the tip becomes higher in **resistance**. Nonstick **active electrode** tips can facilitate the removal of eschar, but does not eliminate the need for frequent cleaning. Tips made of materials such as Teflon® (PTFE) or elastomeric silicone coating can be cleaned with a damp sponge (Figure 38). A damp sponge is recommended because **active electrode** tips are extremely hot immediately after activation. Use of a damp sponge will make cleaning easier and reduce the risk of accidental ignition of the sponge. Coated tips should be used according to the manufacturer's recommendations, which includes use of appropriate power settings.

Figure 38 – Coated Active Electrodes

HOLSTERS

Holsters are one of the most important safety devices available to surgeons and perioperative nurses. When the **active electrode** is not in use, it should be in a holster that is visible to the surgical team and in easy reach of the surgeon and scrubbed person. It is, however, the responsibility of any person who is scrubbed to ensure that when the **active electrode** is not in use, it is in a holster recommended by the manufacturer. Only holsters recommended by the manufacturer meet safety standards for heat and fire resistance. Use of plastic pouches, folded towels or other makeshift holsters are a threat to patient safety and should never be used.

PATIENT RETURN ELECTRODES

Patient return electrodes, also called grounding pads, bovie pads, neutral electrodes or patient plates, remove monopolar **current** safely from the patient. There are many types of return electrodes that can be used ranging from metal plates to large gels pads to dual section foam pads. Reusable metal plates are made of stainless steel and fit under the patient. A later edition of the metal plate was a foil-coated cardboard plate. Whenever metal plates are used, conductive gel must be used to make the patient's skin more conductive and to fill any voids in contact between the plate and the patient's skin. As with anything that is placed under the patient, contact is dependent on patient size, and conditions between the patient and the plate. Something that the patient lies on does not conform to body contours and effectiveness may vary as points of contact with the plate vary. A most important consideration for patient safety is that none of the metal plates have **contact quality monitoring** capabilities.

Water-based gel foam pads replaced the metal or cardboard plates in most operating rooms. They are disposable and come in many sizes and shapes. These adhere well to body contours,

and usually have an adhesive edge to hold the **pad** on the patient. When using a **pad** that is made of water-based gel, care must be taken to store cartons flat to prevent the gel from migrating to one side of the **pad**. If a **pad** is used that has a greater concentration of gel on one side, uneven heating and a **pad** site burn could occur. The water-based nature of these pads also means that storage time is limited otherwise the gel will dry out. Pads that dry out will have reduced conductivity and could also result in a burn. When using water-based gel pads, care must be taken to rotate stock and store cartons properly.

Conductive adhesive pads replace gel with a layer of adhesive over the **pad** surface. The adhesive maintains good contact with the patient's skin, increasing the conductivity of the **pad**. These pads come in two basic types—a dry conductive adhesive or a high-moisture conductive adhesive. Both have the capability of conforming well to the patient's varying body contours. This type **pad** is also available in the split dual section design that denotes it is part of a quality contact monitoring system. If the **generator** interrogation **circuit**, used with a dual section **pad**, senses conditions that could cause a patient injury, the system will inactivate the output of the **generator**.

Proper placement of the **patient return electrode** is one of the most important considerations in the safe use of the electrosurgical system. The **patient return electrode** should always be placed on a large muscle mass as close to the surgical site as possible. Muscle and blood are the best conductors of the electrical energy in the patient's body. Higher **resistance** tissue, such as scar tissue and any bony prominence, should also be avoided. Patient tissues that are higher in **resistance** slow down the passage of the **current** through the patient's body. As more **impedance** or **resistance** is encountered, the greater the likelihood an electrosurgical burn could occur (Fairchild, 1996). Grounding pads should not be placed over metal prostheses because the scar tissue surrounding the implant increases **resistance** to the flow of electrical **current**. The pad site should be clean, dry, and free from excessive hair. The grounding **pad** should not be placed where fluids are likely to pool during surgery. If the patient has a pacemaker, the return electrode should be placed as far from it as possible. The pacemaker manufacturer should be consulted to determine if the pacemaker is susceptible to electrical interference.

It is also important to read and follow manufacturer's recommendations for the dispersive electrode being used. Safety features, such as quality contact monitoring systems, should never be bypassed. These recommendations are legal and binding instructions for using the product. Failure to follow recommended use could constitute negligence should a patient injury occur.

PERIOPERATIVE CARE OF THE PATIENT

Nursing care of the patient during **electrosurgery** can be enhanced by following routine and systematic procedures. Points to consider during perioperative care of the patient during **electrosurgery** include, but are not limited to:

PREOPERATIVE

- Know which ESU will be used and how to use it. Consult the instruction manual for specific instructions or questions.
- Have all equipment and accessories available, and use only accessories designed and approved for use with the unit.
- Check the operation of the alarm systems.
- Avoid the use of flammable anesthetics.
- Place EKG electrodes as far away for the surgery site as possible.
- Do not use needle electrodes. They may transmit leakage current.
- Check the line cord and plug on the ESU. Extension cords should not be used.
- Do not use any power or accessory cord that is broken, cracked, frayed or taped.
- Check biomedical sticker to insure the generator has undergone a current inspection.
- Cover the foot pedal with a plastic bag.
- Document generator serial number on the perioperative record.
- Record exact anatomical pad position and skin condition of the pad site.
- Never cut or alter a grounding pad.

INTRAOPERATIVE

- If alcohol-based skin preparations are used, they should be allowed to dry prior to draping.
- Use the lowest possible power settings that achieve the desired surgical effect. The need for abnormally high settings may indicate a problem within the system.
- Position cords so that they present no tripping hazard. Do not roll equipment over electrical cords.
- If the patient is moved or repositioned, check that the patient return electrode is still in good contact with the patient. Patient return electrodes should not be repositioned. If the patient return electrode is removed for

any reason, a new pad should be used.

- When an **active electrode** is not in use, remove it from the surgical field and from contact with the patient. A manufacturer-recommended insulated holster should always be used.
- Do not coil **active electrode** cords. This will increase leakage current and may present a potential danger to the patient.
- If possible, avoid "buzzing" hemostats in a way that creates metal to metal arching. If "buzzing" a hemostat is necessary, touch the hemostat with the **active electrode** and then activate the generator. This will help eliminate unwanted shocks to surgical team members.
- Use endoscopes with insulated eye pieces.
- Keep **active electrodes** clean. Eschar buildup will increase resistance, reduce performance and require higher power settings.
- Do not submerse active accessories in liquid.
- Note the type of **active electrode** used on the perioperative record.
- If an ESU alarm occurs, check the system to ensure proper function.
- Do not use the generator top as a storage space for fluids. Spills could cause malfunctions.

POSTOPERATIVE

- Turn all controls to zero (or minimum).
- Turn off the electrosurgical unit.
- Disconnect all cords by grasping the plug—not the cord.
- Inspect patient return electrode site to be sure it is free of injury (AORN, 2006).
- Inspect the patient return electrode after removal. If an undetected problem has occurred, such as a burn, evidence of that burn may appear on the pad.
- Discard all disposable items according to hospital policy.
- Remove and discard the plastic bag covering the foot pedal.
- Clean the ESU, foot pedal and power cord.
- Coil power cords for storage.
- Clean all reusable accessories.
- Routine Care and Maintenance of ESU Equipment.
- Routinely replace all reusable cables and **active electrodes** at appropriate intervals, depending upon usage.
- Have a qualified biomedical engineer inspect the unit at least every six months.
- If an ESU is dropped, it should not be used until it can be inspected by a biomedical engineer.
- Replace adapters that do not provide tight connections.
- Inspect "permanent" cords and cables for cracks in the insulation.
- Proper use and maintenance of electrosurgical equipment can prolong its life and reduce costly repairs.

SUMMARY

Surgeons and perioperative nurses have the opportunity to combine evidence-based practice with unique technical skills and knowledge to achieve high-quality, safe patient care. The importance of skill and knowledge is particularly critical during the use of **electrosurgery**. An educated perioperative team is the patient's best advocate.

GLOSSARY

Active Electrode
An electrosurgical instrument or accessory that concentrates the electric (therapeutic) current at the surgical site.

Active Electrode Monitoring
A system that continuously conducts stray current from the laparoscopic electrode shaft back to the generator and away from patient tissue. It also monitors the level of stray current and interrupts the power should a dangerous level of leakage occur.

Alternating Current
A flow of electrons that reverses direction at regular intervals.

Bipolar Electrosurgery
Electrosurgery in which current flows between two bipolar electrodes that are positioned around tissue to create a surgical effect (usually desiccation). Current passes from one electrode through the desired tissue to another electrode, thus completing the circuit without entering any other part of the patient's body.

Bipolar Instrument
Electrosurgical instrument or accessory that incorporates both an active and return electrode pole.

Blend
A waveform that combines features of the cut and coag waveforms; current that cuts with varying degrees of hemostasis.

Capacitive Coupling
The condition that occurs when electrical current is transferred from one conductor (the active electrode) into adjacent conductive materials (tissue, trocars, etc.).

Cautery
The use of heat or caustic substances to destroy tissue or coagulate blood.

Circuit
The path along which electricity flows.

Coagulation
The clotting of blood or destruction of tissue with no cutting effect, electrosurgical fulguration and desiccation.

Contact Quality Monitoring
A system that actively monitors tissue impedance (resistance) at the interface between the patient's body and the patient return electrode, and interrupts the power if the contact quality and/or quantity is compromised.

Current
The number of electrons moving past a given point per second, measured in amperes.

Current Density
The amount of current flow per unit of surface area; current concentration directly proportional to the amount of heat generated.

Current Division
Electrical current leaving the intended electrosurgical circuit and following an alternate path ground; typically the cause of alternate site burns when using a grounded generator.

Cut
A low-voltage, continuous waveform optimized for electrosurgical cutting.

Cutting
Use of the cut waveform to achieve an electrosurgical effect that results from high-current density in the tissue causing cellular fluid to burst into steam and disrupt the structure. Voltage is low and current flow is high.

Desiccation
The electrosurgical effect of tissue dehydration and protein denaturation caused by direct contact between the electrosurgical electrode and tissue. Lower current density/concentration than cutting.

Diathermy
The heating of body tissue generated by resistance to the flow of high-frequency electric current.

Direct Coupling
The condition that occurs when one electrical conductor (the active electrode) comes into direct contact with another secondary conductor (scopes, graspers). Electrical current will flow from the first conductor into the secondary one and energize it.

Direct Current
A flow of electrons in only one direction.

Electrosurgery
The passage of high-frequency electrical current through tissue to create a desired clinical effect.

ESU
ElectroSurgical Unit.

Frequency
The rate at which a cycle repeats itself. In electrosurgery, the number of cycles per second that current alternates.

Fulguration
Using electrical arcs (sparks) to coagulate tissue. The sparks jump from the electrode across an air gap to the tissue.

Generator
The machine that coverts low-frequency alternating current to high-frequency electrosurgical current.

Ground, Earth Ground
The universal conductor and common return point for electric circuits.

Grounded Output
The output on a electrosurgical generator referenced to ground.

Hertz
The unit of measurement for frequency, equal to one cycle per second.

Impedance
Resistance to the flow of alternating current, including simple direct current resistance and the resistance produced by capacitance or inductance.

Insulation Failure
The condition that occurs when the insulation barrier around an electrical conductor is breached. As a result, current will travel outside the intended circuit.

Isolated Output
The output of an electrosurgical generator that is not referenced to earth ground.

Leakage Current
Current that flows along an undesired path, usually to ground. In isolated electrosurgery, RF current that regains its ground reference.

Monopolar Electrosurgery
A surgical procedure in which only the active electrode is in the surgical wound; electrosurgery that directs current through the patient's body and requires the use of a patient return electrode.

Monopolar Output
A grounded or isolated output on an electrosurgical generator that directs current through the patient to a patient return electrode.

Ohm
The unit of measurement of electrical resistance.

Pad
A patient return electrode.

Patient Return Electrode
A conductive plate or pad (dispersive electrode) that recovers the therapeutic current from the patient during electrosurgery, disperses it over a wide surface area and returns it to the electrosurgical generator.

Power
The amount of heat energy produced per second, measured in watts.

Radio Frequency
Frequencies above 100 kHz; the high-frequency current used in electrosurgery.

Resistance
The lack of conductivity or the opposition to the flow of electric current, measured in ohms.

RF
Radio frequency.

Tissue Response Technology
An electrosurgical generator technology that continuously measures the impedance/resistance of the tissue in contact with the electrode and automatically adjusts the output accordingly to achieve a consistent tissue effect.

Tissue Fusion Technology
An electrosurgical technology that combines a modified form of electrosurgery with a regulated optimal pressure delivery by instruments to fuse vessel walls and create a permanent seal.

Volt
The unit of measurement for voltage.

Voltage
The force that pushes electric current through resistance; electromotive force or potential difference expressed in volts.

Watt
The unit of measurement for power.

Waveform
A graphic depiction of electrical activity that can show how voltage varies over time.

Electrosurgery Self-Study Guide

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SELF-STUDY GUIDE TEST QUESTIONS

1.) Electricity always seeks
   a.) the path of most resistance to return to earth ground.
   b.) the path of most resistance to return to its source.
   c.) the path of least resistance to return to earth ground.
   d.) the path of least resistance to return to its source.

2.) The properties of electricity include
   a.) current, circuit, resistance and voltage.
   b.) current, ground, current and voltage.
   c.) current, resistance, hertz and voltage.
   d.) current, circuit, ground and amperage.

3.) Neuromuscular stimulation from the flow of alternating electric current ceases at frequencies above
   a.) 50,000 cycles per second.
   b.) 100,000 cycles per second.
   c.) 200,000 cycles per second.
   d.) 350,000 cycles per second.

4.) When current concentration/density is high
   a.) the resistance is reduced.
   b.) the resistance is unaffected.
   c.) heat is produced.
   d.) heat is dissipated.

5.) A patient return electrode is not required when using bipolar electrosurgery because
   a.) the voltage is too low to cause an injury.
   b.) the voltage is confined to the target tissue.
   c.) the current is confined between the two poles of the instrument.
   d.) the current disperses in the tissue at the tip of the instrument.

6.) As the current concentration is increased
   a.) the power setting requirement is decreased.
   b.) the power setting requirement is increased.
   c.) the heat produced in the tissue remains the same.
   d.) the heat produced in the tissue is decreased.

7.) The cutting waveform can be modified to provide simultaneous hemostasis (blended waveform) by
   a.) decreasing the voltage and increasing the duty (on/off) cycle.
   b.) increasing the voltage and decreasing the duty cycle.
   c.) decreasing the voltage and decreasing the duty cycle.
   d.) increasing the voltage and increasing the duty cycle.

8.) Contact quality monitoring is a system that
   a.) constantly monitors the quality of the pad/patient interface.
   b.) constantly monitors the quality of the generator/pad interface.
   c.) combines isolated and interrogation circuitry to monitor output.
   d.) combines isolated and interrogation circuitry to monitor resistance.

9.) The hazards associated with endoscopic electrosurgery use include all of the following except
   a.) direct coupling.
   b.) current division.
   c.) insulation failure.
   d.) capacitive coupling.

10.) Tissue response technology incorporates a computer-controlled tissue feedback system that
   a.) automatically changes the power settings.
   b.) automatically reduces the amount of power required.
   c.) senses the conductivity of the target tissue.
   d.) senses the impedance/resistance of the target tissue.

11.) The smoke produced from the electrosurgical device is
   a.) not as harmful as laser plume, and need not be evacuated.
   b.) not as harmful as laser plume, but should be evacuated.
   c.) potentially as harmful as laser plume, and evacuation is recommended.
   d.) potentially as harmful as laser plume, and evacuation is optional.

12.) The site selected for the patient return electrode should be all of the following except
   a.) over a large muscle mass.
   b.) as close to the surgical site as possible.
   c.) protected from fluid invasion.
   d.) close to a pacemaker to divert the current.

13.) Tissue fusion technology is incorporated into a specialized electrosurgical generator that combines
   a.) modified monopolar electrosurgery with regulated pressure delivery.
   b.) modified bipolar electrosurgery with regulated pressure delivery.
   c.) increased voltage electrosurgery with decreased pressure delivery.
   d.) decreased voltage electrosurgery with decreased pressure delivery.

TEST KEY

1.) c	5.) c	9.) b	13.) b
2.) a	6.) a	10.) d	
3.) b	7.) b	11.) c	
4.) c	8.) a	12.) d	

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EVALUATION

We appreciate your comments and evaluation of this offering which will assist us in planning future educational programs.

	Yes	No
1. Did the activity meet the stated objectives?	❑	❑
• Relate the properties of electricity to the clinical applications of electrosurgery.	❑	❑
• Review four of the variables the surgeon controls that impact surgical effect.	❑	❑
• Discuss the relationship between current concentration and tissue effect.	❑	❑
• Identify potential patient injuries related to electrosurgery and technological advances designed to eliminate these problems.	❑	❑
2. Did the activity meet your personal learning objectives?	❑	❑
3. Do you plan on changing any aspect of your practice as a result of this activity? If yes, what?	❑	❑

Scoring Key: 5=Excellent 4=Good 3=Average 2=Fair 1=Poor

Organization of content	5 4 3 2 1
Effectiveness of this learning method	5 4 3 2 1
Relevance of content to practice	5 4 3 2 1
Relevance of test questions to content	5 4 3 2 1
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Suggestions for additional topics to be presented in this format: ____

How much time did it take to complete this activity? _____

Comments: _____

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TEST QUESTION RESPONSES

Please circle the correct response.

1. a b c d	6. a b c d	10. a b c d
2. a b c d	7. a b c d	11. a b c d
3. a b c d	8. a b c d	12. a b c d
4. a b c d	9. a b c d	13. a b c d
5. a b c d		

EXPIRATION DATE

This offering was originally produced for distribution in **September 2009** and cannot be used after September 2012 without being updated. Therefore, credit will not be issued after **September 30, 2012.**

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