CHAPTER **16**

RADIOSURGERY: ELECTROSURGERY AT RADIOFREQUENCY

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As surgeons, two important goals are to minimize tissue damage and obtain hemostasis during reconstruction, excision, or ablation procedures. Judicious use of an electrosurgical instrument can assist towards these objectives. Unfortunately, most clinicians do not understand electrosurgical devices, perceiving them as something of a "black box" phenomenon. As a result, they fail to realize the potential of optimizing the efficiency of such equipment. The purpose of this paper is to help the interested surgeon understand the basic terminology, physics, and practical applications of electrosurgery using radiosurgical instrumentation.

RADIOSURGERY

The term radiosurgery refers to a refined type of electrosurgery that utilizes a wave of electrons at a radio frequency, usually between two and four MHz (which includes part of the maritime and amateur radiofrequency bands between AM and FM), to incise, excise, ablate, or coagulate tissue. The active electrode similarly remains "cold," yet sterile throughout the surgery. The electrosurgical unit functions with the active electrode concentrating the high frequency electrical energy at its tip, and then transmitting it to the passive electrode which returns the waves to the unit, making them more effective (Fig. 1). The unit must have a facility for a true earth grounding. This should not be confused with the passive or indifferent electrode, nor should it be combined with the passive electrode. Therefore it is inaccurate to identify the passive electrode as a "ground plate" for radiosurgical devices.

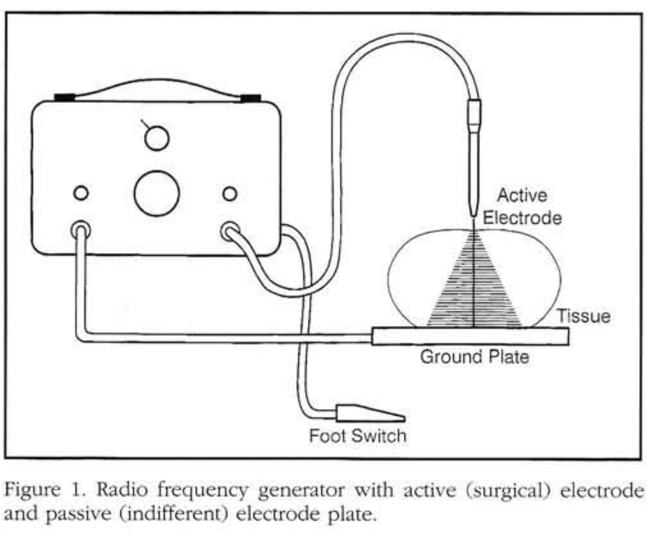

Figure 1. Radio frequency generator with active (surgical) electrode and passive (indifferent) electrode plate.

The electronic unit used in radiosurgery is similar to a radio transmitter which transmits high frequency, low voltage radio waves. This is contrasted with the high-resistance soldering iron, which creates incandescent heat, for cautery, and with the high voltage spark-gap generator or hyfureator, which causes charring. It has been determined that the ideal radio frequency for cutting of tissues is approximately 4 MHz.

The circuitries of all electrosurgical instruments share certain design features that are required to produce electrical outputs suitable for electrosurgery. The utility companies supply power that first passes through a transformer which alters the supply voltage, providing levels and characteristics required for the electrosurgical instrument's various circuit functions. Following this, the current travels through an oscillating circuit that serves to increase the frequency and modify the waves of the current (Figs. 2A, 2B). It may also be further filtered. Finally, it enters the patient's circuit via the active and passive electrodes.

It is the modulation of the oscillating waves of current that makes radiosurgery units unique, allowing for the selection of current settings for specific applications. The Ellman Surgitron unit (Ellman International, Hewlet, New York) has both a spark-gap oscillating circuit and a vacuum tube oscillating circuit, the latter of which can provide partially rectified, fully rectified, and filtered fully rectified output using a frequency of 3.8 MHz (Fig. 3). In addition, the more a wave form is damped, the more likely it is to arc or spark-gap onto the tissue. Undamped waves can then be rectified to increase their ability to cut versus coagulate tissue.

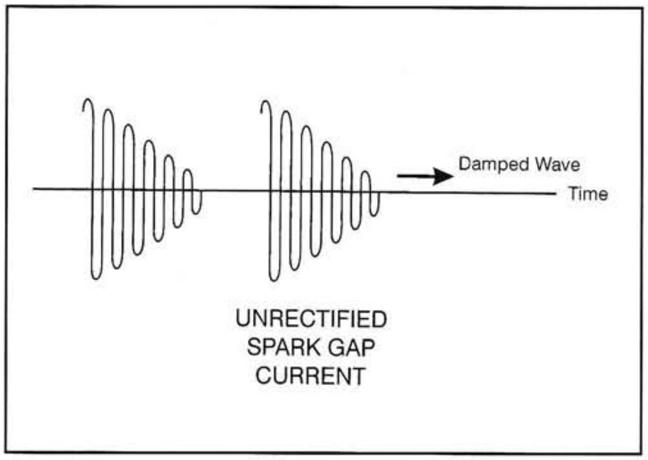

Figure 2A. Damped wave form utilized in an unrectified spark-gap current.

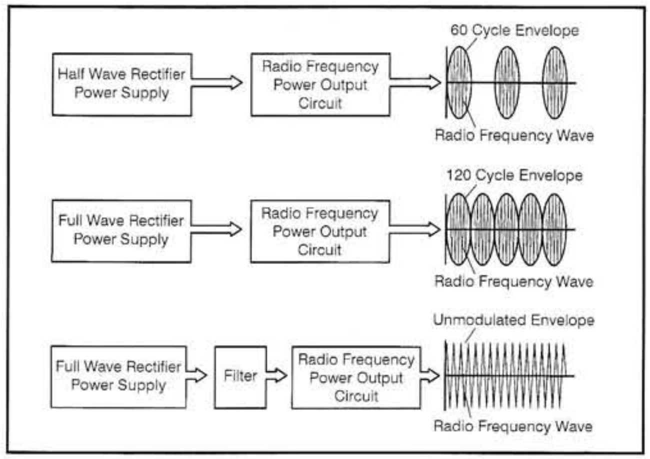

Figure 2B. Output waveforms as a function of rectification.

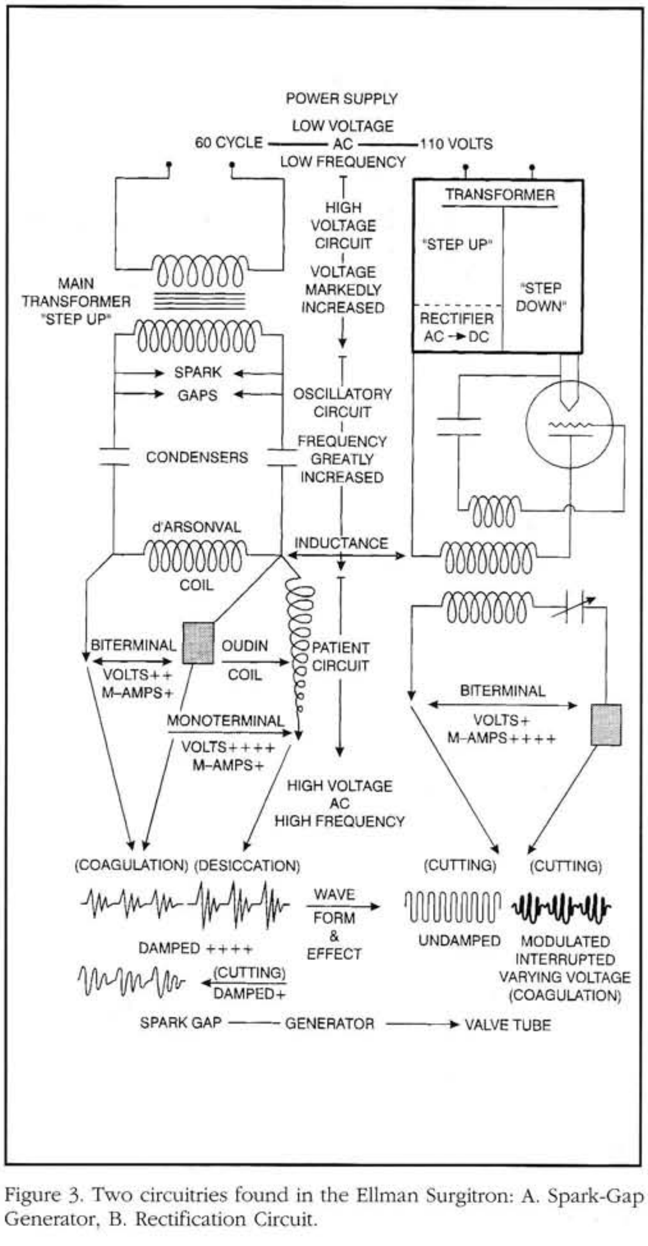

Figure 3. Two circuitries found in the Ellman Surgitron: A. Spark-Gap Generator, B. Rectification Circuit.

Lateral Heat

Correct tuning may be defined as the adjustment of factors to cause the least amount of lateral heat production. The accumulation of lateral heat is due to the impedance or resistance of the local tissues. Such resistance allows for the heat build-up and results in coagulation or volatization. Lateral heat is the result of several factors as depicted in the following formula:

$$LH = \frac{T \times I \times E \times C}{TI_1 + TI_2}$$

- PR
- FR
- FR filtered

in which LH is lateral heat, T is time the electrode is in contact with the tissue, I is power intensity, E is electrode size, and C is current type (partially rectified, fully rectified, fully rectified filtered).

TI_1 refers to the impedance of the patient, and TI_2 refers to the impedance of the specific tissue. Lateral heat can, therefore, be controlled in several ways: time, intensity (power), electrode size, and current type.

Time. The electrode should not be in contact with the tissue any longer than is necessary to produce the desired effect. The slower the movement, the greater the development of lateral heat. The quicker the movement, the less production of lateral heat. Therefore, good technique for cutting tissue involves a smooth, continuous stroke of the electrode.

Intensity (Power). Minimal lateral heat is produced when the current is properly adjusted. It should be just sufficient to coagulate or to vaporize the cells and separate the tissues. Too much power will lead to spark-gapping and charring.

Insufficient current intensity will allow for lateral heat accumulation and "stickiness" of the electrode as the tissues coagulate and adhere onto it, creating drag.

Electrode Size. The larger electrodes require more power and therefore produce more lateral heat. Thus, a thin electrode is more suitable for incisions.

Current Type. The more the waves of the radio frequency current are rectified and filtered, the less lateral heat production there is. Setting 1, Filter-cut (FR filtered) develops the least amount of lateral heat. Setting 2, Cut and coag (FR) develops more lateral heat, sufficient for mild coagulation during cutting. Setting 3, Partially rectified current develops the most lateral heat for radio frequency, suitable for coagulation, at higher power settings, or spark-gapping (Fig. 4).

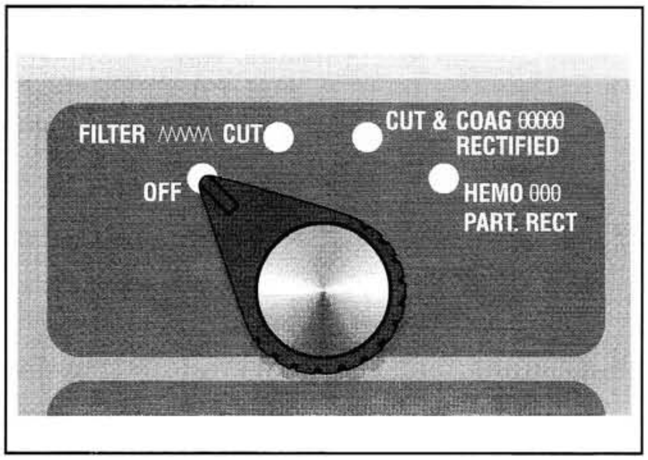

Figure 4. Wave form function setting: Filter/Cut - (Filtered, fully rectified), Cut and Coag (Fully rectified), Hemorect. (Partially rectified)

CLINICAL APPLICATIONS OF ELECTRO-RADIOSURGERY

The simplest way to think of electrosurgical applications in the clinical setting is to consider the three major capabilities of radiosurgery units. These include superficial tissue destruction (electrodesiccation, electrofulguration), deep tissue destruction (electrocoagulation), and cutting (electrosection) (Table 1).

Electrofulguration

Electrofulguration refers to a monoterminal technique in which the active electrode is held just slightly out of tissue contact (1 mm to 3 mm) and moved over the surface, causing sparks to spray onto the tissue and produce an eschar (from the Latin *fulgar* meaning "lightening"). Its destructiveness is limited by the spark-gap and the carbonization of the tissue, which acts as an insulator limiting deeper destruction. Thus, fulguration provides only limited hemostasis.

The area and depth of tissue destroyed are dependant upon the current intensity, the length of time for which the current flows, the density and moisture content of the tissue, and the distance of the electrode from the tissue. An application for this process is the fulguration of the crater left after excochleation of a verruca. Earlier devices for fulguration were spark-gap generators known as *hyfurcators*.

Table 1

APPLICATIONS OF DIFFERENT WAVE FORMS IN ELECTROSURGERY

MODALITY	ELECTRODES OUTPUT	SPARK-GAP OUTPUT	TUBE
Electrodesiccation	Monoterminal	Markedly damped	———
Electrofulgaration	Monoterminal	Markedly damped	———
Electrocoagulation	Biterminal	Moderately damped	Partially rectified
Electrosection with Coagulation	Biterminal	Moderately damped	Fully rectified
Pure Electrosection	Biterminal	Undamped	Filtered, Fully rectified

Electrodesiccation

Electrodesiccation is a monoterminal technique in which the active electrode is inserted either immediately adjacent to or in direct contact with the tissue to be destroyed. Electrodesiccation (from the Latin *desiccare* meaning "to dry up") is a dehydration process. Normally, it produces only mild heat that blanches the local tissues with evaporation of cellular fluids, but prolonged contact will result in tissue destruction and some charring.

The area and depth of tissue desiccation is dependant upon the current intensity, the length of time for which the current flows, the density and moisture content of the tissue, and the surface area of the electrode. It is important to remember that the current intensity and the time allowed must both be increased in direct proportion to the larger needle diameter and depth of insertion.

Both electrodesiccation and electrofulguration are ideal modalities for superficial tissue destruction such as plane warts, seborrheic or actinic keratoses, small epidermal nevi, or in order to achieve minimal superficial hemostasis of capillary bleeding. Should scarring occur, it is usually minimal.

Electrocoagulation

Electrocoagulation comes from the Latin word *coagulare,* which means to clot or to curdle. This term refers to a biterminal electrosurgical technique whereby a low voltage/high amperage radio frequency current is passed from the active electrode to the passive electrode, causing sufficient accumulation of heat so as to coagulate the local tissue near the active electrode.

Electrocoagulation is particularly useful for deep tissue destruction and surgical hemostasis. Small skin lesions, such as uncomplicated basal cell and squamous cell carcinomas, can also be treated with this modality.

Hemostasis can be achieved using either a monopolar electrode or bipolar forceps. The vessel should be clamped with a hemostat and then the monopolar electrode applied to the hemostat at the lowest setting to achieve electrocoagulation. Too high a power setting will burn the vessel off and not provide adequate hemostasis, allowing delayed bleeding from the damaged vessel.

Partially rectified current is the selected mode, as it will develop a fair amount of local heat in the tissues. The coagulation of protein will cause the wall of the blood vessel to seal together, obviating the need for tying it off. The vessel should immediately change color and shrink. It will later heal with scar tissue formation and further shrinkage. Large veins or arteries (greater than 1/16" or 1 mm) should be ligated.

Electrosection (also Acusection or Electrotomy)

These terms refer to a biterminal radiosurgical cutting technique using slightly damped (fully rectified) current that causes very little lateral heat production. It utilizes different types of current, fully rectified filtered current, and fully rectified current.

Fully rectified filtered current produces the smoothest and cleanest incision with the least amount of lateral heat. It vaporizes approximately one layer of cells on either side of the incision (50 microns) without hemostasis. No pressure is required, which prevents further cellular damage, as with a scalpel. In fact, the electrode passes through the tissue like a "hot knife through butter." This is an ideal setting for clean incisions and for dissection where hemostasis is not necessary. It is also useful in the excision of lesions or making of incisions where minimal tissue damage and scarring are essential, such as in plastic surgery procedures, and the excision of superficial skin lesions, particularly in visible areas. (Fig. 5). It has been demonstrated that cutting nerves (such as Morton's neuroma) at this setting reduces stump neuroma formation.

Fully rectified current alone produces a smooth incision with a slightly reduced cutting

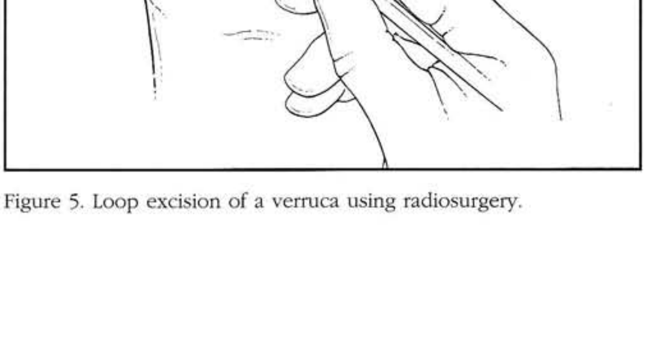

Figure 5. Loop excision of a verruca using radiosurgery.

effect, and is accompanied by slight, superficial coagulation of the incision margins. This is due to a greater production of lateral heat. Thus, it produces hemostasis of small capillary bleeders while the tissue is being cut. It is an excellent technique for making skin incisions or for deeper dissection where hemostasis is desirable. Both of these settings require a smooth paintbrush stroke by the surgeon. It should be practiced on animal specimens before human application.

Electrodissection

Electrodissection refers to the use of electrosurgical techniques as the primary method of hemostasis while exposing a surgical wound and establishing tissue layers.

Electrodes

There are four types of electrodes: Needle electrodes, primarily used for making incisions; Loop electrodes, used for excising and shaping tissue; Ball electrodes, used for coagulation; and Rod electrodes, used for fulguration and desiccation.

PRECAUTIONS

There are numerous precautions which must be observed when conducting radiosurgery. Radiosurgery should not be used by, or on anyone who wears a pacemaker, without first consulting the primary physician to ensure that the pace maker is protected and not affected by high frequency interference. The radiosurgical instrument should not be used in the presence of flammable or explosive liquids or gasses. Do not prep the skin with alcohol.

Remember to deactivate the hand piece by removing your foot from the foot pedal each time an electrode tip is changed. When using some models with two hand pieces, both of them may activate when the foot switch is depressed. Accessories which are not in use should not be placed on the patient or on the surgical drapes, as possible burn or fire may occur.

If the radiosurgery unit is not used for a period of time, or if proper settings are not known, the operator should start off with low power setting and cautiously increase power until an ideal cut is accomplished, with no tissue drag and minimum sparking. Minimal tissue damage is important since it has been shown that electrosurgery can increase the chances of infection when there is too much cellular destruction.

Due to radio frequency, any EKG monitoring electrode should be placed as far away as possible from the radiosurgical indifferent (ground) plate.

CONCLUSION

Electrosurgery at radiofrequency can greatly expand the capabilities of a surgeon when used judiciously. It is recommended that a hands-on, introductory course be taken prior to attempting use of this technology. The skilled application of radiosurgery can result in great patient satisfaction while using time more efficiently (Fig. 6).

Figure 6. A radiosurgery unit consisting of generator, electrodes, and foot pedal. (The Ellman Surgitron, Courtesy of Ellman International, Hewlet, New York)

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