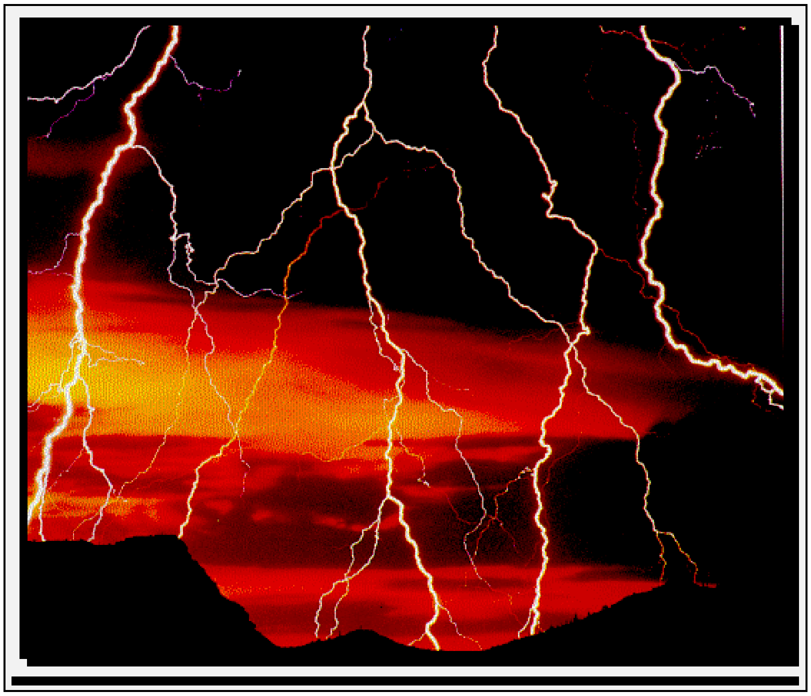
PRACTICAL ELECTROSURGERY

For Clinicians



** Multi-Media CD-ROM's on Laser and Electrosurgery (with testing & certificates) are available on the website*
These are excellent for Resident and Staff training programs

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Special thanks to Valleylab and Erbe for use of some of the graphics in this manual.

Practical Electrosurgery

Did you know this about the "Coag" mode on electrosurgical units?:

- "Coag" is NOT the mode to choose when "buzzing" a bleeder through a hemostat.
- When you "zap" yourself through a glove it is usually caused by use of the "Coag" mode, and NOT an initial hole in your glove.

Did you know this about the "Cut" mode?:

- This is the BEST way to get deep coagulation of structures such as for tubal sterilization's or deep hemostasis within a structure.
- In Hysteroscopy, this is the BEST way to get hemostasis while using the roller ball or barrel.

Did you know that when using Bipolar Coagulation?:

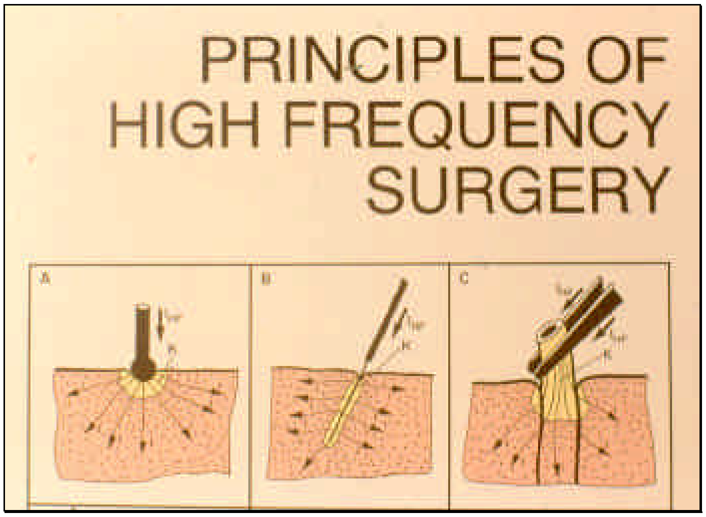
- That the coagulating current is NOT necessarily confined to only the small area between the tines of your grasper?
- That there are now available bipolar cutting and resecting electrodes?

***READ ON!* - This practical manual will review the biophysical basis for electrosurgery, practical safety considerations and the surgical implications of various technical variations of equipment.**

High Energy Surgical Instruments

Surgical instruments today span a wide range of devices - from the "low tech" end of simple sharp knife, to the "high tech" end of nanosecond pulsed surgical laser systems. With the advent of High Energy surgical devices now available - such as electrosurgery, cavitational ultrasonic aspirators, harmonic (ultrasonic) knives, cryosurgery, various laser systems and endocoagulators - it is useful to view these various devices simply as different means of delivering energy to tissue. Even a simple scalpel may be viewed as delivering mechanical energy to tissue at a concentrated pressure point (the blade edge) to incise tissue. No one particular system is inherently better than the others for all surgical purposes. Each may have advantages in certain situations, and user preference is frequently only a personal bias, influenced by past familiarity and training with a system.

In electrosurgery, an understanding of basic electrical conduction, heating and vaporization of tissue, allows these units to be used safely in a wide variety of circumstances.
The relative advantages of electrosurgery versus laser have been confused in recent years - particularly for laparoscopic use. **Though it is true that electrosurgery is less expensive, easier to use and provides better hemostasis than laser, it is *NOT* true that electrosurgery is an inherently "safer" modality than laser. The quintessential advantage of laser lies in its very precise, predictable and controllable tissue effects.** The question of whether this high degree of control is worth the added cost and encumbered use will vary from procedure to procedure and user to user.



A simplified review of basic electrical concepts will go a long way toward gaining the best use from electrosurgical units. We'll present a simplified version up-front here, then expand these technical concepts in the Appendices for those who have the interest.

Electricity is attraction of two oppositely charged particles, arbitrarily referred to as positive and negative. When an electrical connection (such as an electrode on tissue) is made between the two poles of positive and negative, an electrical current will flow between them. This is an exchange of electrons along the pathway.

Electricity must have two poles in order to flow. This is why standard household plugs have two metal prongs. In electrosurgical units, when these two poles are localized in one instrument or probe, it is referred to as a **bipolar unit,** since both poles are contained within the one instrument. When one of the poles is an instrument, and the other a remotely located ground pad (dispersive electrode), it is referred to as a **monopolar, or unipolar** instrument, since the instrument is only one of the two poles.

Direct current is the most simple of circuits, such as contained in a flashlight using batteries. Figure 4 compares the simplified circuit of the flashlight to an electrosurgical power supply where the switch is the foot or handswitch, the patient becomes the resistor (R) in the circuit, and the flow of electricity is the current (I, for Induced Current). Electricity must have the two poles in order to flow.

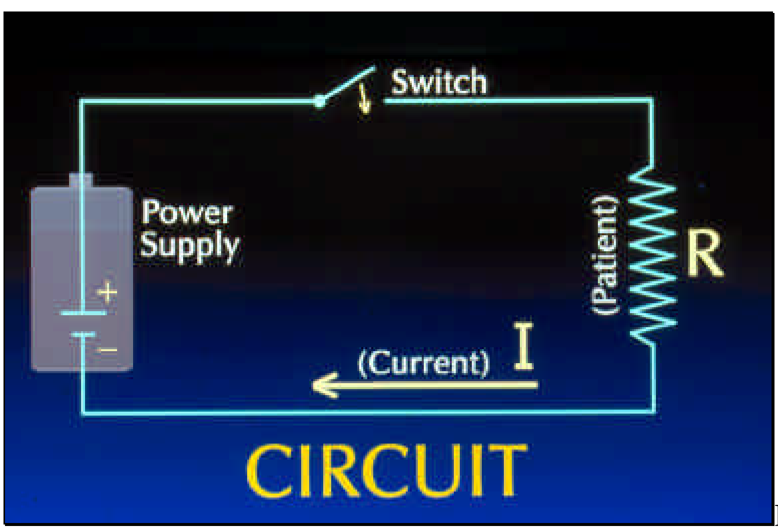


Fig 4

Alternating Current (AC) takes the concept of positive and negative just one step further by quickly reversing the polarity, or order of positive and negative, back and forth (Figure 5). AC is the type of electricity we find in household electrical outlets. At home the AC circuit reverses about 60 times per second, or 60 hertz (Hz). This frequency of AC electricity can directly interfere with our own biological electrical frequencies and result in shocks or stopping of the heart. The ability of electricity to create this type of interference with our own bodies - muscle tetany and contraction, interference with normal heart rhythms, etc. - is termed the Faradic effects of electricity.

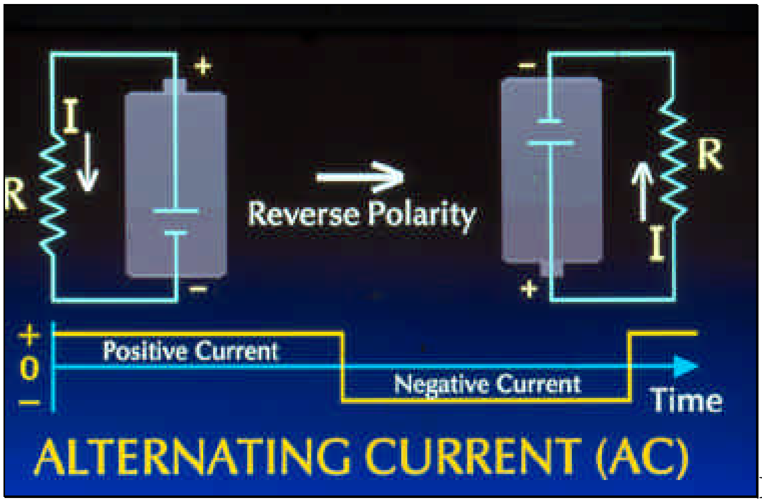


Fig 5

An actual monopolar ESU circuit shows the electrosurgical probe introducing the current which finds its way to the dispersive electrode and back to the power supply. (Figure 6)

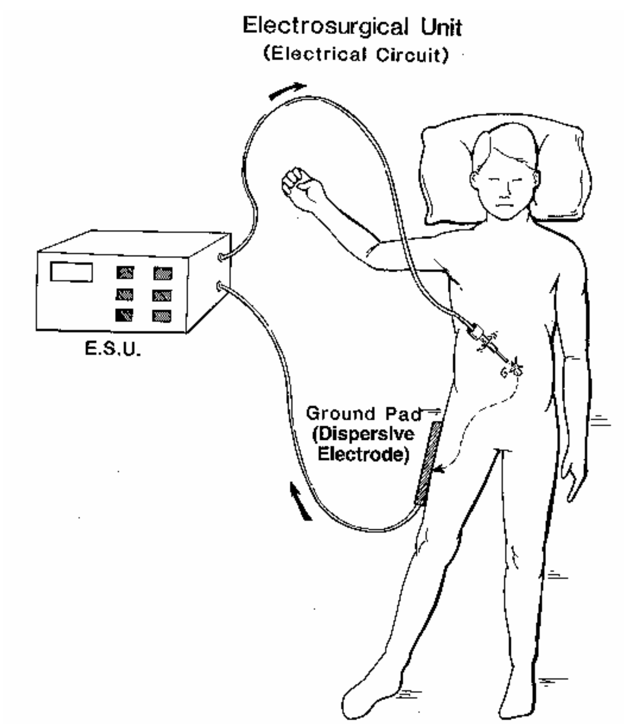
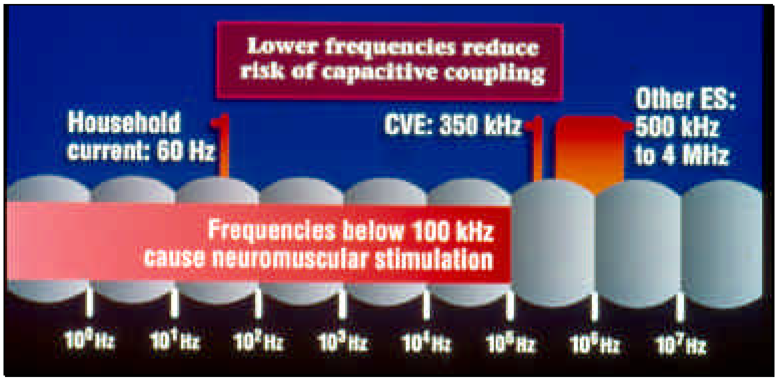


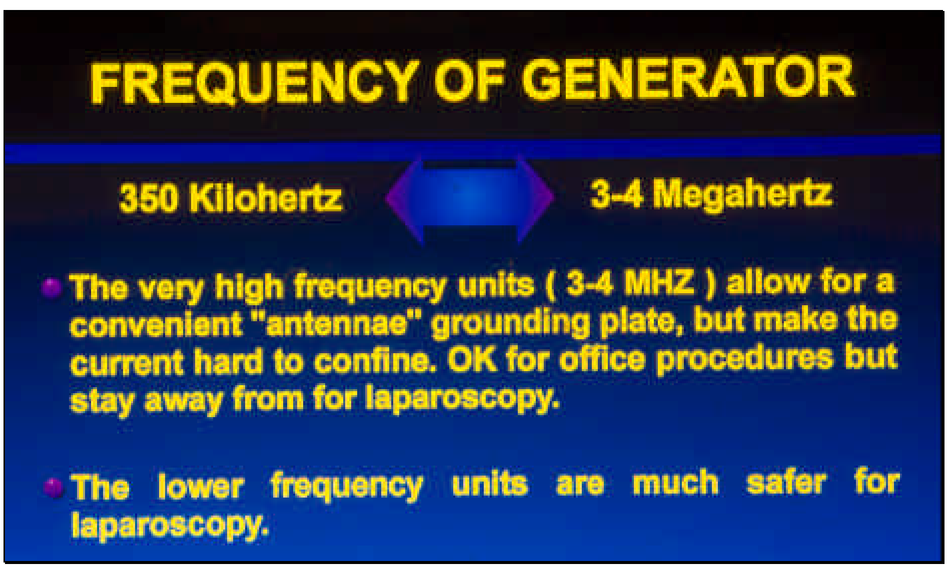
Fig 6

Electrosurgical units utilize AC electricity but at significantly faster rates of reversal for the polarity. ESU's utilize frequencies of around 350,000 to 500,000 times per second, or Kilohertz (kHz). Some go up to 3 or 4 Megahertz (MHz). This extremely high frequency does not interfere with our own biological processes to any significant degree, so Faradic effects do not apply. These high frequencies are up in the range of AM radio station transmissions and beyond, and are referred to as **RF, or Radio Frequency current**. Television frequencies are up in the 800MHz range.



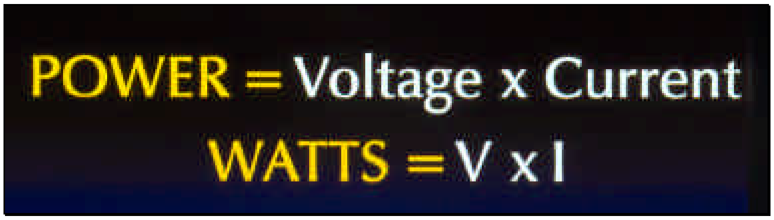
The neuromuscular stimulation effects, or "muscle twitching" are known as the Faradic effects of frequencies lower than about 100KHz. You'll see this muscle twitching effect sometimes with the use of ESU's above 350KHz when the electrode is "sparked" into tissues. The frequencies of the sparks can be much lower than the frequency of the ESU.

(Such sparking (using "Coag" mode and light to no tissue contact to create sparks) is appropriate for superficial fulguration and resulting hemostasis, but if deeper hemostasis is desired – such as coapting small bleeders – then desiccation is preferred by using good tissue contact (no sparking) and use of the "Cut" mode. Read on to learn more)



<u>The Question of "Cut" vs. "Coag" (i.e., Voltage vs. Current)</u>

When one chooses parameters to use on an ESU, a choice of "cut" or "coag" is made, and the power setting selected. The first basic electrical relationship we have is that of Power, or rate of energy delivery, expressed in Watts:



From a practical standpoint you can apply this to your home electricity. For instance, a 1500 watt hair dryer consumes about 14 amps of electricity (1500 watts divided by 110 volts). A 1000 watt microwave oven consumes about 9 amps. If both are connected to an outlet with a 20 amp circuit breaker, the circuit breaker will "pop" because it won't handle the 24 amps.. This means that your teenager cannot use the hairdryer at the same time you use the microwave oven! - if the outlets are on the same circuit breaker.

Power in watts is the "rate" at which the energy works, but doesn't tell you how much total energy you're putting into tissue, nor does it tell you the speed of the cut (this is dependent on the combination of power and electrode size.)

One can see below that Voltage and Current may be oppositely varied (balanced) and still deliver the same power output in watts. **This is approximately the choice we make in choosing the "cut" versus "coag" modes on the ESU[1]. "Cut" accentuates the current aspects of the equation, and "coag" that of the voltage.** (Figure 7) Associating these technical terms "cut and coag", and the physiological terminology of cutting and coagulating creates the wrong impression of how each modality is best used.

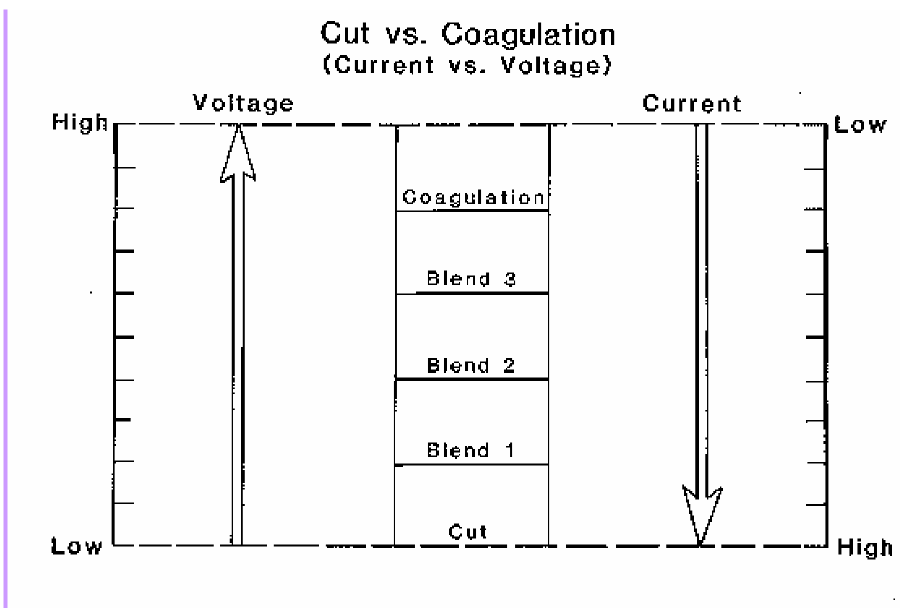


Fig 7

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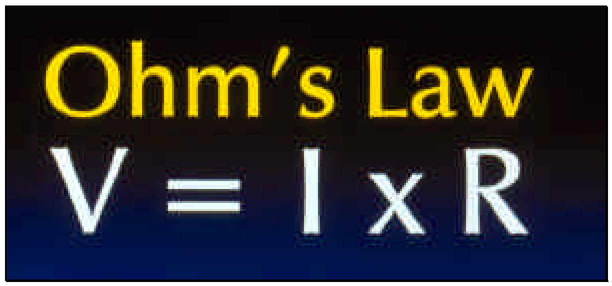
[1] **See appendix A for a more technically accurate description of these waveforms: cut, coag and blend settings**

Should you really know about these things simply to use an ESU for surgery?
You Bet!

One needn't delve deeply into the technical details, but a conceptual understanding of these parameters is important to an adept use of the instruments and the prevention of "stray current" injuries. As we discuss these electrical concepts, remember that you will usually adjust only the POWER setting and choose which MODE to use. The underlying voltages, currents and resistances will be invisible to you, but their implications are important.

Before we examine more of the implications of "cut" and "coag" modes on an ESU, we need to look at one more fundamental electrical relationship which describes the three electrical parameters of voltage(V), current(I) and resistance(R):



Voltage = Current x Resistance

This is a fundamental law of electricity called Ohm's law. The electrical units for measure of resistance are called "Ohms".

Remember that Voltage (V) and Current (I, for induced current) are factors of the power you have selected on the ESU (Watts = V x I) . Resistance is not controlled by the operator but is a function of the tissue. **We will see that voltage "drives" or pushes the current through tissue** against the tendency for tissue to "resist" this flow. As the flow is resisted, heat is generated in tissue.

Resistance[2] varies in different tissues. It may vary from 100,000 ohms for dry callused Palmer skin, to 2000 ohms for fat, to 400 ohms for muscle. High electrolyte tissues such as blood and muscle offer low resistance and easily transmit the electrical current. Skin and fat have higher resistance. More importantly, **as electricity is applied to tissue and it begins to desiccate or char, the tissue resistance will begin to change immediately**. A 40 watt setting may remain constant, but the voltage and current are in constant flux as a function of this varying tissue resistance, and distance from electrode to tissue. Changing voltages will then cause fluctuating levels of lateral damage from cut to cut, or even during the same excision.

Some ESU's sense this changing resistance in tissue, and allow the power to adjust accordingly to allow for constant voltage application[3]. - providing more consistent margins of lateral damage. These are termed constant voltage ESU's. Power is set on the unit, but does NOT remain constant. The power will fluctuate in order to keep the voltage constant, at a level to provide consistent, char free margins. (voltage determines the lateral extent of the burning or charring at the incision). ERBE, and several other units, utilize constant voltage units.

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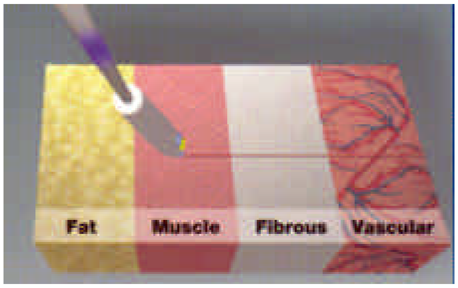
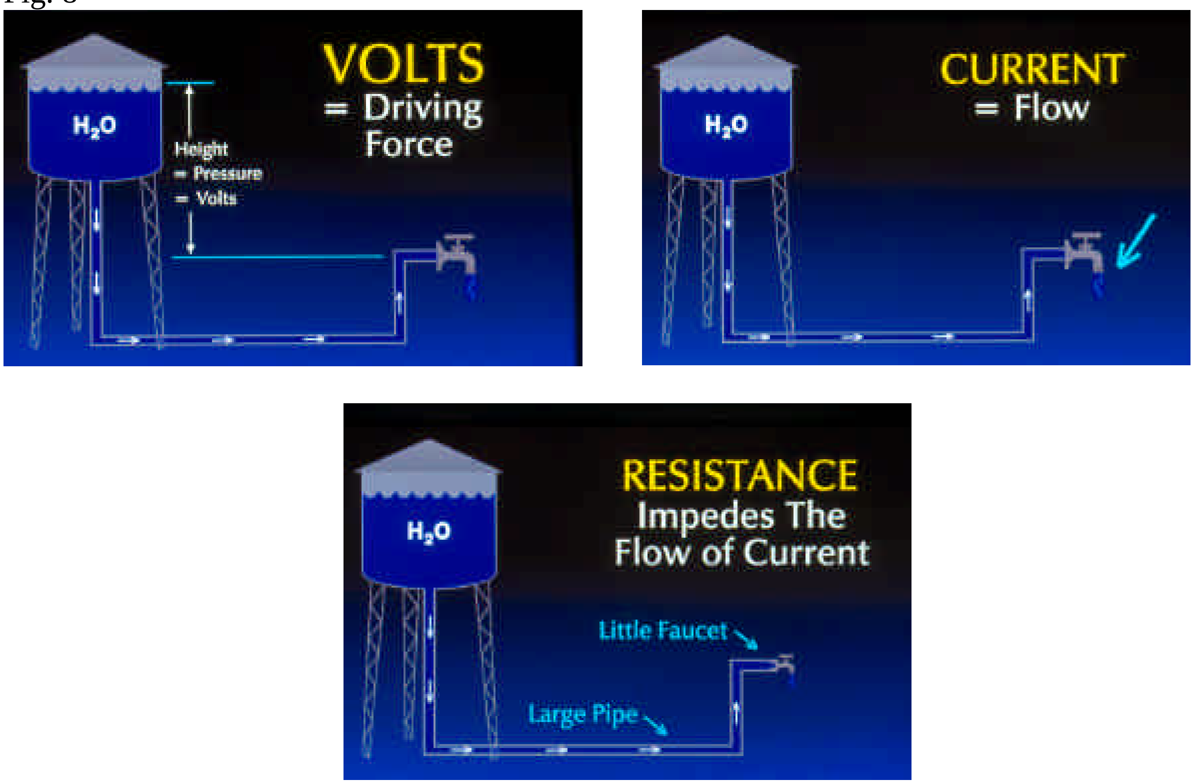
[2]**Impedance is actually the term we would use instead of resistance when referring to RF electricity**
[3]**See Appendix C on Constant Voltage generators**



Valleylab has developed what they term the "Instant Response™" technology. This computerized system senses tissue resistance at 200hz, and automatically adjusts voltages and current to compensate for differing tissue types and hand speed of the cut. Though the voltage is not held constant, it is limited at a threshold to prevent unwanted tissue charring and the other drawbacks of excessive voltage. It produces a consistent speed and feel of the cut for the surgeon even when going from one tissue type to another without dropping the power output of the unit. It minimizes capacitive coupling and reduces EMF interference with other O.R. equipment such as video systems.

Our understanding of the relevance of these electrical parameters of voltage, current and resistance is enhanced by the frequently used analogy of flowing water to the flow of electricity. Voltage is the driving pressure, or head, of the water and current refers to the actual flow of water in the pipe.

Fig. 8



Voltage is equivalent to the height of the water in the tower in figure 8. The higher the tower, the better the pressure "head" at the faucet. Voltage drives or pushes the current through tissue like pressure drives the water through the pipe. The "flow" of the water becomes the amperage, or current, in an electrical circuit – the larger the pipe, the more the water can flow. We have already mentioned that voltage is the parameter enhanced when choosing the "coag" mode on an ESU, and current (amperage) enhanced when choosing "cut".

The use of "coag" with a monopolar instrument will allow for a higher "driving force" (voltage) through all the tissues between the instrument and the dispersive electrode, and increasing the probability of "stray energy" damaging unintended tissues somewhere outside the immediate target area. The higher "driving force" also allows sparks to jump farther in air. This is seen with the long sparking when fulgurating tissue in "coag" mode. This high voltage "coag" is also the primary reason the current can "jump" through a surgical glove and "zap" the recipient. The hole you see in the glove was not there when the current first jumped - it was created by the heat of the spark. Electricity can jump right through insulators if given enough "driving force" of voltage[4]. This also applies to the insulation surrounding a monopolar instrument - particularly the disposable ones which have less insulation than reusables. **Don't reuse disposable insulated electrodes!**

Resistance results from the diameter of the pipes in our analogy, and the outlet size of the faucet or pipe. The greater the diameter, the less the resistance and the more the water will flow. One can increase water flow through the pipe by either increasing its diameter (lower resistance) or increasing the height of dam (voltage or driving force).

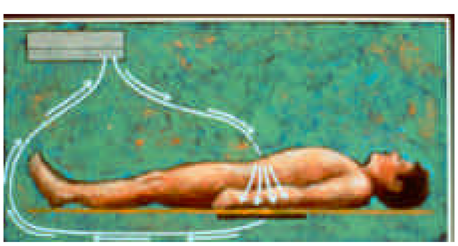
Current is then the amount of water that flows in the pipes. With electricity, this is the actual number of electrons which are moved per unit time (amperes, or amps). The "cut" mode on an ESU accentuates the amperage aspects of the power setting. It's lower attendant voltages provide for better control over any "stray" energy, and cause less margin damage on an incision. The constant delivery of the higher current creates the steady sparking within the steam envelope (very short sparks - not long like fulguration) allowing tissue to be cut by the high temperatures generated within these short sparks.

Don't try to over analyze the water pipe analogy. It isn't perfect, especially when considering AC electricity, but it does convey the basic concepts.

Current Density and Electrode Geometry - **a critical parameter of ESU technique**

The intensity of power from a laser beam is described as power density - power and spot size. This applies equally to electricity and is sometimes referred to as current density, though the former is still more correct. The concept is the same - **the amount of energy distributed over a certain contact area.**

This remains the most important parameter controlling the quality of an electrosurgical cut and the level of hemostasis achieved. For instance, though the use of pure "cut" with a fine wire electrode would probably provide inadequate hemostasis, using the same "cut" setting with a broader spoon (spatula) electrode can provide good dissection and hemostasis together. The size of the electrode contact surface makes the difference.



Have you ever wondered why the electricity from an ESU will cause a cut at the active electrode, but does nothing at the dispersive electrode?

It's not the direction of current flow - you could change the connections to the machine and still get the same effect. The

[4]The misconception of insulators totally blocking electricity is seen in the belief by some that rubber soled shoes should offer some protection from a lightning hit - you are insulated from ground by the rubber soles. In truth, one would have to be wearing rubber soles more than one mile in thickness to offer any protection from the voltage levels in a bolt of lightning with a direct hit!

difference is created because of the relative surface contact areas of the electrodes. The cutting electrode has a relatively small contact area. The electricity "crowds" together at this point of contact, resulting in a high power density and intense thermal effect. The dispersive electrode (ground pad) does just what the name implies. It collects the electricity over a wide surface contact area allowing a "dispersion" of the energy. This creates a very low power density and totally eliminates any induced heating of tissue. The current is harmlessly dispersed over this electrode. If this pad were to pull away from the patient however, the surface contact area would get smaller and smaller, causing a "bottleneck" in the flow of electricity, increasing the power density, and resulting in a burn. Some units incorporate Failsafes to sense this - many called Return Electrode Monitors (REM) or Neutral Electrode Safety System (NESSY) - both marketing names for similar functions.

The choice of electrode size, and how one applies it to tissue, affects the cutting and hemostatic effect as much or more so than the choice of "cut" and "coag" modes. (Fig 9)

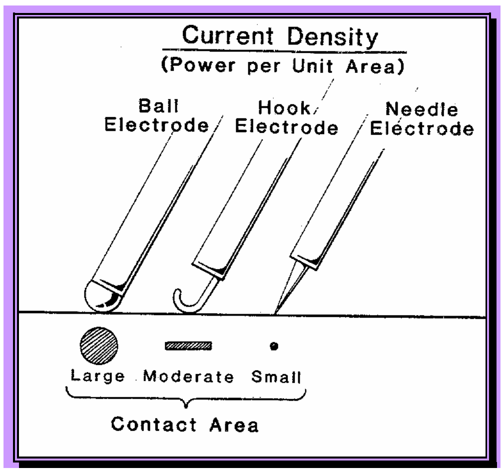
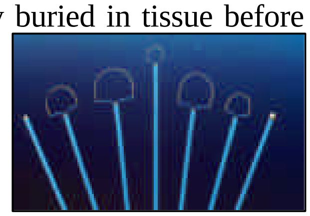


Fig 9

Fine wire loops are used on resectoscopes for hysteroscopy, or used as handheld loops for cervical excisions. The finer the wire, the smaller the contact area with tissue, and the cleaner the cut. Finer wires don't require as high powers to drive them as do thicker wires, and in fact overdriving fine wires with too much power will prematurely cause them to burn out.

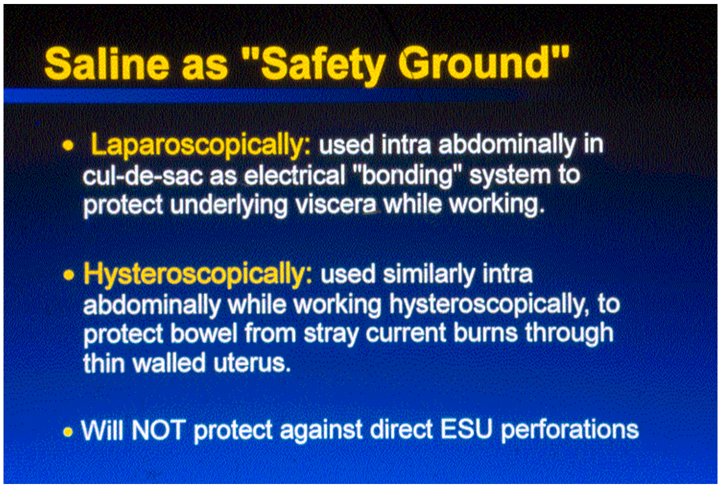


How one places a loop in tissue is also important. If the loop is partially buried in tissue before activation of the electrode, then the initial large surface contact area with tissue drops the power density to a level which kind of "wallows" and "burns" in tissue before cutting adequately. **The correct technique is to activate the loop electrode just before touching tissue**. The small contact area of the initial point of contact allows clean cutting with a high power density. This activation just before touching actually applies to most situations where clean cutting is desired.

In laparoscopic use of ESU, power densities are varied by using different sizes and configurations of electrodes (Figure 9). A hook electrode, besides having a convenient geometry to handle tissue, has a moderate electrode size to allow hemostatic dissection. A finer needle point electrode will allow finer and cleaner incisions, but at some expense to hemostasis. Ball electrodes will be good for electro-desiccation and fulguration of oozing tissue beds. A spoon electrode, when brushed against tissue with it's narrow side, will allow clean dissection. By angling the spoon slightly so that more and more surface area is used, various degrees of hemostasis may be achieved while leaving the ESU in a "cut" setting.

The reason for this discussion of power density, versus electrode configuration and hemostasis, is that **selecting and manipulating use of the electrode is the first step, and far better way of obtaining desired hemostasis than using the ESU in the "coag" or high blend modes.**

High power densities can be a very real cause of pedicle type injuries which are unintentional and frequently unobserved. When tissue is grasped then put on a "stretch", a small trunked pedicle may be created. Current applied to tissue at it's end sufficient to cause coagulation, may see an increase in power density where the electricity tries to "dive" through the small pedicle trunk, resulting in an inadvertent burn.



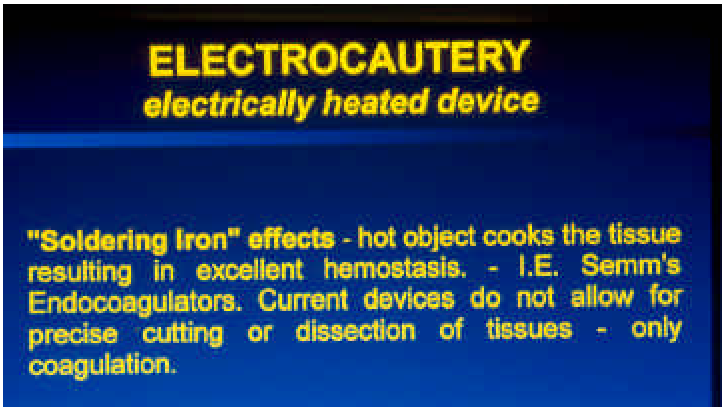
Lowering power density may also be exploited as a technique to safely protect intra-abdominal organs from accidental injuries. The use of monopolar ESU is ineffective if you try to activate the electrode under a conductive solution such as saline. It's not particularly harmful, the conductive solution simply dissipates the energy so that it is ineffective. This same characteristic however, may be used to provide **electrical protection to all organs under the conductive fluid** - as long as the electrode is working OUT of the fluid. In laparoscopic surgery, if the target tissue may be lifted high anteriorly, then the cul-de-sac and posterior abdomen may be flooded under warmed saline. Organs which are entirely immersed in this pool of fluid would be totally protected from inadvertent electrical injury. The extremely large contact surface of all **organs tied electrically together by the conductive saline will harmlessly disperse any current.** (Non conductive solutions such as sterile water or glycine will offer NO protection) This technique may also be applied during hysteroscopy when using monopolar ESU (roller ball or resectoscope) if there is any reason for concern about electrical injury to abdominal contents such as bowel in contact with the serosal surface of the uterus. Flooding the abdomen with the conductive solution, then ensuring that the patient is positioned so that the base of the pool envelopes the uterus, offers protection from "stray current". The non conductive solution is then used within the uterine cavity itself so that the electrode is effective here. Be advised however that physically penetrating the uterine wall too deeply with the electrode can still create bowel injury by bringing the electrode into close direct contract with the structure.

Clarification of Electrosurgical Terminology

Learning the "language" is the first step in developing a good understanding of a "foreign" technology. The semantics involved with electrosurgery can become quite confusing, so it is useful to clarify several terms.

"Bovie" is not a generic term for electrosurgical units. It is frequently used this way but actually refers to the name of the gentleman that originated the electrosurgical unit. WT Bovie worked with a neurosurgeon by the name of Harvey Cushing to pioneer electrosurgery in the 1920's. Modern **electrosurgical units (ESU's)** are not the old, green "Bovie" units and work in a technically different fashion.

"Electrocautery" or "Cautery" (Figure 10) is not the correct term to use for electrosurgical units, though this term is commonly used. Cautery refers to a direct heating process, like a soldering iron, whereby the electricity does not flow through the tissue. The Semm's endocoagulator is a type of cautery unit. The use of electrically created "hot wire" cautery was first described in the 1890's. In the 1940's this "hot wire" saw some resurgence to perform cervical conizations. This should not be mistaken for current LEEP cervical excisions that uses an ESU loop, which is NOT a hot wire.



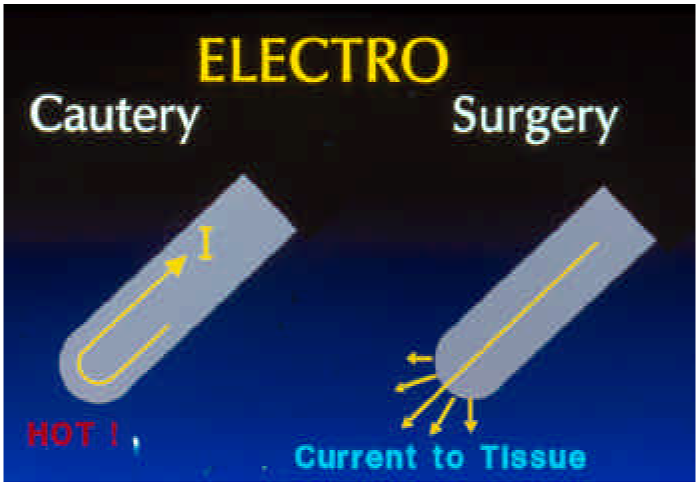


Fig 10

"Electrosurgical Unit" (ESU) is the correct term for modern units that utilize either monopolar or bipolar electrosurgical elements. This involves an electrical current flow through tissue to generate the heating effects on tissue. They may be monopolar or bipolar.

"Monopolar" or "Unipolar" refers to the surgical instrument having only one electrical contact surface, or electrode. Instruments like monopolar graspers may still have two jaws but they are electrically the same surface or pole. Since electricity requires two electrodes in order to flow, the other electrode will be some type of ground pad (dispersive electrode) on the patient. Electricity will flow between the active electrode and dispersive electrode. Heating and tissue damage can theoretically occur anywhere between the two electrodes. Monopolar is used for needle and hook electrode dissection in laparoscopy, loops and roller balls for hysteroscopy, fine wire loops for cervical excisions, and handheld scalpels (pens) for general surgical dissections.

"Bipolar" refers to both electrodes being contained within the surgical instrument itself. The dispersive electrode (ground pad) is inactive or not used. This means that the flow of electricity is confined to only the space between the two surfaces of the instrument. Tissue damage is theoretically confined to only this direct space, but the current can "mushroom" out somewhat peripherally around the instrument. Bipolar has traditionally been used in the form of coagulating graspers which were unable to cut and dissect, though newer instrumentation is changing this. New bipolar cutting instruments, are changing the way bipolar has been used laparoscopically and hysteroscopically.

"Cutting Current" on an ESU does NOT refer to a setting designed to make a surgical incision or cut. It refers to a setting that accentuates the amperage, or current, aspects of the power setting with the lowest attendant voltages. Though this setting is most effective for cutting, deep desiccation of tissue is also best performed in this mode. The size of the electrodes and way tissue is touched produces the difference in effects.

"Coag Current" on an ESU does NOT refer to a setting which is REQUIRED to obtain good hemostasis. It refers to a setting that accentuates the high voltage aspects of the power setting with the lowest attendant amperages or current. This creates the most fulgurative and sparking effect on the surface but is not deep unless the electrode is firmly planted in tissue to eliminate the sparking. Fulguration is useful to obtain hemostasis from a diffuse and oozing bed, such as a raw peritoneal surface. The attendant high voltages can create problems with unseen tissue damage though such as induced burns from trocar cannulas, and "zaps" through surgical gloves.

"Desiccation" of tissue refers to its being destroyed by drying and protein coagulation. Either the cut or coag modes will achieve good desiccation of tissue provided the electrode contact area is reasonably large, is held in good firm contact with tissue, and the probe is clean. Bipolar is safest for this, followed by the cutting mode on monopolar. The coag mode is the least safe and effective in gaining deep desiccation and coagulation.

"**Fine Point Cautery" or "Microcautery"** is used frequently to describe the use of very fine wire needle-like monopolar electrodes, frequently used in laparoscopy for hemostatic dissection. Microcautery for microsurgery (such as neurosurgery) uses different ESU power supplies.

Biological Effects of Electricity

The effect of Electrosurgical instruments on tissue is due to heating in some form or another. Electrical principles are important to an understanding of how and where this heat may be created by the way it is delivered to an intended site, intensified and localized.

Electricity can have different effects on tissue, dependent primarily on the frequency of the current. Our direct experiences with electricity are generally in the 60 Hz range of household current. These "shocks" produce muscle contraction, pain, and potentially can stop a heart. These are all termed Faradic effects and are associated with the frequencies from about this 60 Hz up to 200-300 kHz. Frequencies higher than this do not produce these types of biological effects. In fact, at high frequencies - as long as the power density is not high - then the electricity will pass through the body with no effects at all! Faradic effects are caused by the depolarization of nerve and muscle tissue.

Sometimes faradic effects CAN be observed when using conventional ESU's, even though their frequencies are above this range. This is because the current can sometimes be "rectified" by biological tissue to lower Faradic frequencies. Rectification of AC electricity is a situation where the current is allowed to flow in one direction, but not the other. This lowers the frequency of the unit. Sparking from an electrode can also set up it's own frequency lower than that of the ESU - again resulting in Faradic effects. When Faradic effects are observed the procedure should be stopped. An example can be seen when using a monopolar electrode for a cervical excision through a metal vaginal speculum. Most speculums for this procedure are insulated, NOT to prevent a burn from the electrode touching the bare metal (the current density is so low that NO burn would occur), but instead to prevent any faradic effects that might be caused by the sparking to the speculum. This in turn might cause involuntary “jerking” of the patient’s pelvis causing their vagina to “jump” right into the activated electrode.

Electricity can also cause electrolysis in biological tissue, causing ions in solution to become polarized, or positive and negative ions separated. This polarization of ions within tissue can cause a chemical cauterization. These effects are minimal with electrosurgery because of the very high AC frequencies. Electrolysis would be more apparent with a Direct Current applied to tissue, and this does not apply to electrosurgery.

The actual surgical effects of electrosurgical cutting or coagulation are created by tissue heating - though an ESU electrode is not "hot" in the sense of a soldering iron. The ESU causes a flow of electrons through the instruments and tissue - concentrated to small contact areas. This induces heat generation by creating molecular motion of the water molecules - kind of like heating water in a microwave. Some of the cutting effects are caused by the intense heating which concentrated "sparks" create within a thin steam envelope around the electrode. The trick in safe and effective use of an ESU is to create the heat just where you want it and preventing it from forming or spreading elsewhere.

Lasers accomplish the same end but by a different mechanism. Lasers produce light as packets of energy, or photons. When photons shine on tissue they are absorbed by the tissue. This creates vibrational energy - which is heat. The localization of heat created in this fashion may be controlled to a much higher degree than the use of electricity, but at greater expense and complexity of instrumentation. Harmonic scalpels create their heat by rapid microscopic oscillation of the instruments blade, causing frictional heat at the tissue interface.

Heat is Heat, whether induced by electricity , light or high frequency vibration.

Heating effects of electrosurgery are indicated by the following relationship:

$$\mathbf{Q = I^2 \times R \times T}$$

where **Q** = quantity of heat, **I** = current intensity, **R** = resistance and **T** = time

A typical scenario might then be:

$$\mathbf{6\ calories = 0.5A^2 \times 100ohms \times 1\ second}$$

One calorie is the amount of heat required to heat 1 cubic centimeter of water 1 degree centigrade. If the current above is distributed over 1 cm^3 of tissue, then a 6 degree C. temperature rise results. If the same current is concentrated to 0.1 cm^3 of tissue, a 60 degree C. temperature rise results (tissue temperature of over 100 degrees). The concentration of energy, as power density, is therefore VERY important.

As tissue begins to heat above 60 degrees C. it begins to desiccate, blanch white and shrink as proteins denature, and flash boil at temperatures somewhere over 100 degrees Centigrade. In tissues with normal blood flow, temperatures below about 45 degrees C are non injurious. Higher temperatures cause irreversible damage, and tissue death and coagulation is time dependent to some degree. One can raise tissue temperature to a higher degree for a very short period of time with no tissue death occurring, while at the same time if one prolongs temperatures in the lower range for many seconds, then tissue death will occur. The generation of heat should occur quickly when using laser or electrosurgery to cut, so that we generally ignore this time variable. Different instruments can take you to different points on this scale, because of the way they transfer their energy into the cell. (Figure 11)

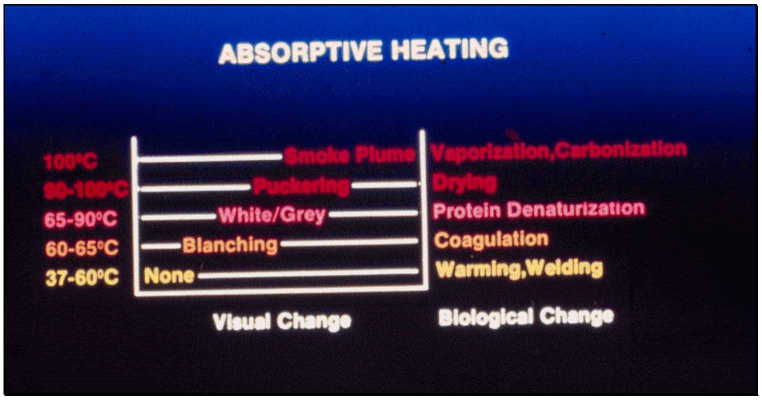


Fig. 11

When used to incise tissue, the ESU is generating heat in the tissues which actually vaporizes cells - much the same way as does the laser. This is a sublimation like process where the cells "flash boil". (Figure 12)

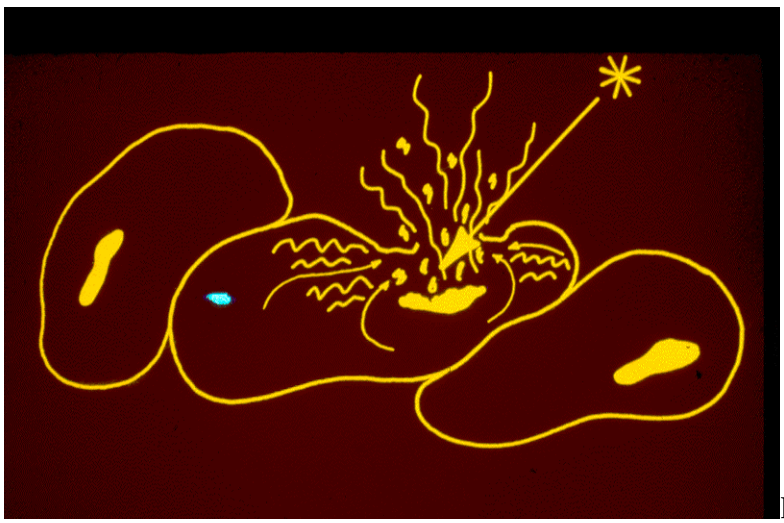


Fig. 12

The smoke like steam rising from the incision is seen as the electrosurgical plume which shares similar properties with a laser plume. Good smoke evacuation equipment should be used to remove the plume. At the very least it is obnoxious to the staff as well as a respiratory irritant. At worst, there is some question to the viability of viruses carried away in this smoke plume. Good smoke evacuators have the ability to filter down to sub-viral sizes of around 0.1 microns.

Heat and Heat Transfer - the way tissue is hemostatically incised

Both lasers and electrosurgery rely on the generation of heat within tissue to effect their work. The way heat is generated, localized or transferred is fundamentally important to the surgical use of either these modalities. Heat was once thought to be a substance. It was believed that when a hot object was placed in contact with a cooler object, an invisible entity called phlogiston enters the cooler object to make it hotter. It is now known that heat is one form of the expression of energy. Heat is the transfer of energy. It is the result of the continuous motion and vibration of the atoms and molecules that constitute matter. In tissue, water molecules are the primary target for increasing motion and heating. Cold is the absence of heat **-** a reduction in molecular motion.

Heat may be measured quantitatively. Typical units of measurement are either the **calorie** or **British Thermal Unit (BTU)**. One calorie is the amount of heat energy required to raise the temperature of one gram of water by one degree C. Similarly a BTU is the amount of heat required to raise a pound of water by one degree Fahrenheit. **Temperature should not be confused with heat.** Temperature measures the intensity of heat but not its quantity. For instance, a fifty gallon drum of water at 98.6 degrees F contains significantly more heat than a cup of boiling water. Temperature measures the intensity of the heat but not its quantity.

Heat may be generated or transferred in one of three ways:
Conduction heat transfer is the flow of thermal energy in matter (or tissue) as a result of molecular collisions. this is one of the major sources of error in the use of electrosurgery or laser. Allowing a heat source to be applied to tissue for extensive periods of time allows unwanted heat transfer into adjacent tissue with resulting damage. Many published examples of "extensive damage" from lasers or electrosurgery are really not due to the modality at all **-** it is simply due to excessive exposure times from unwarrantedly low powers, resulting in conduction heating and excessive thermal damage.

Radiation heat transfer involves the flow of thermal energy by electromagnetic waves (i.e.: light or electricity). The heat may even be transferred across a vacuum in this way. This is the way lasers transfer their energy as heat through the absorption of the electromagnetic waves by tissue.

Convection heat transfer involves larger scale movement of heat by currents of gases or liquids, such as a pan of boiling water. It is important in electrosurgery since the steam generated by in an incision dissipates the heat and prevents conduction deeper into tissue. Situations where an electrode "stalls" by forcing it through tissue will allow for excessive accumulation of heat since the dissipating steam envelope is eliminated.

Cutting, Fulguration and Desiccation

So far we've learned the basics of an electrical circuit, examined parameters of voltage, current and resistance and seen how these are affected by choice of "cut" or "coag" modes, and discussed the relationship of electrode configurations to power density. These are all technical parameters of the ESU's and the electricity itself.

Now we should look at electrosurgery from the point of view of the surgical effects, and tie these effects together with the technical parameters which influence them.

Remember our initial discussion of "cut" and "coag" modes. These have meaning only in terms of voltage and current parameters. They should NOT be selected simply because one wants to cause an incision, or achieve hemostasis. The surgical effect is achieved through a combination of the mode and power selected, the size and geometry of the electrode, and the technique by which the electrode is applied. A more detailed look at these surgical effects will allow us to use an ESU more effectively and safely.

Appendix A describes in more detail the AC waveforms of "cut" and "coag" modes. We previously oversimplified in order to describe the "cut" mode as the one which accentuated the current aspects of the AC, and the "coag" mode as accentuating the higher voltages. The appendix explains in more detail how this is really related to a comparison of average and peak voltages called the "crest factor" - even though actual peak voltages may vary between "cut", "coag" and bipolar modes. For our purposes here we simply want to look at the "cut" mode as an uninterrupted emission of the AC sinusoidal waveform. It is emitted in an "undampened" fashion and is frequently called an undampened waveform. "Coag" on the other hand provides for interrupted bursts of the same AC waveform, and is frequently called a "dampened" waveform.

Cutting has traditionally been possible only with monopolar ESU. This is changing and **several companies have developed cutting bipolar instruments.** The physical mechanism of the cut is the same whether using BI or monopolar, but techniques of use will vary. Theoretically a cut with bipolar should be no different than a cut with monopolar, but in practice there is some difference in "feel" and efficacy of the respective instruments. Bipolar is most definitely a safer modality to use during laparoscopy, but that is not to say informed application of monopolar is "unsafe". The rest of the discussion on cutting and fulguration is applied primarily to monopolar ESU.

Cut

With an undampened waveform ("cut" mode) it makes sense that the water molecules will be most highly vibrated and generate more intense heat. The pure cutting mode, coupled with high power density from a small electrode, always gives the most controlled and precise tissue effects, but at the price of limited or nonexistent hemostasis if the electrode geometry is not manipulated.

Cut works best when the electrode is lightly floating just above the tissue, but not making firm contact with it. A very narrow steam envelope is created in the small gap between tissue and electrode which allows intense, short sparking to tissue. **If the envelope is lost by forcing the electrode into tissue, the cutting has changed to desiccation**. Figure 13 shows an exaggerated view of this steam envelope and the short sparking which occurs.

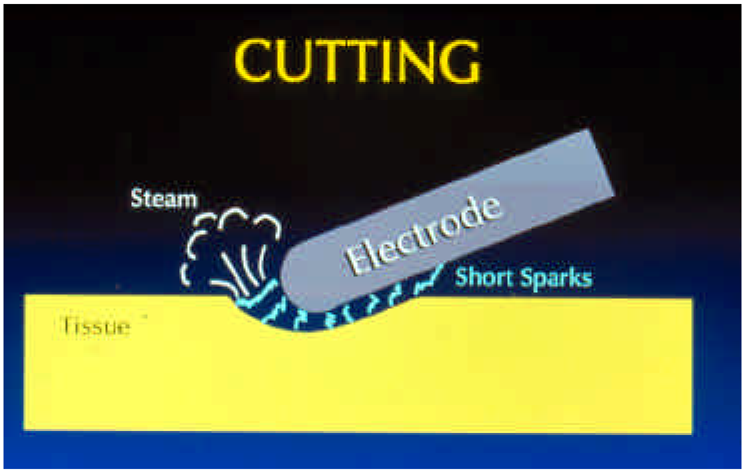


Fig 13
Exaggerated View of Cutting and the Steam Envelope

Combined with the undampened delivery of current, the small pinpoint tips of the sparks concentrate the current to even higher power densities and intensify the explosive vaporization effect. It is intense and unrelenting enough that the tissue is not given any chance to desiccate or char before more current continues driving through it. The steam plume further dissipates heat which would otherwise accumulate at the incision. The steam also acts as a good ionized gas conductor allowing uninterrupted movement of ions in the cells and flash boiling of cellular contents (vaporization). The result is a very clean and narrow margin vaporization of tissue with very little lateral heat damage - translating into poor hemostasis.

The power should be set at a level just sufficient to obtain a smooth, clean cut. Unlike vaporization by laser, which is made more precise by short applications of very high power, use of excessive powers in electrosurgery is unnecessary and can create potential for "stray energy" injuries. If the electrode stalls and "waddles" though tissue without its being forced, try turning the power up until a clean incision results. With a fine wire like a needle electrode, 20-30 watts is frequently sufficient to obtain a good cut. With slightly larger electrodes, power settings of 45-75 watts may be needed. Loop electrode excision varies considerably with the size and thickness of the electrode, and the site where it is used.

The very clean but bloody incision of "cut" works only when the steam envelope is maintained, and a high power density electrode is utilized. The finer the edge or point on the electrode, the cleaner the incision and lower the power required to obtain it.

If the electrode is rushed through tissue rather than "floating" it at its own rate, then the tissue will bunch up as it makes contact with the electrode and a "stall" occurs. At this point the electrode should be removed from tissue and deactivated, and the incision restarted, preferably beginning just off tissue and using light stroking motions.

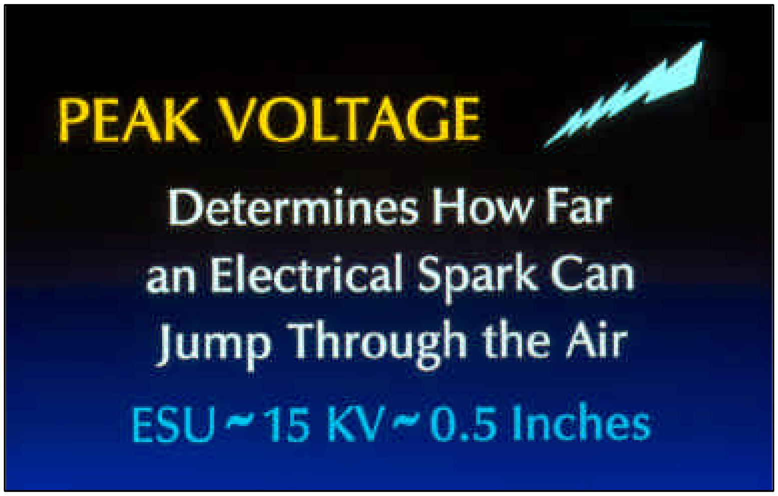
Altering the size of electrode and way it touches tissue is the first step in enhancing hemostasis when using the pure cut mode. Often, pure cut can be successfully used throughout a laparoscopic procedure by using a spoon or similar electrode, and manipulating the edges which are allowed to stroke tissue. This approach of manipulating electrode use should be tried before resorting to blends or "coag" settings on the ESU.

A key point in proper technique of electrosurgical cutting is the maintenance of good traction on tissue being incised. Tissue on stretch presents a smaller contact point to an electrode which increases power density. Tissue on stretch will be immediately removed from contact with the electrode when cut, allowing power density to be concentrated in the next segment of tissue. **Good traction is an essential requirement of proper cutting with either laser or electrosurgery.**

A large contact area electrode may be used in firm contact with tissue using the "cut" mode, and the surgical effect will change entirely to that of deep desiccation discussed in a following section.

"Coag"

Voltage determines how far a spark can jump a gap. The "coag" mode allows for longer sparking than the "cut" mode. Figure 11a (graphical) and 11b (Actual) illustrates this long sparking of fulguration in the "coag" mode. **The damage is very superficial unless the electrode is held in contact with tissue so that no sparking occurs. This would create deeper damage.**



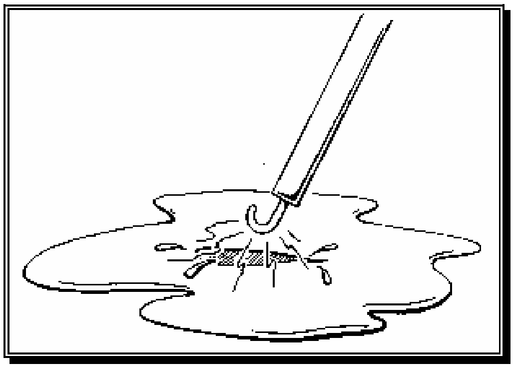
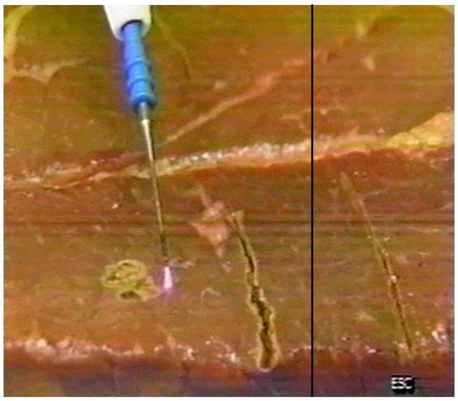


Fig 11a **Damage is very superficial unless the electrode is held firmly into tissue and sparking eliminated. This would cause deeper damage. (desiccation)**

Fig11b - Arcs from end of electrode

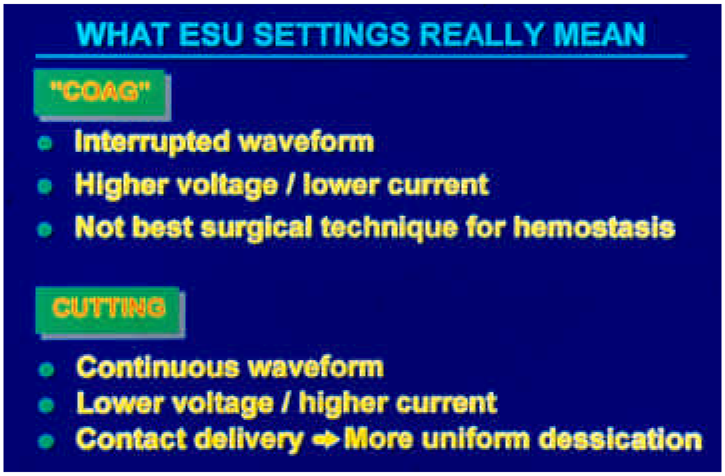
Voltage determines the margins of damage surrounding an incision. Wider margins of thermal damage produce less precise incisions, but allow for better hemostasis. Use of cutting loop electrodes are frequently used in a blend setting to obtain this hemostasis.



The "dampened" aspect of the "coag" waveform means that the RF current is applied only about 6-10% of the actual time the unit is on (varies among companies). This "rest" time of motion of the tissue's water molecules, and the fact that heating can occur with no explosive vaporization of tissue to carry away this heat in the steam, allows a progressive thermal insult to build in tissue. Tissue desiccates and gradually builds up char on the surface. Tissue resistance continues to build until the current eventually stops entirely. Charring of the electrode surface will also stop the electrical flow.

In the author's experience, the "Coag" modality on ESU's is highly overused, and frequently used for the wrong reasons. **The best and most apparent use of "Coag" is to dry a diffuse, oozing bed by fulguration.** (raw pelvic sidewall in laparoscopy, base of cervical excision in LEEP, etc) This involves holding the electrode just off tissue, allowing it to "sparkle" over the surface. It is also sometimes use to lightly "spray" a surface for a shallow burning effect. Some companies refer to this as "spray" coagulation. This technique is used with a ball electrode to "spray" the raw surface left in the base of a cervical loop excision.

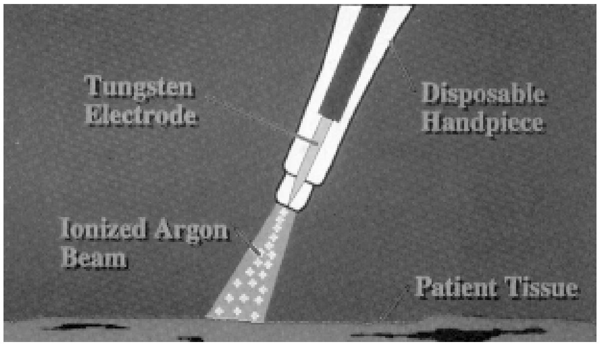
Inappropriate or unnecessary uses include it's use to stop a bleeder by touching an electrode to the clamp, or achieving deep protein coagulation in structures such as fallopian tubes or infundibular pelvic ligaments. These are desiccation techniques where the pure "cut", or undampened waverform should be used, as we'll see later. (Figure 12a&b)



(see Appendix A for more discussion)

Argon Beam Coagulator (ABC) for controlled fulguration

Though conventional "spray" type coagulation will not result in very deep damage, it is rather destructive to the surface of the target. When fulgurating like this, the sparks carry quite a "punch", and the spray pattern of sparks can be rather erratic within the sparking area. Air, or in the case of laparoscopy the pneumoperitoneum, offers a fair amount of resistance which must be overcome before the spark can jump. This also limits the distances which the spark can jump and uniformity of effect.



The argon beam coagulator is a conventional monopolar ESU used in the "coag" mode for fulguration. The difference is that the probe delivers a purging flow of the inert argon gas while the unit is activated. Argon gas offers very low electrical resistance to the sparking and this alters the nature of the fulgurative sparking. Lower "coag" powers may be used to generate the sparks. The sparking is more homogeneous and uniform, and produces a "gentler" effect on tissue. The gas flow has the added effect of blowing blood away from the surface as the fulguration coagulates the surface. Since the gas will penetrate irregular surfaces the fulguration is more uniform even on an irregular surface. Some advocate it's use even in bone for this reason. The sparks can seek out nooks and crannies.

The argon beam coagulator is not associated in any way with an argon laser - even though the word "beam" is used. The laser uses argon gas internally in the tube to generate the blue/green laser beam, usually delivered laparoscopically by a fiber. The ABC actually blows the argon gas into the pathway of the fulguration inside the patient's abdomen.

Since the constant flow of the argon gas is an additional gas source during pneumoperitoneum, the abdominal pressure must be closely monitored to prevent overpressure. There have been reported cases of overpressurization and even embolization.

Desiccation

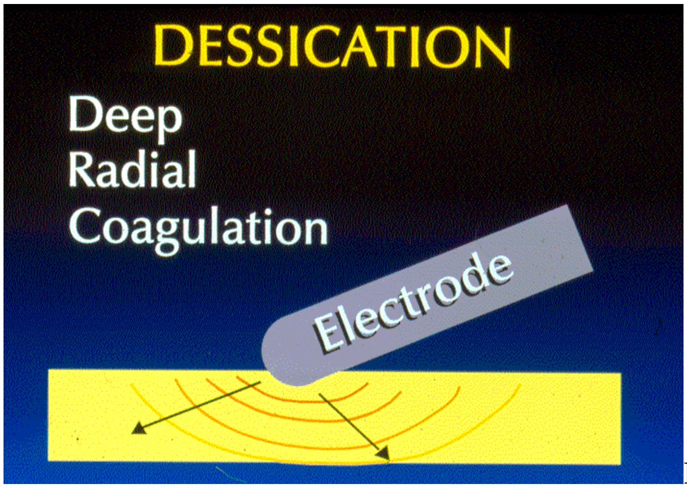
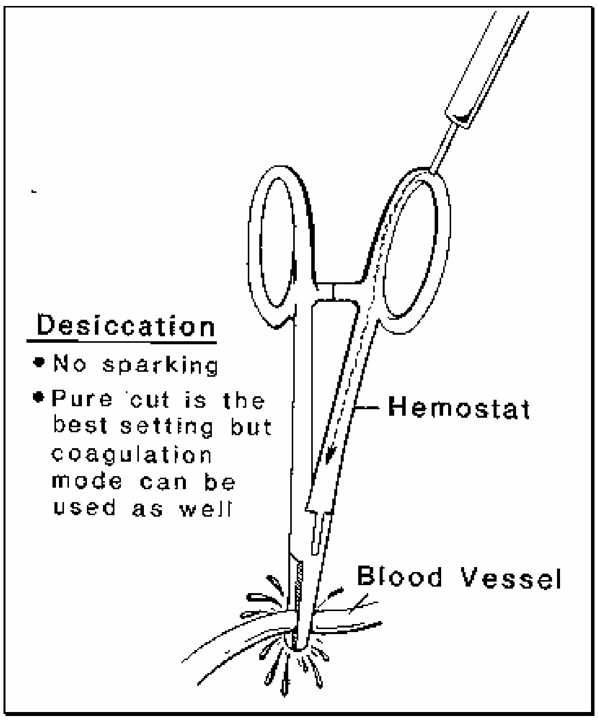


Fig 12a

Firm contact with tissue is required and no sparking is allowed to occur

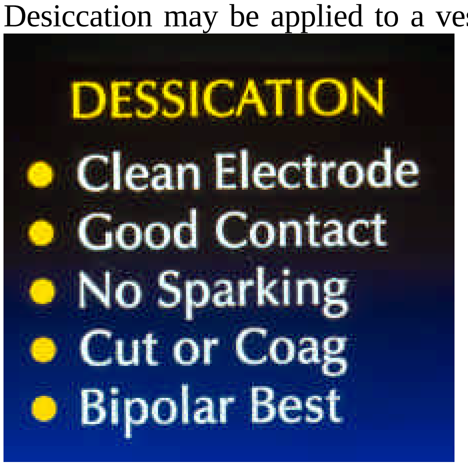


Unlike techniques of cutting or fulguration, desiccation involves no sparking to tissue of any sort. The electrode, which must be clean, is held in firm contact with tissue and water is driven from tissue as it progressively heats from resistance to the electrical current. (Figure 12a&b)

Fig 12b

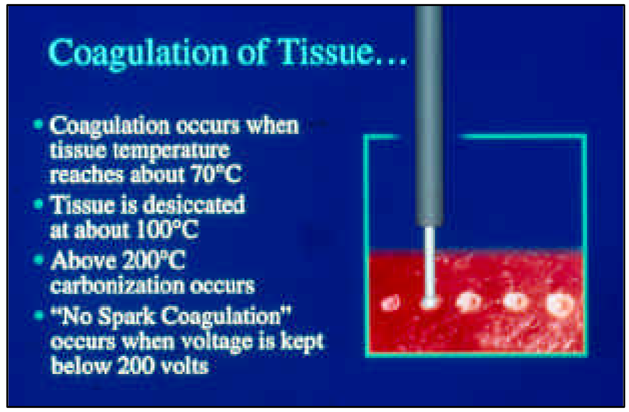
Desiccation is different than Fulguration and "Cut" is the best mode to use. The best and most safe way to obtain protein hemostasis, whether for clamping and "buzzing" a bleeder, or performing tubal sterilization, is to firmly grasp the tissue with a large contact area electrode and using a straight "cut" mode.

Desiccation may be applied to a vessel to stop bleeding, or to a larger structure like a fallopian tube to cause deeper protein coagulation and tissue destruction. **The "cut" modality on an ESU is the safest, and most effective way of obtaining desiccation. Bipolar is safest when this is possible.** A look at a couple of specific examples will help illustrate this claim.



Tubal sterilization's are now most frequently performed with bipolar rather than monopolar ESU. These principles of using "cut" Vs "coag" apply equally to bipolar, but are more pronounced with monopolar because of the higher attendant voltages.

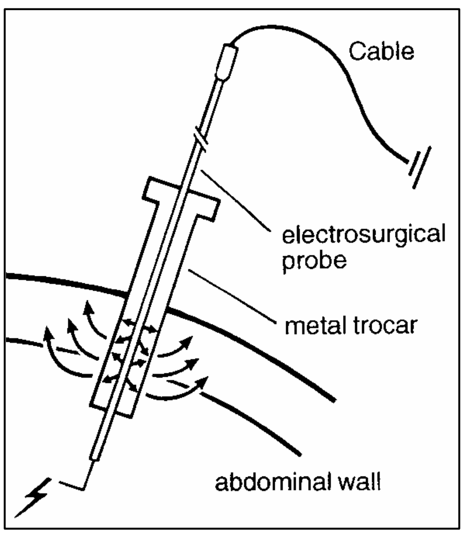
Either "cut" or "coag" could achieve deep tissue necrosis (coagulation of tissue), but cut mode is definitely safer and frequently more effective to achieve such coagulation.



Using the "coag" mode involves higher voltages and interrupted current delivery (dampened current). When using monopolar these higher voltages are present throughout the entire circuit. So what? - Your chances of getting zapped through your glove increase. The chance of "stray current" causing unintended injury through downstream sparking or high current density burns increases. The chance of insulation breakdown and inadvertent burns increases in laparoscopic instruments. These are not small theoretical increases in risk either. They are easily demonstrated, substantial safety problems.

The risk of capacitance in laparoscopic trocars and instruments also goes way up - making an unobserved and injurious burn from the instrument very possible. What's capacitance? - and how can you burn organs by instruments that are not even in contact with the electrical circuit!?

Capacitance involves transferring electrical energy through intact insulating materials to nearby conductive instruments, such as laparoscopic suction irrigator probes, some trocar sleeves, or operating laparoscopes. This induced energy can then burn tissues which touching it, even though the instrument is not touching any "live" electrodes!

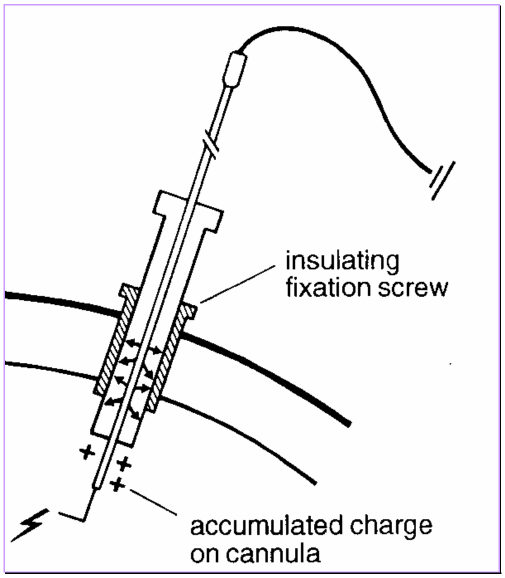


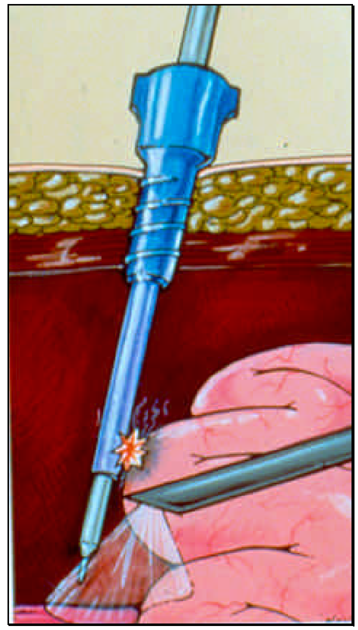
The use of all metal trocars eliminates any problem of capacitance. Any current that is induced in the trocar is harmlessly "bled" away into the surrounding abdominal wall. The resulting current density where the trocar contacts tissue is so low that no burn occurs. (Fig 13)

Fig 13

Flow of electricity down a conductor (your active electrode) produces a magnetic field around the device. The high voltages of "coag" produce the strongest fields. Insulators like plastic are of course transparent to magnetic fields, so that the magnetism will go through the insulator and set up the reverse process in closely situated metal instruments. That is, the magnetic field will induce an electrical current in the nearby instrument even though it is not touching the conductor. Higher frequencies present more potential for capacitance. Some of the inexpensive 3+ megahertz ESU's used for office work, though working fine for those purposes, would present a significantly higher chance of capacitance than surgical ESU's operating in the 350-550 kilohertz range. This magnetic field and resulting capacitance is highest when the electrode is activated but not actually touching tissue, such as when fulgurating just off tissue, or inappropriately activating the electrode in the abdomen prematurely before actual use.

This happens all the time, but presents no problem when all metal instruments are used. An all metal trocar sleeve is in contact with the abdominal wall. Any induced current created in the sleeve (or any metal instrument in it such as the suction irrigator) will be harmlessly bled into the abdominal wall and back to the dispersive electrode. The surface contact area of the sleeve with the abdominal wall keeps the power density low enough so that the electricity is harmless here and causes no burns.



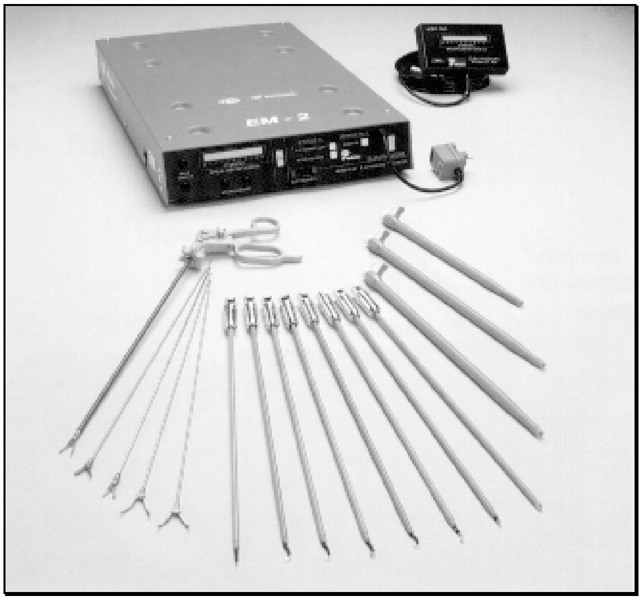


Figs 14a&b

Problems with capacitance begin when using all plastic or plastic/metal trocar sleeves. (Figs 14a&b) In a plastic/metal sleeve, the plastic is in contact with the abdominal wall and provides no means for conduction of electricity back to the dispersive electrode. The metal tip of this plastic sleeve is "hanging out there" in electrical isolation. Any current that is induced here has no way to be harmlessly bled off. Instead a charge builds on the metal tip and when it lightly touches some internal organ (small contact area and high power density) it will discharge at this point, potentially causing a burn.

All plastic sleeves are not a problem - until you put a metal instrument down them, and then put the electrode down a channel of this now isolated instrument. This would apply to a suction/irrigator, or even an operating laparoscope. The electrical current is induced by capacitance in the instrument the same way, and the all plastic sleeve prevents it from being harmlessly bled off. A touch to internal tissues by the isolated instrument (suction/irrigator - operative laparoscope) allows the discharge to occur.

This is enough of a problem that the company ELECTROSCOPE (owned by Valleylab) has developed a "shield", which slips over the electrode to protect against capacitance or insulation breakdown. The shield requires it's own control unit and wiring to tie into the ESU, but eliminates many hazards of monopolar ESU. The company terms this “Active Electrode Monitoring”.

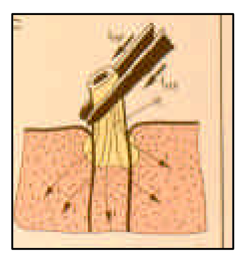


ACTIVE ELECTRODE MONITORING

Active Electrode Monitoring surrounds the active electrode with a protective shield. This collects any stray current produced by either insulation failure or capacitive coupling and safely returns it to the generator.

Another potential problem with induced capacitance comes during colposcopic procedures with insulated vaginal speculums and use of high frequency generators. The coated speculums ordinarily used in LEEP procedures of the cervix protect the vaginal tissue from any sparking induced faradic effects (remember that a bare metal speculum is not a burn hazard because of low current density, but can cause muscle contracture from sparking if it occurs). The problem can occur when an otherwise insulated (coated) speculum gets a chip or scratch in the insulation. High frequency generators in the 3-4 MHz range can induce capacitance in the speculum. If the insulation were intact (or even bare metal all around) this would not be a problem. However, in the case of the chipped insulation, the induced current makes it way out through the small contact area of the defect, potentially creating a painful or damaging burn from the resulting high current densities. One need not actually touch the speculum with the electrode to generate this effect if the high frequency generators are used. Even if the burn were not serious the resulting jerking of the patient could force a “hot” LOOP electrode right through the vaginal wall.

These are all some of the problems potentially created by using the "coag" mode, with it’s high voltages, to achieve desiccation (and/or the high frequency ESU’s – both induce capacitance). The effectiveness of using straight "coag" in order to achieve deep protein coagulation is also compromised. Two problems can occur.



The best way one could use "coag" to achieve deep coagulation would be to firmly hold the tissue with graspers as the current was applied. Stop the current when thoroughly desiccated and move the graspers to the next site before applying the current again. This should maintain good contact with tissue and eliminate sparking. Sparking (fulguration) will create a shallow zone of charred and desiccated tissue on the surface which would actually electrically insulate deeper structures from further damage. It's kind of like cooking a steak on a super hot grill. The surface would be seared and sealed, but the inside could be raw.

The first problem occurs because the graspers are usually not applied in this manner if using "coag" for deep coagulation. They are frequently lightly run up and down the structure, causing significant sparking, or tissue is repeatedly regrasped without deactivating the electrode - again causing much sparking. This builds up the insulating barrier of desiccated surface tissue and decreases the chances of deep coagulation.

The second problem occurs even if good contact with tissue is maintained. Remember that the higher voltages will cause more tissue damage at the interface. Desiccation begins and deep coagulation proceeds as the electrode is held in firm contact. At some point the damage at the tissue/electrode interface will be enough to either stop electrical flow by char formation, or by steam vaporization at the interface. This terminal point in desiccation will occur more quickly with "coag" settings than with "cut", and prematurely limit the depth of coagulation. (Fig 15)

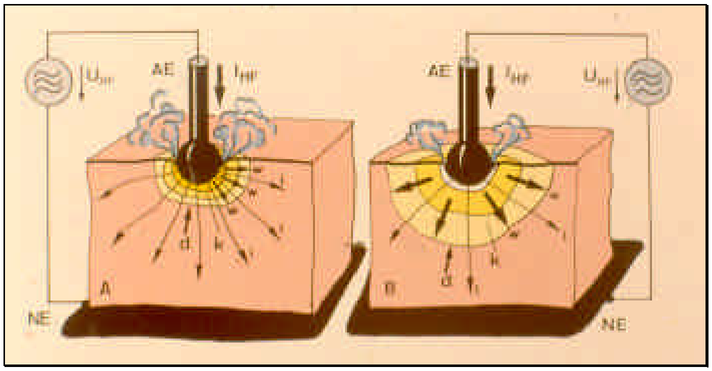


Fig 15

“Coag” setting shown on left and “Cut” shown on right. Both are used with good tissue contact to achieve desiccation. The “Coag” mode will result in more superficial coagulation because the higher voltages create a vapor layer earlier than the “Cut” mode, terminating the desiccation.

Bipolar ESU and Electrodes

When using bipolar electrodes, the two poles are both in contact with the target tissue right at the active site. (Figure 16) No remote dispersive electrode is needed. Less electrical energy is therefore needed to achieve the same effects since the current does not need to pass through the entire body to get back to the other electrode. Attendant voltages and currents are lower with bipolar than monopolar instrumentation. This, and the fact that the **current stays pretty much right between the two active electrodes, makes it a much safer modality to use.**

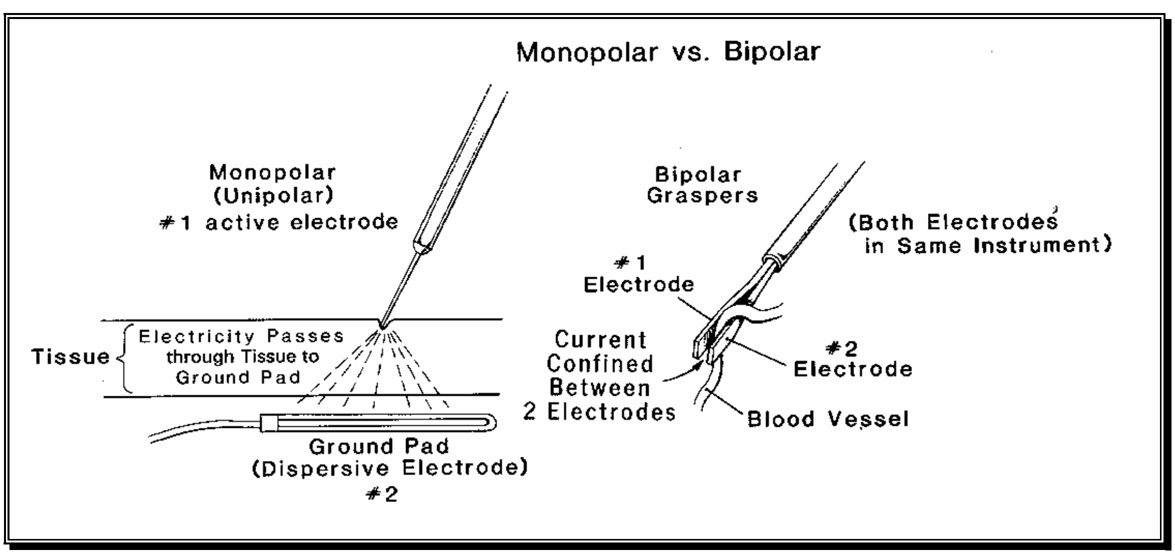


Fig 16

Capacitance is not a problem with bipolar instrumentation. Since both electrodes are contained in the same instrument their magnetic fields will cancel out. Electrical current will not be induced in other instruments, even if they are isolated.

The use of bipolar in laparoscopy has traditionally been very limited and specific. It was used with flat bladed graspers to achieve localized coagulation. It has been great for control of bleeders and for tubal sterilization's, but could not cut or dissect tissue. New instruments are changing all that.

New instrumentation allows for bipolar cutting and dissection with bipolar scissors, hook electrodes and the standby coagulation graspers. The power supplies on these cutting instruments are somewhat different than their old counterparts which were designed for only coagulation. This instrumentation should substantially increase the safety of laparoscopic ESU procedures.

When using bipolar for coagulation, hold the conductive portion of the forceps exactly where the coagulation should occur. If tissue is held too high up in the forceps then no electrical contact will occur, because of the insulation. (Fig 17) The forceps must be clean to achieve good electrical contact.

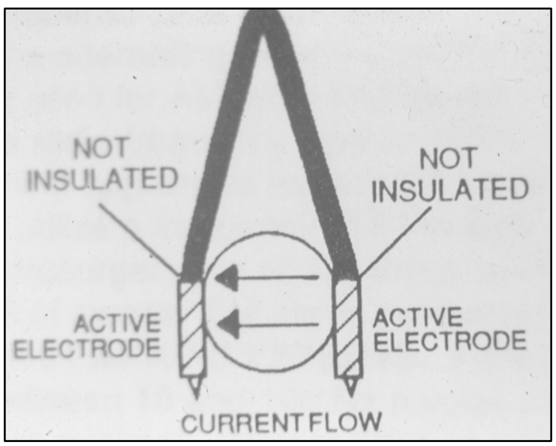


Fig 17

Remember that the tissue to be coagulated must be in between the two jaws of the forceps in order to make the tissue an integral part of the electrical circuit. Many times the jaws of the forceps will be squeezed closed so tightly that the tips of the forceps actually meet. This causes a short circuit to occur and allows electricity to flow directly from one jaw to another, entirely bypassing the tissue. This reduces or eliminates the desired effect, and may make the forceps look like they're not working. The solution is to lightly but firmly grasp the tissue and avoid complete closure of the jaws. (Fig 18)

Another characteristic of bipolar to be considered is its potential to create a "mushrooming" coagulation effect around and outside the actual space between the jaws of the instrument. This is created because of the magnetic field like nature of electrical conduction. It travels in curving lines between electrodes when not confined by a wire or other conductor. This means that a delicate structure, such as a ureter, is not immune from injury simply because it is not directly in the jaws of the instrument. The spread is not large, but it can go several millimeters around the tip of the device. This is usually seen as the tissue blanches white with coagulation.

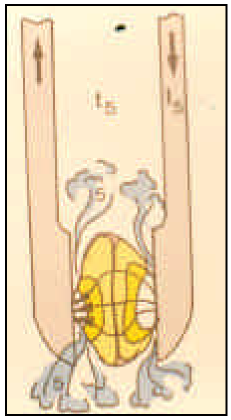


Fig 18

In spite of this mushrooming, bipolar instruments offer much more control over the electrical current than does monopolar. For the most precise control , predictability and uniformity of thermal effect , one would transition to various laser modalities.

Like anything else however, it is not just the selection of the instrument which increases the control and precision, but the knowledgeable use of the device.

ELECTROSURGICAL SAFETY[5]

Hazards of ESU are best avoided by having a working knowledge of the principles of Electrosurgery we've already discussed. Figures 19-21 summarize common hazards.

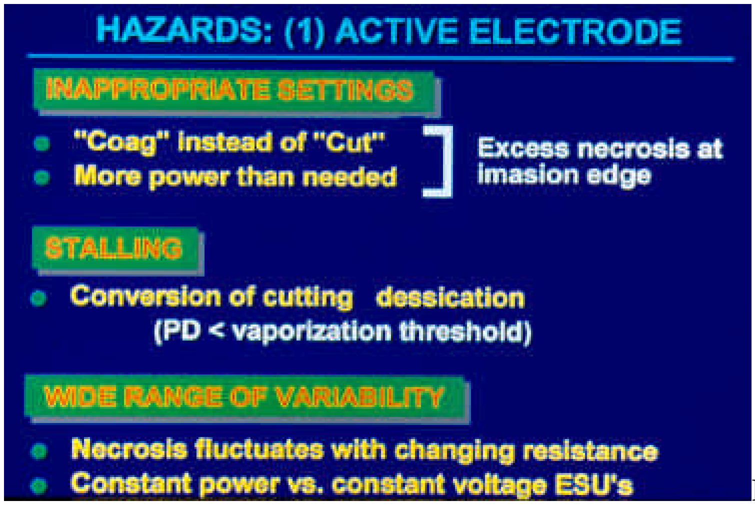


Fig 19

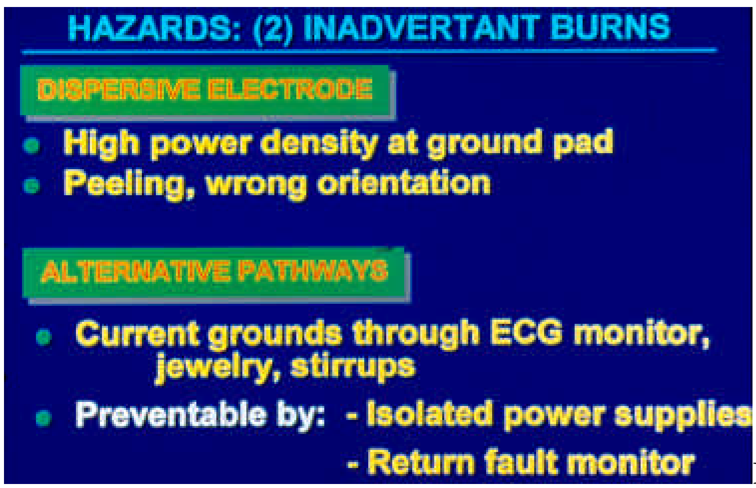


Fig 20

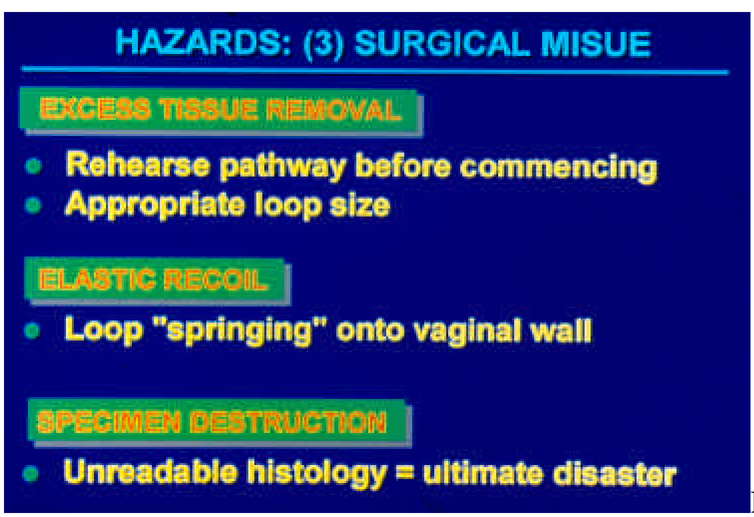


Fig 21

[5] This section does not discuss ALL aspects of Electrosurgery that might be hazardous – the manufacturer's checklists and recommendations should be referred to prior to using any Electrosurgical Unit.

Figure 21 applies primarily to LEEP procedures of the Cervix, though the rest of the hazards may apply in about any ESU use.

Stray current burns can be a problem with any ESU, though some models have more failsafes and built-in alarms than others. This is one of the primary differences between more expensive units used in main surgery than the smaller and less expensive office units. Stray current burns to the patient generally take a short while to progress (seconds to minutes) rather than occurring instantaneously. An asleep patient in surgery would of course not feel the pain associated with a progressing burn, while an awake patient in an office setting would. An awake patient would generally complain (or scream) before the burn became serious. This is not always the case but it is certain that anesthetized patients will not alert one to such a burn.

Remember too that stray burns are not caused simply by the electricity being somewhere it should not, it must be CONCENTRATED into a small enough area to create a high current density and resulting burn. We saw that back in our discussion of capacitance where an all metal trocar in laparoscopy would harmlessly disperse excess energy because of its larger surface area. Return electrodes (a.k.a. grounding pads, dispersive electrodes) also work the same way – they spread out the current to a large enough area that it "disperses" its effects and no burn occurs.

GROUNDING & inadvertent burns:
The patient's skin or tissue touching a grounded object - like an EKG lead, edge of metal table, metal stirrups, etc – is one way in which an inadvertant burn can occur. Let's first look at this as analogous to receiving a "shock" (Electroplexy) at home on a defective appliance like a washer or dryer (Fig 22), and how "safety grounds" can prevent such shocks.

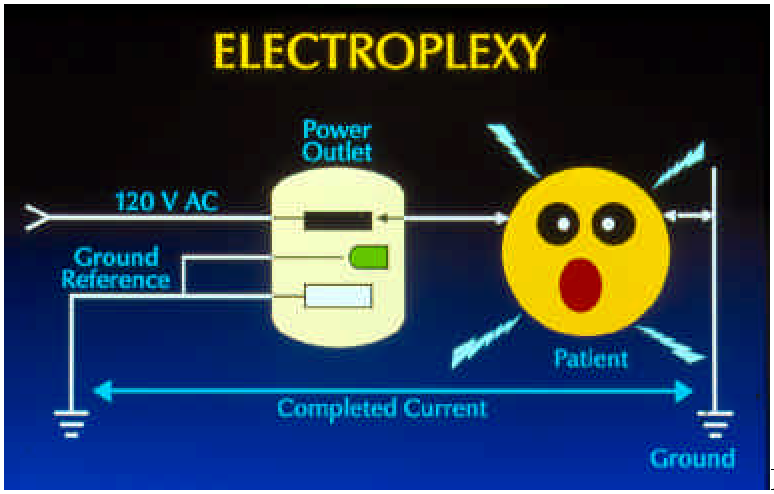


Fig 22

Similar to monopolar electrosurgery, your household current uses two poles for the electicity. One side of your household outlet is the "hot" side (black in Fig 22 and analogous to the active electrode in an ESU) and the other is the "neutral" side to return the current back to the outlet (white in Fig 22, and analogous to the dispersive or return electrode in an ESU). This neutral pole is actually physically connected to an earth ground. The third pole in a household outlet is the middle semi-round one that is used for a safety ground. In fact this really is connected to the same earth ground as the neutral pole. One gets shocked when you touch the "Hot" side of an electrical outlet at the same time you are "grounded" to another object (barefoot on a bare concrete basement floor, touching a water faucet, etc.). Here's how that happens on a defective appliance and how your safety grounds prevent such a shock (analogous to a burn on an ESU):

Your washer for instance has both the “Hot” and “Neutral” leads running to the motor and electrical controls inside the metal cabinet of the washer. Both of these leads are insulated around the wire. Imagine though that after a couple years of use the vibration of the washing machine in use has rubbed a bare spot on the insulation of the “Hot” wire against the cabinet. This now means that current from this pole is being conducted into the metal cabinet of your washer, which you are usually touching while you use it. At the same time you’re touching the cabinet you might be standing in your bare feet on the concrete basement floor. Voilla! – You’ve successfully completed the electrical circuit and shocked yourself! How does the safety ground help prevent this? Remember that it is connected to the same earth ground as the neutral lead, but is ordinarily not part of the circuit – it is redundant. This safety ground is physically attached to the metal cabinet of your washer by a screw. Should the “Hot” wire now make contact with the metal cabinet, the current will go to ground through the safety ground (it’s more efficient because of less resistance than you are so it goes that way), and protects you from the shock.

Electrosurgical units are analogous but a burn would result instead of the shock if the point of contact were sufficiently concentrated.

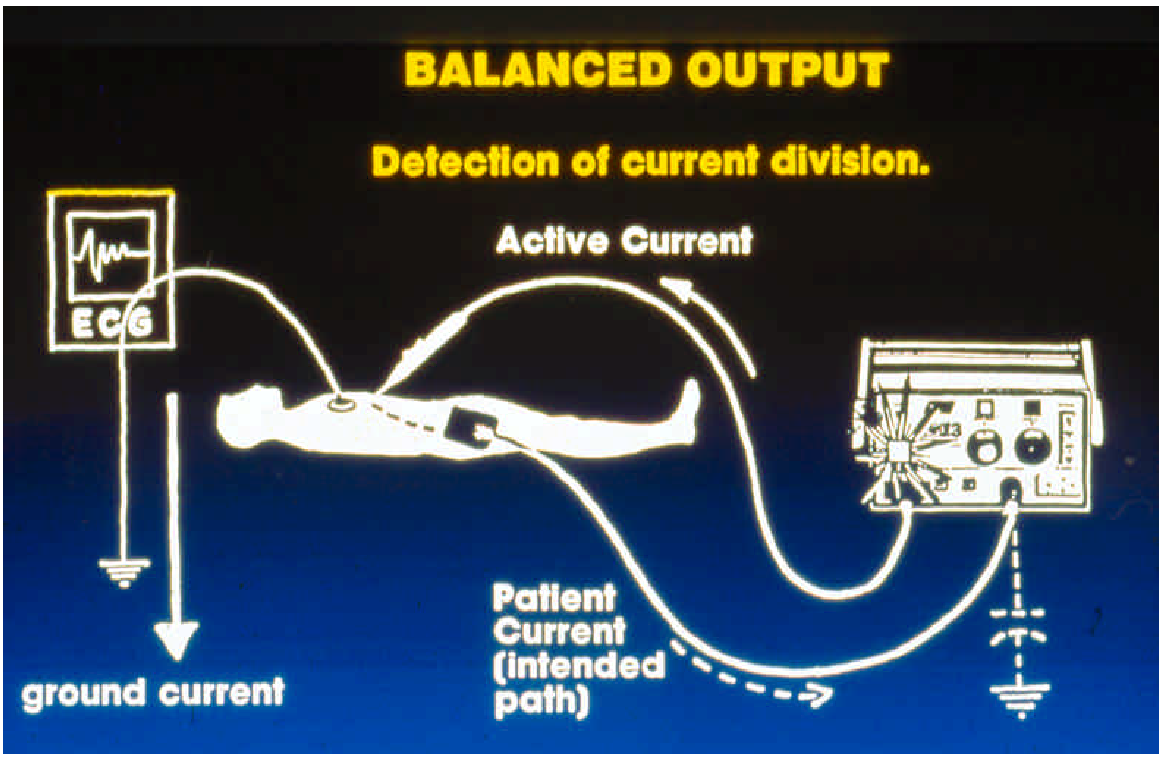


Fig 23

Figure 23 shows a monopolar ESU and the intended and potential current paths. The current should go from the Active electrode (the “Hot”) to the Return Electrode (ground pad, or “Neutral”) to complete the circuit. However the ESU does plug into the wall electrical outlet and potentially has a connection to the earth ground[6]. This makes it possible for “stray” current to travel other grounded pathways, such as the EKG lead in this illustration. If the surface contact area is small enough, and current large enough (Current density), then a burn can occur. Some models of ESU’s have built in failsafes for this condition by measuring the electrical current both

[6] Many ESU’s utlize isolated power supplies to minimize this problem, but it can still occur for a variety of technical reasons. See Appendix B for a discussion of isolated power supplies.

leaving from and *returning to* the ESU. Should any discrepancies occur then the ESU will shut down with a "Return Fault" indication.

Another way this "Inadvertant Ground" burn can occur is through jewelry – particularly with the high frequency (3-4 MHz) units found in some offices. The high frequency ESU are sometimes promoted as "Radio Frequency" generators rather than Electrosurgical generators – it's all in the semantics of the frequency used – they're ALL RF (Radio Frequency) generators. With such high frequencies the placement of the Return Electrode (ground pad) is not as critical as it is with lower frequency units because the high frequencies "seek out" the Return Electrode even when there are gaps between it and the patient. This does make it safer in the sense of avoiding Return Electrode burns, but it presents other hazards. This Return Electrode is generally a ceramic type plate on these high frequency units. Though the Active electrode will still work when the plate is not in direct patient contact it works less and less effectively as the distance increases between the patient and the plate. At the same time the voltages are building up in the patient's tissues since the current is not being effectively returned to the ESU. Remember that high voltages (& also high frequencies) become harder to contain the higher they get. The electrical current is looking for a way to return to the ESU. Now imagine a scenario such as a woman who is wearing pierced earrings – perhaps a tiny thin wire loop through her ear and large dangling metal earrings below it. At this point you're not just looking at an earring, you're looking at a Radio Frequency antennae connected to a cutting electrosurgical loop in her ear! Without good proximity/connection of the Return Electrode to the patient the current is looking for a way to escape and may find that by radiating out the earring. The small wire loop creates a very high current density situation and burns or even cuts through the patients earlobe. **Though not all ESU use nor types of jewelry present such a risk in every case, it is the safest and best policy to simply have the patient remove all jewelry when anticipating ESU use.**

<u>RETURN ELECTRODE (Ground Pad) BURNS</u>
Electrosurgical effects are created at the smaller Active Electrode rather than the larger Return Electrode (a.k.a. Dispersive Electrode or Ground Pad) because of CURRENT DENSITY. The Return Electrode spreads out the current over such a large surface that no heating or burning occurs there – IF the pad is properly placed.

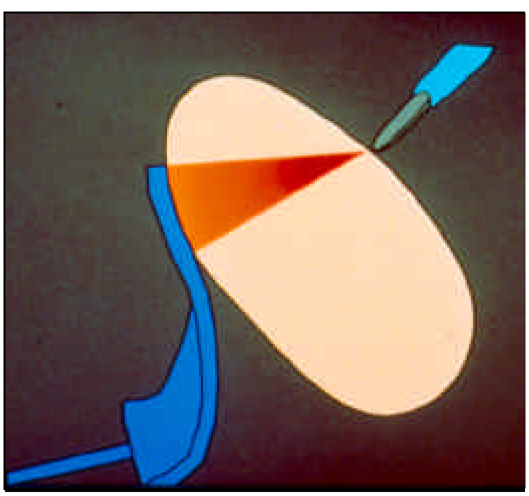


Fig 24

Fig 25

Figure 24 shows a concentration of the current as the Return Electrode is peeled away from the surface, forcing the current to flow through a progressively smaller surface area. A patient burn in the area is a factor of time and how small the area gets. Ensuring good placement of this electrode is essential. Figure 25 illustrates such a burn on a child.

One way to minimize the risk of these ground pad burns is for the system to monitor the way in which the current is distributed on the ground pad. This is analogous to monitoring the Balanced Output of the entire generator with the Return Fault monitor, but instead of just comparing current out with current in, it also ensures that the ground pad does not have it all concentrated on one side of the pad. This is called Return Electrode Monitoring (REM), or Neutral Electrode Safety System (NESS).

For this electrode monitoring to be effective the Return Electrode must be split into two halves so that each side may be monitored (Fig 26).

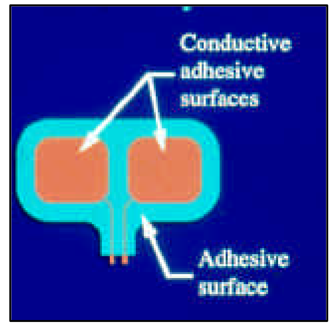


Fig 26

Each of the two surfaces may now be monitored independently and the unit's failsafes will shut it down if any discrepancy occurs in the amount of current returning to each side.

Fig 27 - Valleylab ForceFX unit shown with a variety of Split Return Electrodes used for Return Electrode Monitoring. (The upper right one is a single surface electrode not used for such monitoring).

Proper orientation of the Return Electrodes is also important. While incorrect orientation would generally not result in the type of burn as a pad that has partially pulled away, it frequently results in slightly erythematous, swollen areas seen in patients when the pad is removed.

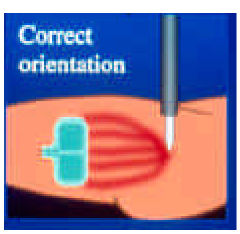


Fig 28

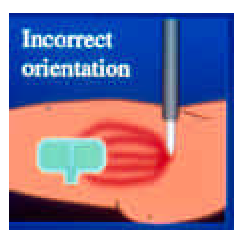
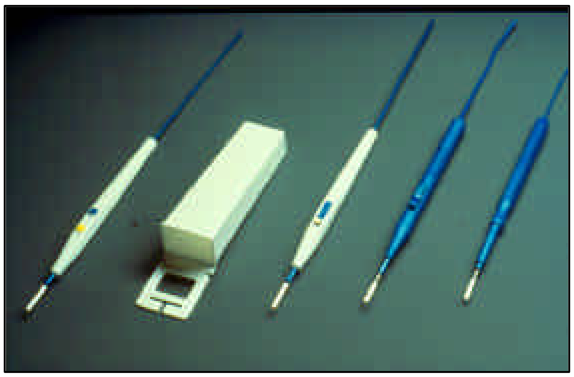


Fig 29

Imagine the current returning to the electrode as a river of water making it's way back to the drain. The objective is to keep it as highly dispersed as possible and not concentrate it into any little "tight", "tiny" streams of current. Figures 28&29 illustrate the proper and improper orientations for the pad, so that the current is dispersed as much as possible. On the split pads and Return Electrode Monitoring (REM), improper placement of the pad can result in frequent REM faults and the unit shutting down because each side of the pad is getting a different amount of current.

In addition to it's orientation, it's important that the pad NOT be placed directly over bony prominences (such as the Iliac Crest) or Fatty areas if possible because of the difference in resistance of these tissues. Muscular areas should be chosen which are as close to the surgical site as practical. Placing it farther away than necessary (on the ankle for instance when performing abdominal or cervical procedures) requires that more power and voltage be used than would otherwise be necessary, in order to get the same effect. This unnecessary use of higher power settings increases the chances of stray current burns or capacitance elsewhere.



Safety Holsters are very important for isolation of the Active Electrodes. These plastic, safety "containment" holsters would prevent an inadvertent burn if the ESU footpedal were accidentally depressed. When not in use, the Active electrodes should always be placed in these holsters.

Special Circumstances in Laparoscopy:

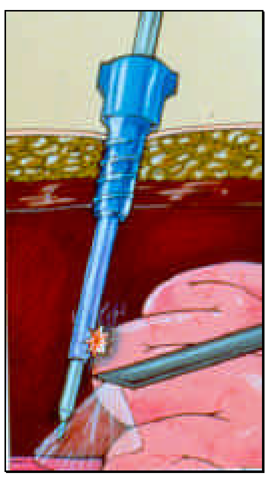


Fig 30
Capacitive Coupling

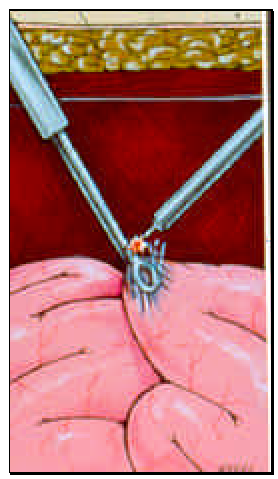


Fig 31
Direct Coupling

Capacitive Coupling:
We've already discussed this is some detail and will refer back to that section. These hazards are primarily in laparoscopy, and in colposcopy with high frequency ESU's. Note that in Fig 30 that the injury is occurring in an area that is outside of the laparoscopists view. There may be no indication of an injury until the patient returns with complications.

Direct Coupling:
If the Active electrode is accidentally (or intentionally) touched to a metal instrument then that

instrument will also become an active electrode. Stray current burns can occur anywhere that the current crosses to tissue in a small surface area. It may or may not be in the operators view.

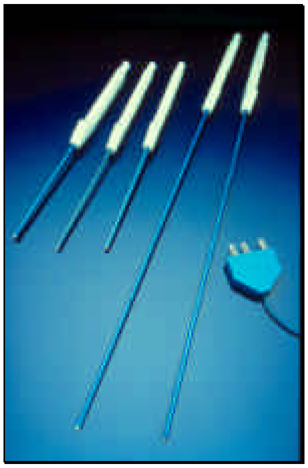


Fig 32
Laparoscopic Handpieces (on right)

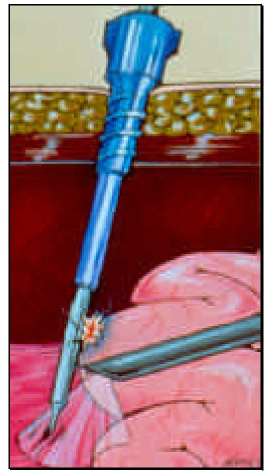


Fig 33
Insulation Failure

Insulation Failure:
Figure 32 shows the blue insulation on these electrodes. If the insulation fails (Fig 33) then a stray current burn can occur which may be outside the operators view. Overuse of the "COAG" mode and its attendant high voltages is one way to create this insulation failure during use. Recleaning and resterilizing electrodes that are intended for single patient use is another way to break down the insulation. The insulation on reusable electrodes is much thicker and reliable than on ones intended only for single patient use. Do NOT re-use disposable electrodes.

Electrically Isolating Tissues in a truncated fashion and creating "upstream" burns:

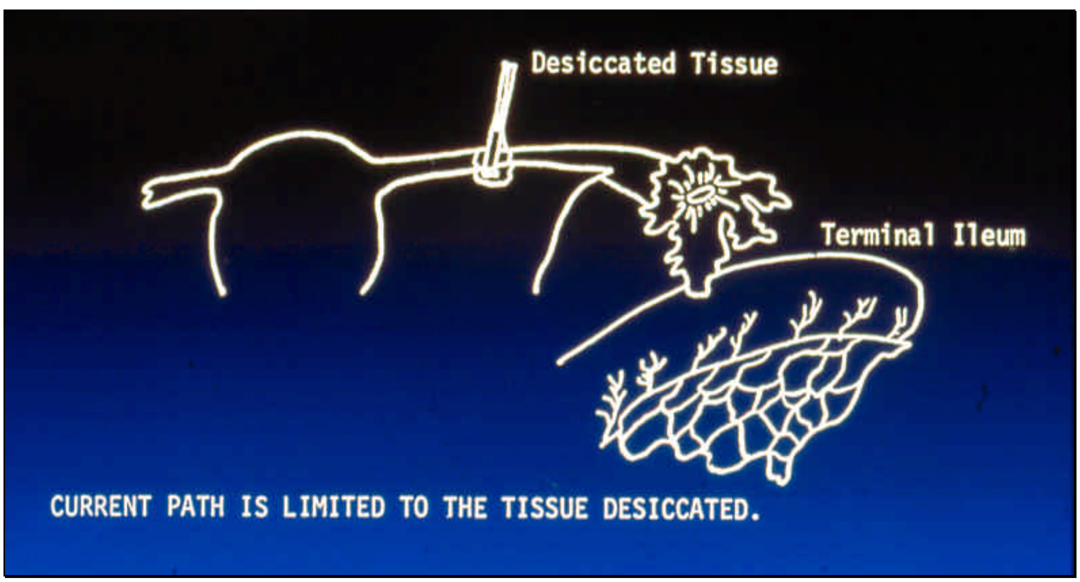


Fig 34
This illustrates tubal sterilization with a monopolar grasper. In this diagram the return flow of current will pass to the left through the body of the uterus, and also to the right through the fallopian tube, onto the bowel (ileum) and back to the return electrode. No injury occurs here because the surface areas are large enough to prevent high current density burns.

Though the illustration is that of a tubal sterilization, the principle applies anywhere a truncated segment of tissue can be electrically isolated. In figure 34 the desiccation is just beginning and current returns harmlessly through both the body of the uterus and through the tube and bowel (ileum) upon which it is resting.

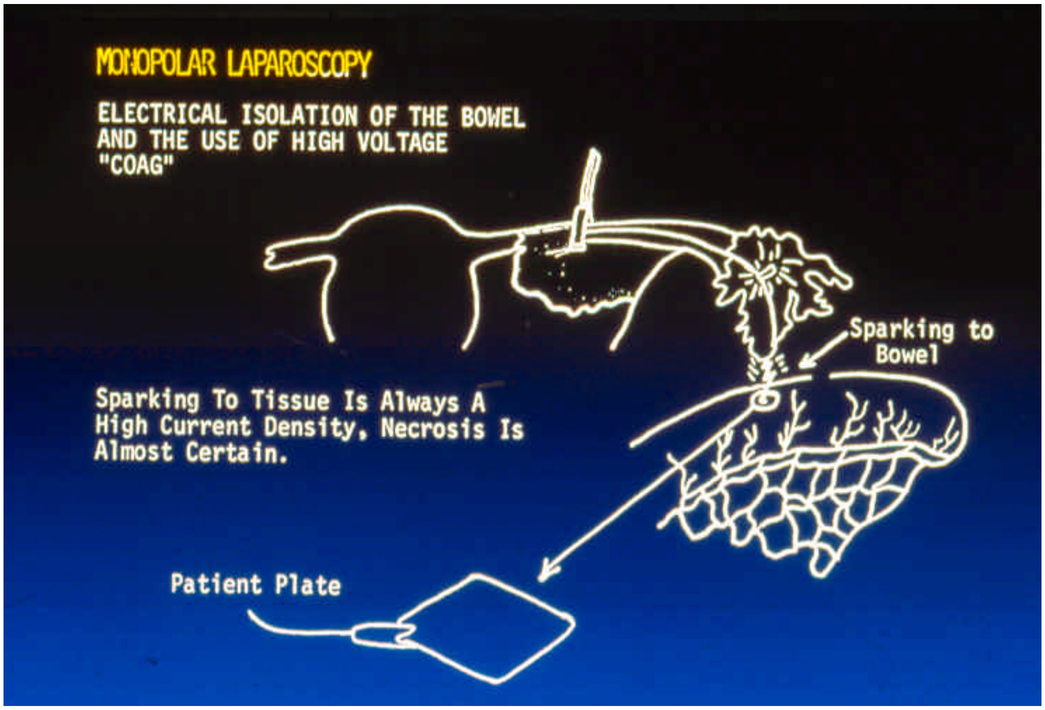


Fig 35

A second stage begins after initial desiccation of the tube. The graspers started desiccation proximally towards the uterus and are now moving distally out on the tube. The result is that the desiccation destroys conductivity of the tissues back through the uterus. This has electrically isolated the tube and all the current must pass out the distal end of the tube. To make matters worse the high voltage COAG mode is used allowing sparks to jump gaps. The fimbria end of the tube is lifted just slightly up off the bowel allowing a spark to jump the gap onto the bowel. This spark will always cause tissue necrosis with a high probablility of delayed perforation.

As the desiccation continues distally out the tube it becomes electrically isolated from the uterus and forces all the current to travel down to the end of the tube. The high voltages of Coag cause a small spark to jump to bowel when the tube is slightly lifted – the tube is electrically isolated, the current has no where to go but this small “spark-gap”. This could be prevented by using the CUT mode, desiccating from distal to proximal towards the Uterus, and keeping good contact with the tissues. A saline (conductive) pool flooded into the pelvis would also protect all tissues immersed in this pool, though of course they’d have to be out of the fluid to work on that portion.

Use of BiPolar forceps for such desiccation would be much preferred since this would eliminate these stray current burns from isolated segments of tissue. The current path would be limited to the area betweent the jaws of the grasper. (Fig 36)

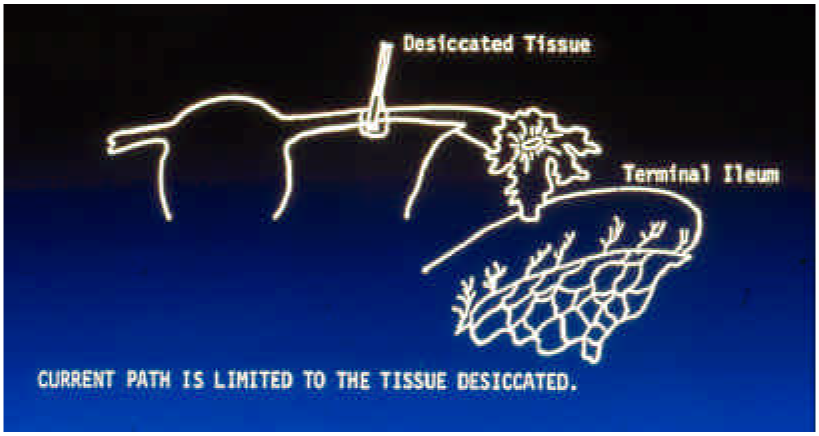


Fig 36

BiPolar desiccation of the tube is preferred over monoplar, keeping the current path limited to just the portion of the tube in between the grasper jaws.

Other general safety concerns include creating sparks around flammable liquids and gases. Bowel preps should be considered for ESU use in those areas. Endotracheal tube fires are a consideration if using the ESU in the immediate vicinity of the tube – particularly with high Oxygen concentrations.

Adequate training is the single most important aspect of ESU safety. Check the appendix of web links and look at the report of the Royal College of Surgeons, and browse the many training and safety information resources in these various links.

Good Surgeons perform good surgery with whatever tool they choose to use. The Best Surgeons become very knowledgeable of the attributes of every technical tool from which they can choose.

. . . and there was light!

<u>Appenxix A:</u> - Electrical Waveforms

The PRINCIPLES OF HIGH FREQUENCY SURGERY section of this manual simplified the electrical concepts of CUT and COAG into that of accentuating a trade-off between high voltage or high current. This is true in principle (and is actually how the original old "Bovie" unit worked) but current Electrosurgical Generators don't actually work quite this way. Here we'll explain a little more about AC electricity and how these effects are actually generated. The technical aspects vary somewhat from one manufacturer to another, but the general approach is the same.

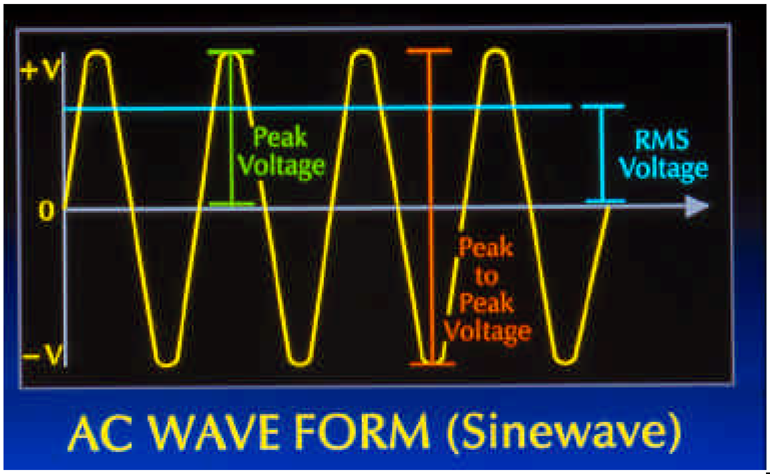


Fig A1

Figure A1 illustrates a typical AC waveform showing three types of voltages. The RMS is the "Root Mean Square" voltage and is like an average of the peak voltage. RMS is most often the voltage referenced when just speaking generically of the voltage. Theoretically the CUT mode would have a high peak voltage and COAG would have a low peak voltage.

BLEND modes (between CUT and COAG) would theoretically be a true blending of these high and low peak voltages as shown in Fig A2. This is not really how it works though, but the analogy was useful in explaining the problems of high peak voltages in COAG.

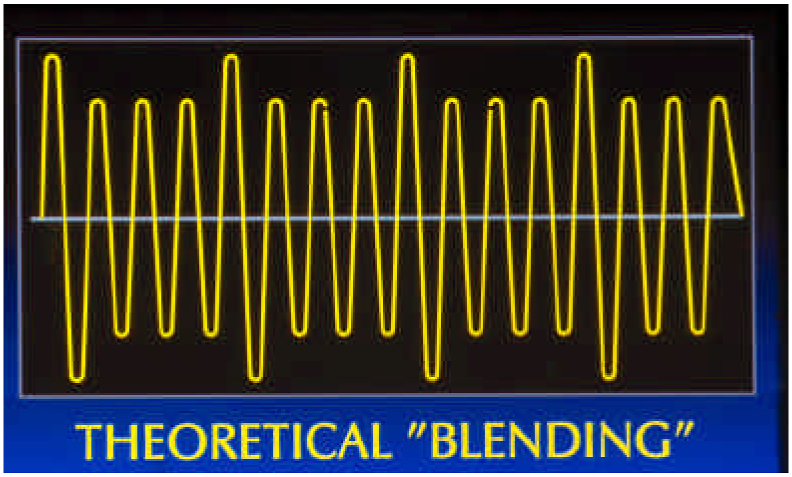


Fig A2

In actuality when an ESU is switched from the CUT to COAG modes, the peak voltages stay about the same, but the entire output is switched on and off at rapid rates to create different "average" voltages (Fig A3). In the straight CUT mode there is no switching on and off of the output so this is sometimes called an "undampened" mode. The actual blend mode, since on and off switching is involved, is sometimes called the "dampened" mode. The ratio of on times to off times, and the peak voltages involved, will alter the RMS voltages (Fig A1).

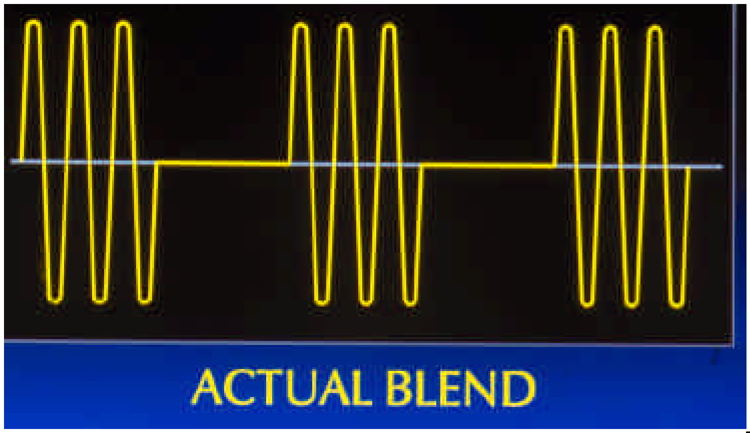


Fig A3

What determines how much of a "Blend" between CUT and COAG is provided is determined by the ratio between the Peak Voltage and RMS Voltage as shown in Figure A4. This is know as the CREST FACTOR. It should make sense that the lower the ratio between the "On" times of output vs it's "Off" times, the RMS voltage will drop compared to the unchanging Peak Voltages. The lower this ratio goes (more "off" time than "on" time), the higher the CREST FACTOR goes, and the closer to a straight COAG the waveform is.

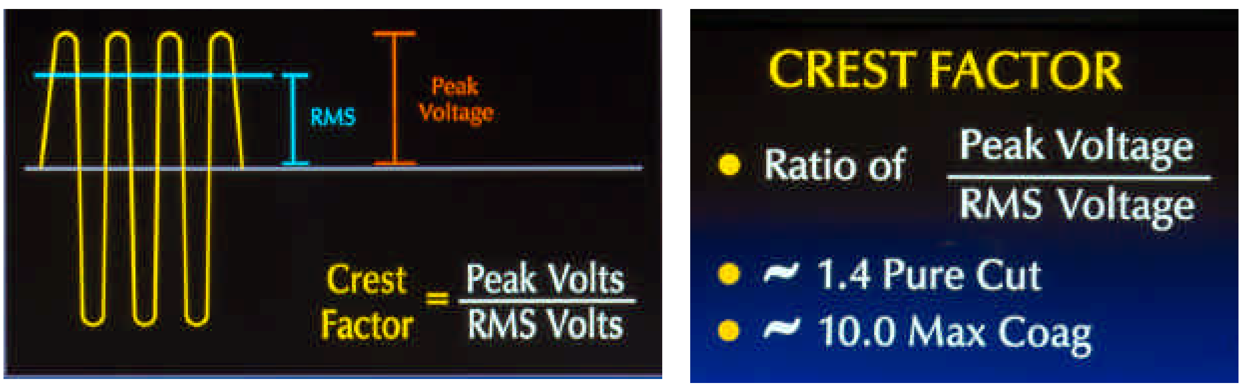


Fig A4

It is still true though that COAG and high blends have high peak voltages (depending on the ESU). This effects the zone of damage around incisions and carbonization of tissue as explained in Appendix B.

When using Blend modes (Blend 1-3 usually) it is important to note that they occur in the CUT mode of the ESU and are activated with the CUT portion of the foodpedal or Handpiece (select the Blend mode, then use the CUT button to activate). In fixed sized electrodes such as wire loops or fine needles, low Blend modes are usually used to achieve some hemostasis since the size of the electrode surface area against tissue can't be altered to achieve lower current densities.

Appendix B: - Tissue effects as affected by Voltage and Resistance

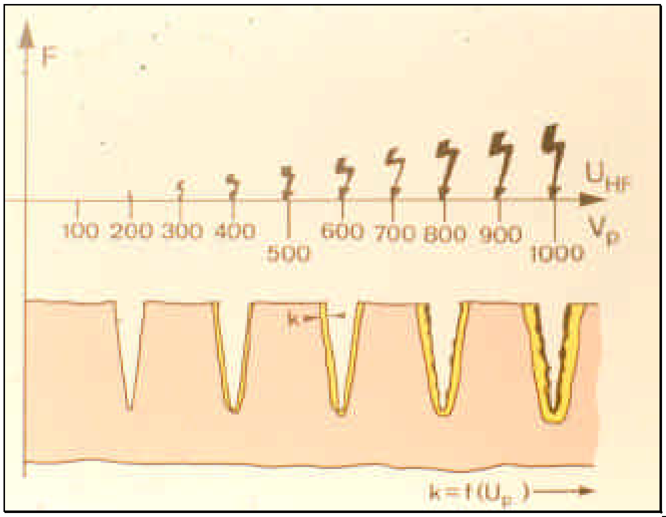
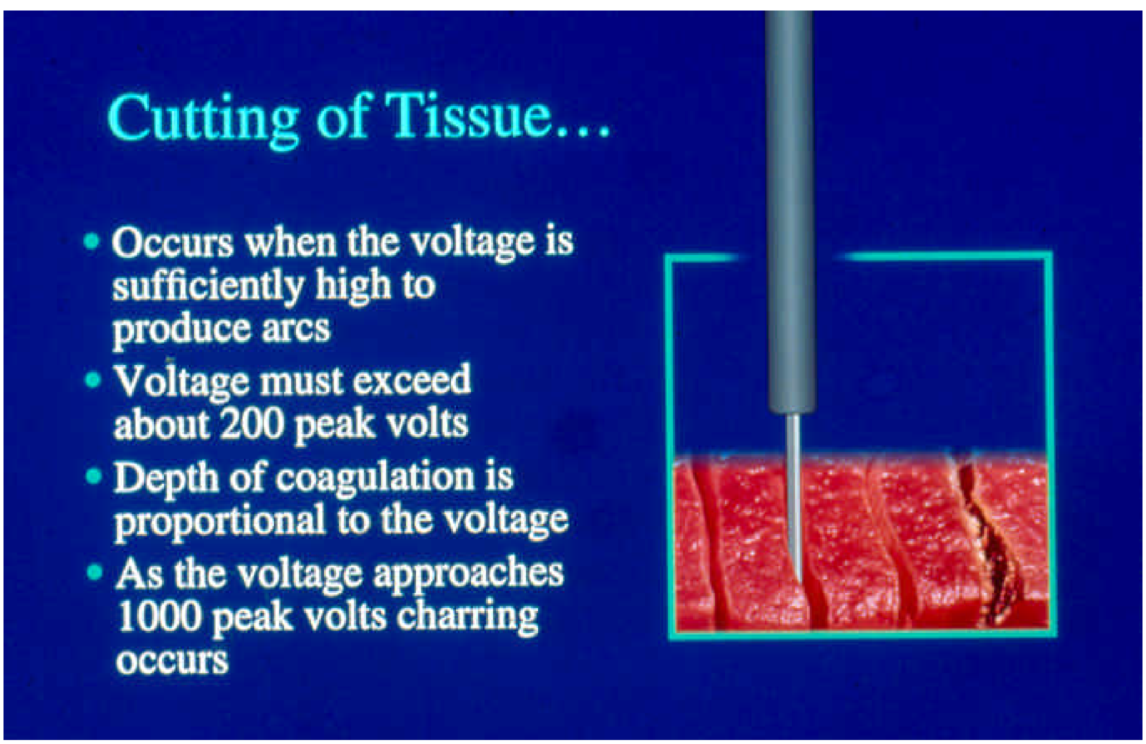
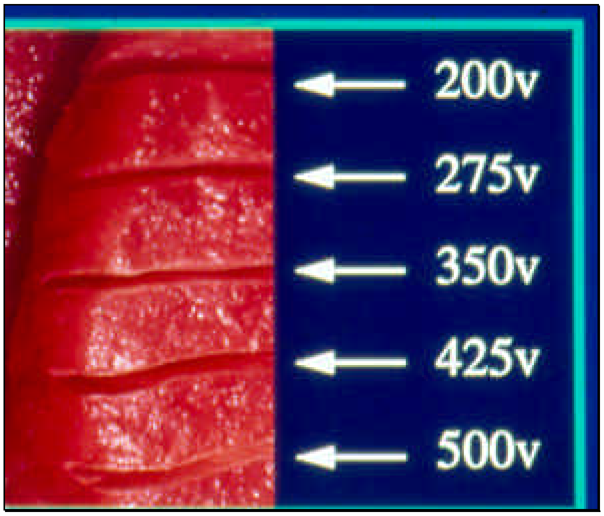


Fig B1

High voltages hit tissue with such a strong "driving force" that carbonization occurs at high voltages – typically 1000 volts. This can occur in the high blend and straight COAG modes. The lateral zone of damage also increases (up to a point) providing good hemostasis but poor margins if the specimen is to go to pathology.

Use of high voltages like this in the COAG mode may be good for superficial coagulation like Fulguration, but is not good at getting deep into the tissue for deeper coagulation because the carbonization layer eventually acts like an insulator preventing the current and heating effects from going any deeper. Therefore in procedures such as hysteroscopic endometrial ablation, or tubal ligation for sterilization, this high voltage COAG mode is NOT preferred because it minimizes the deeper tissue damage that is desired.





Figures B2 shows incisions made at various voltages – all below 500v on the left and none show evidence of carbonization. A 1000 watt incision on the right shows the carbonization. This is from a constant voltage generator which is further explained in Appendix D.

Figs B2

The pathway for the ESU current also follows the path of least electrical resistance (Fig B3). This can result in somewhat unpredictable and nonuniform pathways as shown in the illustration. The current follows the path of the underlying vessel (or ureter or whatever it happens to be). This is in contrast to the uniform distribution of heat damage (isotherms) from a laser which uniformly distributes its energy. Though the precision and predictability of laser is unnecessary in many situations, this is what makes the laser more useful when these traits are desired (i.e. dissecting a ureter from a pelvic sidewall).

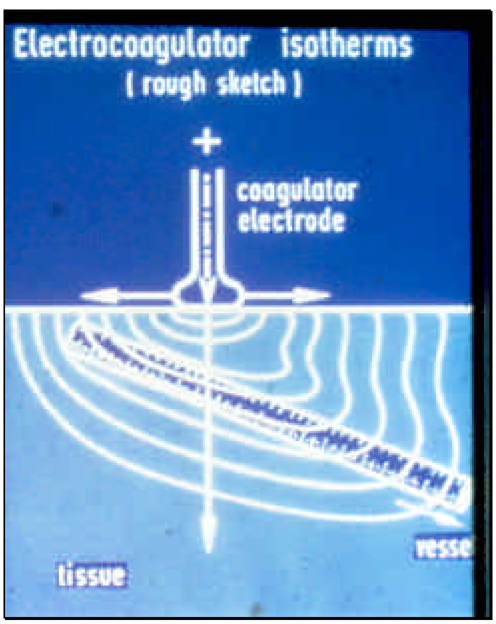


Fig B3

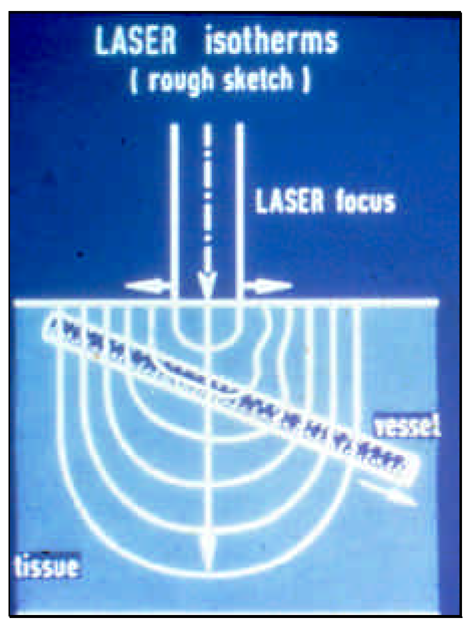


Fig B4

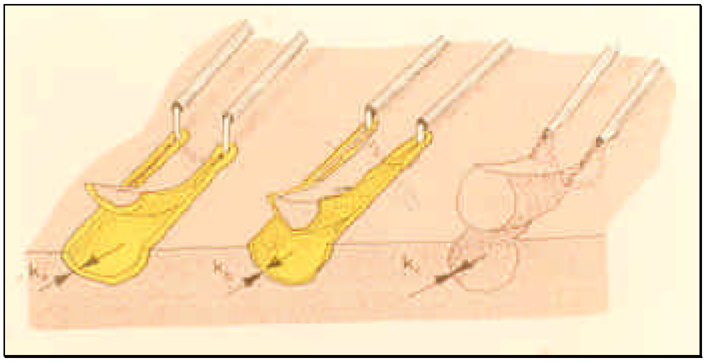


Fig B5

Similar to voltage effects seen in Figure B1, the zone of damage with cutting loops (resectoscopes or LEEP loops) increases with higher levels of blend (because of higher voltages). Figure B5 illustrates a decreasing zone of lateral damage (and less hemostasis) going from left to right with lower levels of BLEND to a straight CUT. In practice, since the size of the loop can't be adjusted to achieve hemostasis, most loop excisions are performed on BLEND 1 or BLEND 2 settings as a compromise between good tissue margins and good hemostasis. When tissue resistance changes (such as also seen here with differing depths) then voltages change and alter tissue margins. This is discussed more in Appendix D with Constant Voltage power supplies.

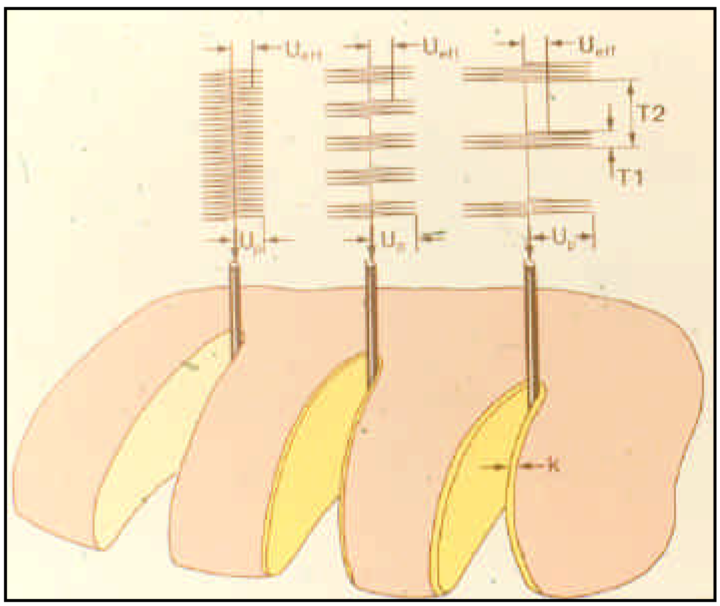


Fig B6

Figure B6 illustrates the increasing zone of damage (& hemostasis) from left to right going from the straight CUT (undampened waveform), to Blend, to COAG. This relates to increasing CREST FACTORS from the modulated current.

Appendix C: - Isolated power supplies

The initial section on PRINCIPLES OF HIGH FREQUENCY SURGERY has already discussed at some length the problems of inadvertent burns from alternate ground sites. A way to significantly reduce the incidence of this problem is to isolate the power supply from the ground source. This is done with the use of an isolation transformer.

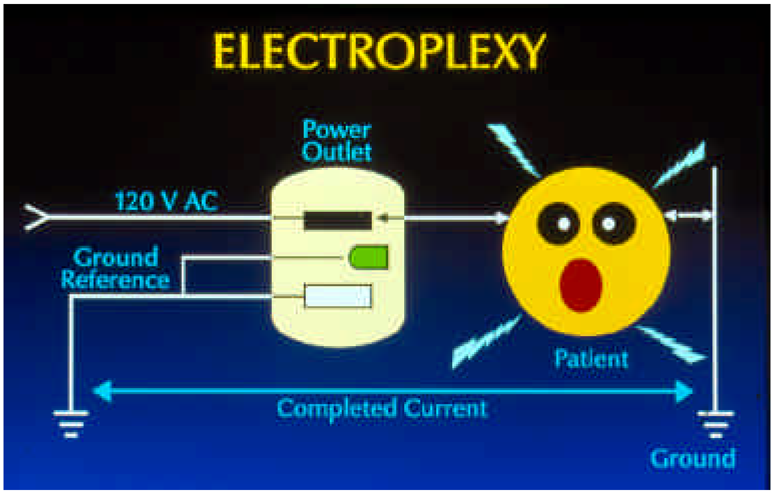


Fig C1

Figure C1 is a rehash of what we discussed in the previous section. Essentially the "shock" (or burn with an ESU) occurs when an alternate pathway to ground is found to the "HOT" (or active electrode).

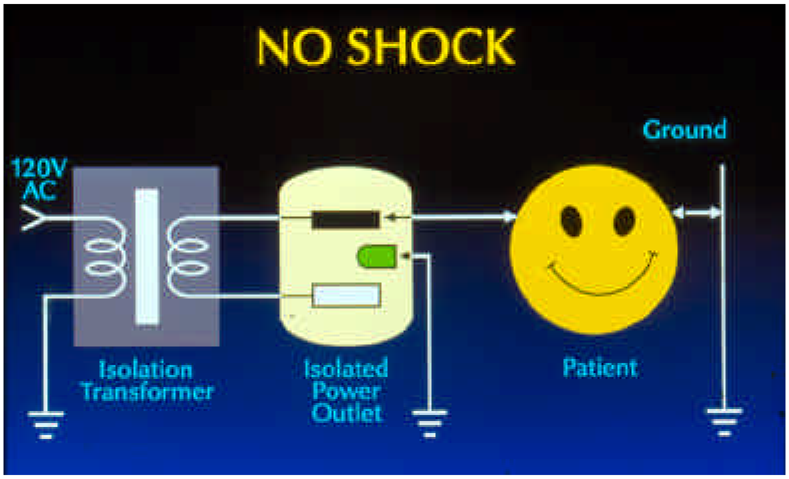


Fig C2

Figure C2 shows the use of an isolation transformer to physically isolate the Neutral lead (return electrode) of the circuit from the actual earth ground. The "Hot" and "Neutral" leads of the incoming circuit are wound around the coil of a transformer. A "Mirror Image" of this current is created on the other side of the transformer by windings on the patient side of the isolation transformer. Current is transferred from the incoming original circuit to the patient circuit wiring by a magnetic field that induces the current in these windings. The "Hot" and "Neutral" leads on the patient side therefore are purely arbitrary poles on each side of the winding, and have no physical connection to a physical earth ground. The circuit MUST be completed between the two poles of the transformer windings. It CANNOT be completed through an earth ground.

Appendix D: - Constant Voltage Vs Constant Power ESU's and the Instant Response

Historically Electrosurgical generators are set by the operator by selecting the POWER level and mode (CUT, COAG or BLENDS) desired. The underlying changes in tissue resistance, output voltages and currents have been unseen by the operator. Tissue resistances change and the operator has no control over this. Any change in resistance causes changes in power output or voltage of the unit. ESU units have primarily been programmed to hold the POWER delivery constant and allow the VOLTAGE to vary to compensate. These are called Constant Power units. Other units hold the VOLTAGE constant and vary the POWER, these are called Constant Voltage units. The Valleylab units utilize a technique similar to Constant Voltage which is called the "Instant Response".

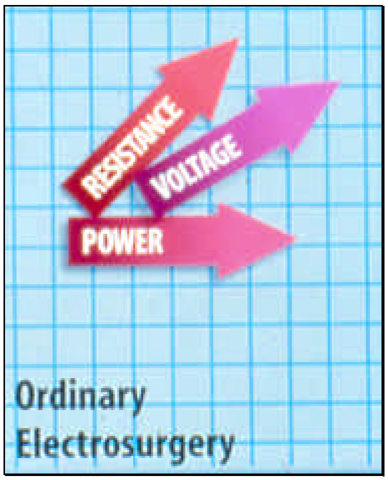


Fig D1
Constant Power ESU

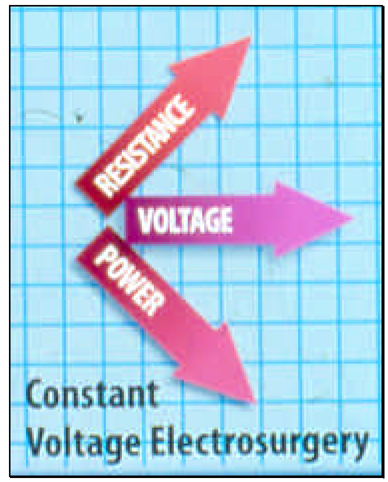


Fig D2
Constant Voltage ESU

The advantage in Constant Voltage units (Fig D2) versus Constant Power units (D1) is the limitation of voltage. As discussed in Appendix B, high voltages cause carbonization and wide margins in tissue. Changing resistances and changing voltages cause irregular margins which present a problem for pathology specimens. In Constant Voltage units sense changing resistance in tissue, the POWER output of the unit will vary, resulting in varying speeds of the electrode through tissue, but consistent tissue effects.

Valleylab units use a proprietary method of balancing tissue resistance with power and voltage, putting limits on the upper ends of the voltage. The result is a unit that has some advantages over both constant power and constant voltage units.

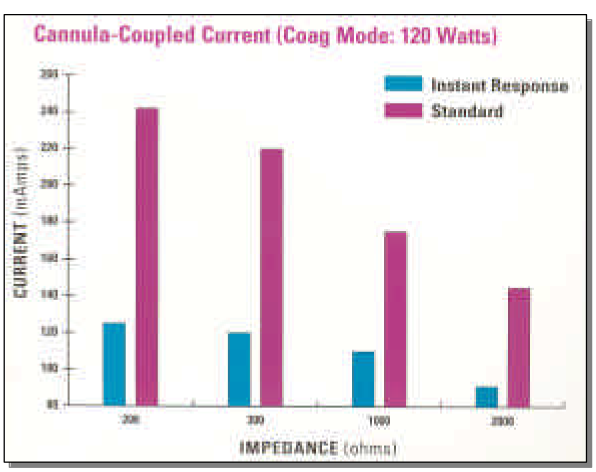


Fig D3

The Instant Response system significantly reduces the chance of capacitive coupling into an abdominal Trocar as shown in Fig D3 (as do Constant Voltage Units).

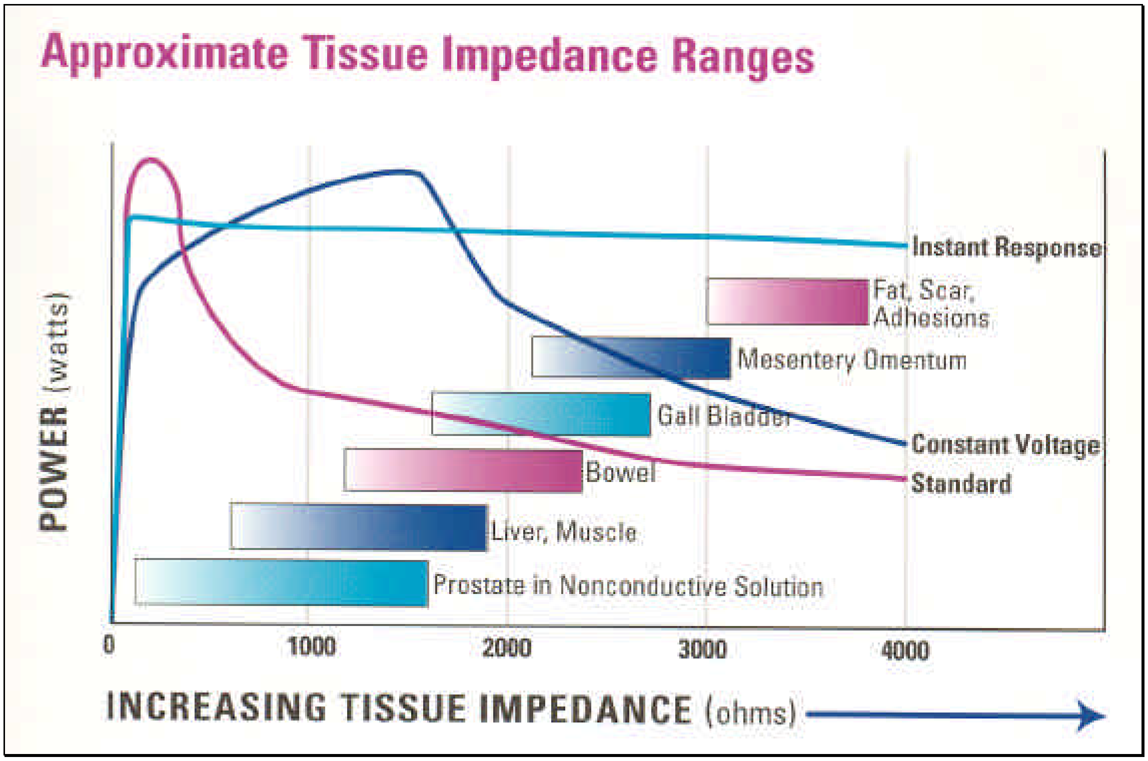


Fig D4

Figure D4 shows that the Instant Response system will hold a constant power output (and hence rate of electrode motion) better than both conventional and constant voltage ESU's in different tissues with changing resistance (impedance is the correct term for RF electricity). The Instant Response system quickly responds to changing tissue impedance and adjusts accordingly, while limiting voltages to sub-carbonization levels.

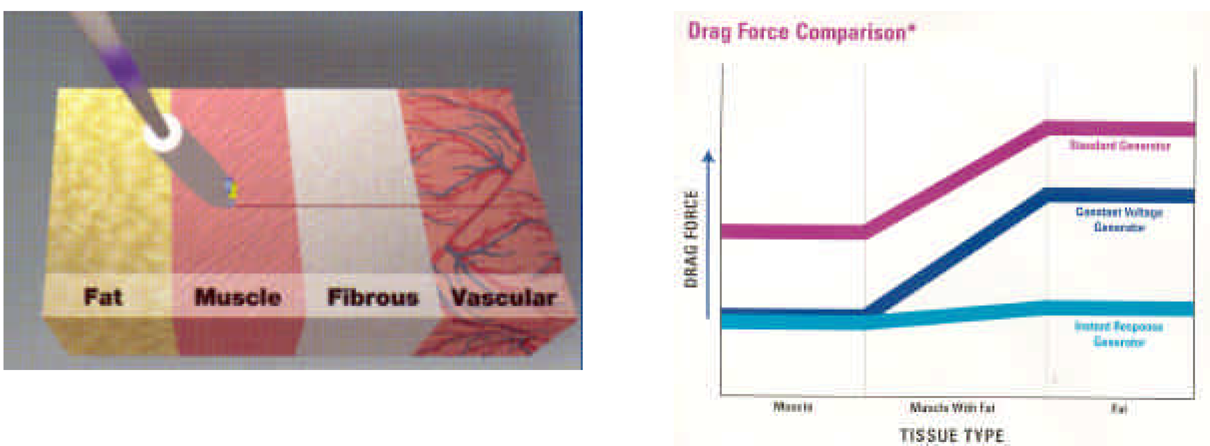


Fig D5

This adjustment to changing tissue impedances by the Instant Response allows the tactile "feel" and "drag" felt on the part of the surgeon to maintain some degree of uniformity as shown in Fig D5.

Appendix E: FURTHER READING:

Capacitive coupled stray currents during laparoscopic and endoscopic electrosurgical procedures. Tucker, Voyles & Silvis. *Biomedical Instrumentation & Technology*. 1992; 26:303-311. Hanley & Belfus, Inc., Philadelphia, PA.

Demodulated Low Frequency Currents from Electrosurgical Procedures. Tucker, Schmitt, Sievert & Silvis. *SURGERY, Gynecology & Obstetrics.* July, 1984, Vol. 159, 30-43.

Direct-current Potentials Created by Arcing during Monopolar RadioFrequency Electrosurgery. Tucker, Kramolowsky, & Stasz. Biomedical Instrumentation & Technology. 1990; 24:212-216,

Education and Engineering Solutions for Potential Problems with Laparoscopic Monopolar Electrosurgery. Voyles & Tucker. 1992. *The American Journal of Surgery* Vol 164, July 1992

Electrosurgical Devices, American National Standard. Association for the Advancement of Medical Instrumenation (AAMI). Arlington, VA.

Electrosurgery Thermal Injury - Myth or Misconception?. Saye, Miller, Hertzman. 1991 Raven Press, Ltd., New York. *Surgical Laparoscopy & Endoscopy* Vol. 1, No. 4, pp. 223-228

Electrosurgery at Laparoscopy: Guidelines to Avoid Complications. Vancallie. 1994. *Gyaecological Endoscopy* 1994, 3, pages 143-150

Electrosurgery in Operative Endoscopy. Wattiez, Khandwala & Bruhat. 1995. Blackwell Science Ltd., Cambridge MA.

Essentials of Monopolar Electrosurgery for Laparoscopy. Voyles & Tucker. 1992 MONOGRAPH Univ. of Mississippi @Jackson, and University of Iowa @ Iowa City

"Instant Response™" electrosurgery generator for laparoscopy and endoscopy. J.L. Eggleston, J.S. Kennedy, R.C. Platt & K.D. Taylor. 1997. *Minimally Invasive Therapy & Allied Technologies.* Vol. 5, No. 5/6. Blackwell Science Ltd., Cambridge MA.

Monopolar Electrosurgical Safety During Laparoscopy. *ECRI Health Devices*. Jan 1995 Vol 24, No 1, 6-27

Principles of Electrosurgery. Valleylab - a division of Pfizer Hospital Products Group. 1995. Educational Booklet. Boulder CO. 800-255-8522 x6349

Review: Recent advances in high-frequency electrosurgery: development of automated systems. Haag & Cuschieri. *J.R. Coll. Surg. Edinb*., 38, December 1993, 354-364.

Appendix F: - Web links to ESU manufacturers and other resources

If you are using the CD-ROM or the Adobe Acrobat version of this manual, and are online while you are reading this, you can click on the links below to go directly to them, then just return to this document to go to more.

Professional Medical Education Assn – www.MedicalSymposia.org – online free manual on practical electrosurgery, plus CD-ROM versions.

Laser/**Electrosurgery** Plume. During surgical procedures that use a laser or electrosurgical unit, a smoke plume develops.
www.osha-slc.gov/SLTC/laserelectrosurgeryplume

LASER VS **ELECTROSURGERY**. KARL HAUSNER – Elmed Electrosurgery
www.elmed.com/lasvselec.htm

ELECTROSURGERY. ELMED ELECTROSURGICAL GENERATORS. **...**
www.elmed.com/elmed2.htm

Electrosurgery products, supplies and information site at MedCatalog.Com
www.medcatalog.com/electros.htm

Shavers. Fluid. Knee. Shoulder. Shutt. Small Joint. **Electrosurgery**. Imaging. Endoscopy. Linvatec Electrosurgical Instruments:
www.linvatec.com/electrosurgery.html

Principles of **Electrosurgery** ONLINE. Table of Contents. Valleylab is pleased to provide you with this on-line educational booklet on **electrosurgery** (Excellent Site)
www.valleylab.com/static/pofe/pofes.htm

www.valleylab.com – Company site for ValleyLab – highly recommended

Electrosurgery. Coagulation. Cauteries. Multipurpose ESU. LEEP. Coagulation Accessories. Combo ESU.
www.medicalresources.com

The Valleylab Institute of Clinical Education **Electrosurgery** Continuing Education Module. July 2001. A self-study guide intended
www.valleylabeducation.org/esself/

MAST **-** Hysteroscopy, Laparoscopy & **Electrosurgery** Training
Course Outline With Learning Objectives. Univ of Alabama, Birmingham
www.medweb.bham.ac.uk/mast/hysttimetable.htm

Article in Infection Control Today:
Education in **Electrosurgery** Technology is Key for Patient Safety.
www.infectioncontroltoday.com/articles/271topics.html

Electrosurgery for Cervical Intraepithelial Neoplasia. **...** The consequences of inhaling this material are unknown, but most viruses can survive **electrosurgery**. **...**
www.obgyn.net/femalepatient/default.asp?page=epperson_tfp

CONMED employs an advanced electronic architecture designed to deliver "spark gap-like performance" – ESU manufacturer
www.conmed.com/products_Electrosurgery.html

Harrell Medical - Surgery **- Electrosurgery**. Toll Free 1 (800) 574-0976
ASPEN LABS. AL-EXCLB, Apsen Excaliber, **-** ESU distributor
www.harrellmedical.com/surgery%20-%20electrosurgery.htm

Specializing in used medical equipment sales and service, biomedical equipment repair of ultrasounds, audiometers and more. **... ELECTROSURGERY**. **...** BIRTCHER ` BOVIE. **...**
www.appliedmedicalinc.com/esus_hyfrecaturs.htm

ADA (American Dental Assoc) Seminar Series offers course on **electrosurgery** By Arlene Furlong. A lot of dentists own **electrosurgery** equipment, but few are using it regularly.
www.ada.org/prof/pubs/daily/0205/0507sem.html

ERBE Elektromedizin GmbH **-** Medical Equipment for **Electrosurgery**, **...**
Constant Voltage ESU manufacturer
www.erbe-med.com

Electrosurgery: Physical Principles and Safety Issues Dr Nick Cook, Clinical Engineering and Device Assessment and Reporting, Cardiff An introduction to the **...**
www.ipem.org.uk/meetings/23Octabs.pdf

PRACTICAL **ELECTROSURGERY**. For Clinicians. Gregory T. Absten BSc., MBA ã 1982, 1996, 1999 GT Absten: Professional Medical Education Association, Inc. **...**
www.lasertraining.org/electros.htm

LEEP. Coagulation. Coagulation, Accessories. Combo ESU. Cauteries. Multipurpose ESU.
www.medicalresources.com/shopping/catdisplay.asp?subcat=65

ELECTROSURGERY SYSTEMS. Best quality and economy without comprise.
Ready to use: all necessary accessories included.
www.wpiinc.com/WPI_Web/AAMicrodissecting/Electrosurgery/Electrosurgery.html

gynecology, urology, **electrosurgery**. Utah Medical – ESU manufacturer
www.utahmed.com/gyn,uro,.htm

Dipolar Electro surgical Technology from Nuvotek Ltd in association with Electronic Developments Ltd. Worlds first truly all purpose **bipolar ESU**
www.btinternet.com/~edl/Eectrosurgery.htm

Cervical Loop **Electrosurgery** Basic Equipment. EJ Mayeaux, Jr., MD Associate Professor of Family Medicine Clinical Associate Professor **...**
http://lib-sh.lsumc.edu/fammed/atlases/leep/leepeqp.html

Excerpt from a 28-page primer for OR nurses on **electrosurgery**.
Types of **Electrosurgery**.
www.legunncommunications.com/electorsurgery%20copy.htm

Suture? Staple? **Electrosurgery**? **... Electrosurgery**: Both bipolar electrosurgical and monopolar electrosurgical energy can be used for coagulation. **...**
www.obgyn.net/cpp/articles/carter_96_102.htm

Safety in **Electrosurgery** Key points from the workshop held at the Royal College of Surgeons on 23 rd October 2000 "A National Strategy for Improving Safety in **Electrosurgery**
www.ipem.org.uk/sigs/cesig/sineconf.pdf

Education in **Electrosurgery** Technology is Key for Endoscopy Team Members.
By Kelly M. Pyrek.
www.endonurse.com/articles/1c1feat3.html

Other Sites & Companies:
Anthony Products, Inc., (877) 428-1610, www.anthonyproducts.com
Boston Scientific/Microvasive, (508) 650-8000, www.bsci.com
Bovie Medical Corp., (800) 537-2790
Circon Corporation, (888) 524-7266, www.circoncorp.com
Citech, (610) 825-6700, www.citechtest.com

Conmed/Aspen Labs, (800) 552-0138, www.conmed.com
Elmed Incorporated, (630) 543-2792, www.elmed.com
Encision, (303) 444-2600, www.encision.com
Erbe USA Incorporated, (800) 778-3723, www.erbe-med.com
Kirwan Surgical Products, Inc., (888) 547-9267, www.kirwans.com
LINK Technology, Inc., (800) 259-6156, www.linksurgical.com
Magna Medical Systems, (305) 261-2211, www.magnamedical.com
PrimeSource Surgical, (888) 842-6999, www.primesourcesurgical.com
Richard Wolf, www.richard-wolf.com
RITA Medical Systems, Inc., (650) 390-8500, www.ritamedical.com
Sklar Corp., (800) 221-2166, www.sklarcorp.com
Solos Endoscopy, (800) 388-6445, www.solosendoscopy.com
Valleylab, (800) 255-8522, www.valleylab.com