MEDICAL INSTRUMENTATION

SECOND YEAR

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BY:

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LECTURE NO.(6)

Electrosurgical unit (ESU)

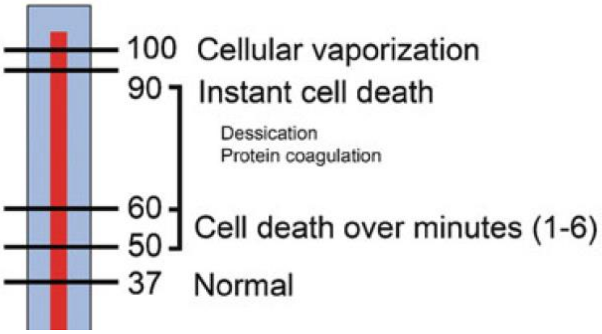
An electrosurgical unit (ESU) passes high-frequency electric currents through biologic tissues to achieve specific surgical effects such as cutting, coagulation, or desiccation. It has been used since the 1920s to cut tissue effectively while at the same time controlling the amount of bleeding. Cutting is achieved primarily with a continuous sinusoidal waveform, whereas coagulation is achieved primarily with a series of sinusoidal wave packets. An electrosurgical unit can be operated in two modes, the monopolar mode and the bipolar mode. The most difference between these two modes is the method in which the electric current enters and leaves the tissue.

Theory of Operation

In principle, electro surgery is based on the rapid heating of tissue. To better understand the thermodynamic events during electrosurgery, it helps to know the general effects of heat on biologic tissue. Consider a tissue volume that experiences a temperature increase from normal body temperature to 45°C within a few seconds.

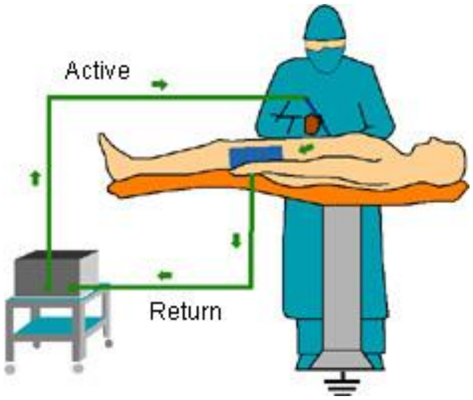
The cytochemical changes do in fact occur. However, these changes are reversible, and the cells return to their normal function when the temperature returns to normal values. Above 45°C, irreversible changes take place that inhibit normal cell functions and lead to cell death. First, between 45°C and 60°C, the proteins in the cell lose their quaternary configuration and solidify into a glutinous substance, this process, termed coagulation, are accompanied by tissue blanching. Further increasing the temperature up to 100°C leads to tissue drying, this process is called desiccation. If the temperature is increased beyond 100°C, the solid contents of the tissue reduce to carbon, a process referred to as carbonization. Tissue damage depends not only on temperature, however, but also on the length of exposure to heat.

In the monopolar mode, the active electrode either touches the tissue directly or is held a few millimeters above the tissue. When the electrode is held above the tissue, the electric current bridges the air gap by creating an electric discharge arc. A visible arc forms when the electric field strength exceeds 1 kV/mm in the gap and disappears when the field strength drops below a certain threshold level.



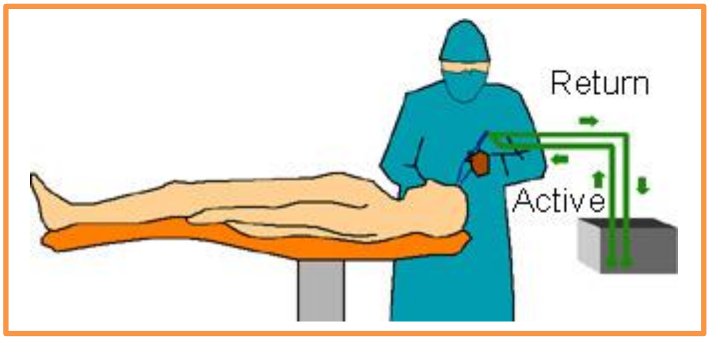
Monopolar Electrosurgery

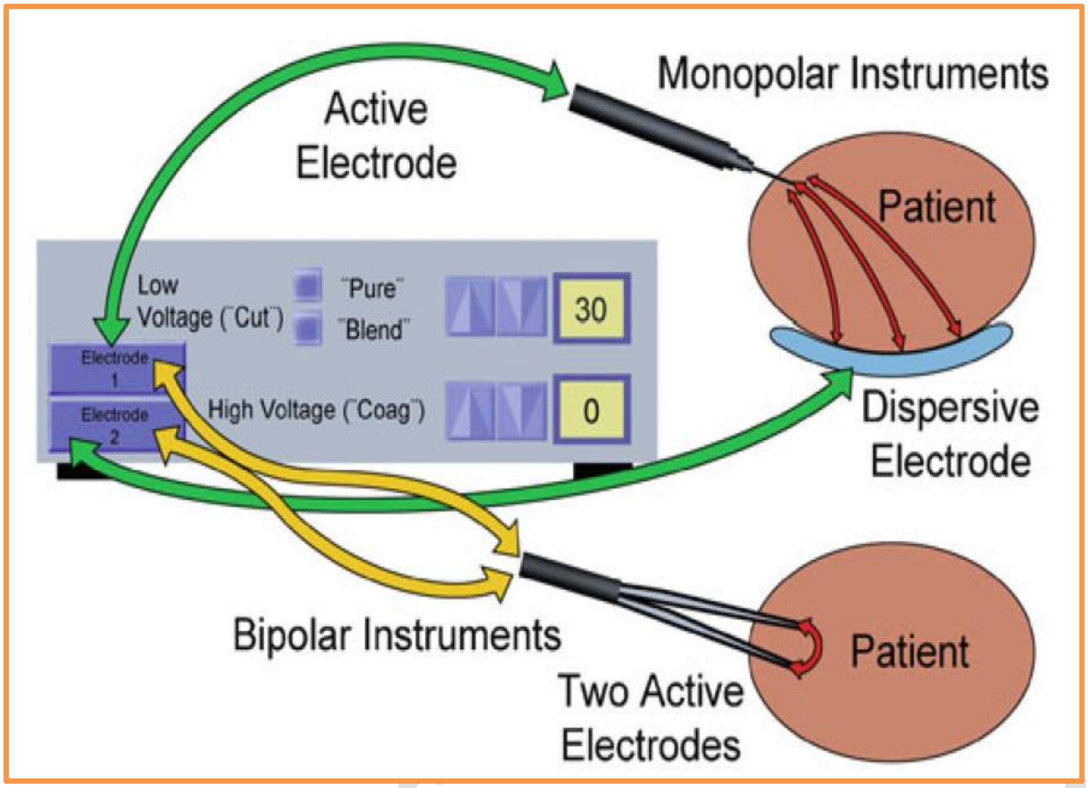
In monopolar electrosurgery, tissue is cut and coagulated by completing an electrical circuit that includes a high-frequency oscillator and amplifiers within the ESU, the patient plate, the connecting cables, and the electrodes. In most applications, electric current from the ESU is conducted through the surgical site with an active cable and electrode. The electrosurgical current is then dispersed through the patient to a return electrode returning the energy to the generator to complete the path. Monopolar electrosurgery has the means of delivering energy to the tissue through several modalities (modes of operation): pure cut, blended cut, desiccation (or pinpoint), and spray (or fulguration). The delivery system of the monopolar electrosurgical generator can be a hand controlled pencil (reusable or disposable) or a foot controlled pencil. A number of accessories can be adapted to the foot control output jack to deliver energy through a number of instruments.



Bipolar Electrosurgery

In bipolar electrosurgery, two electrodes (generally the tips of a pair forceps or scissors) serve as the equivalent of the active and dispersive leads in the monopolar mode. Bipolar electrosurgery does not require a patient plate. Electrosurgical current in the patient is restricted to a small volume of tissue in the immediate region of application of the forceps. This affords greater control over the area to be coagulated. Damage to sensitive tissues in close proximity to the instrument can be avoided. There is less chance of current capacitively or directly arcing to surrounding structures such as the bowel. Patient burns are virtually eliminated.





Dispersive Electrodes

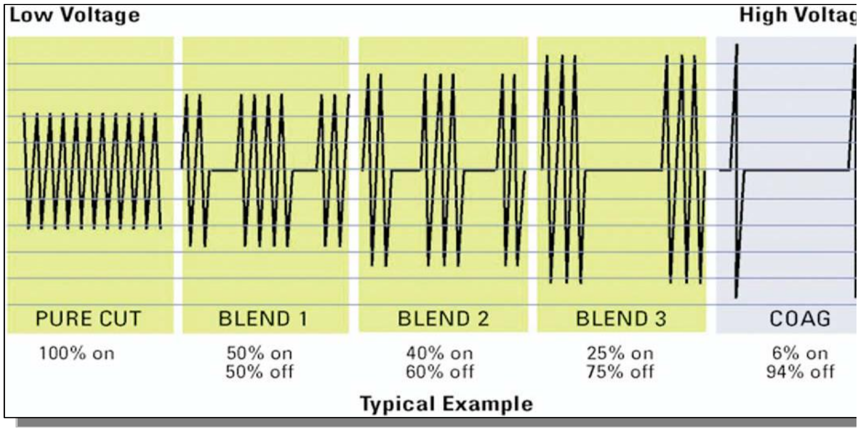
A dispersive electrode is an electrode with a relatively large surface area which is positioned on the patient in order to allow the high frequency current to flow back with a low current intensity in order to prevent any physical effects, such as undesired burns. Over the years electrosurgery has advanced, so too have the types and styles of dispersive electrodes. Early on in electrosurgery the only choice was a solid pad (at first a stainless steel plate) that was placed on the patient to disperse the heat of the RF energy. If the solid plate was not applied correctly or began to move off the patient during the case, the ESU would continue to deliver energy to the tissue, causing a potentially dangerous situation.

Current Density

Electrosurgery makes use of an intensely concentrated current to induce a heat energy that is capable of a range of effects: from the drying out of cells with consequent coagulation of blood, to the vaporization of cells permitting an electrode to physically separate a path through living tissue. The degree of current concentration is called "current density."Current density is one of the most important concepts in electrosurgery. Simply stated, current density is the amount of current concentration at a given point. In electrosurgery all of the RF current is forced to flow through the tiny area where the active electrode makes contact with the skin. At this point, the current flow is concentrated intensely. The heat at the site is great enough to achieve cutting and coagulation. Current leaves the body via a dispersive electrode (grounding pad). The pad has a large surface area thus the current density is quite low. As long as this large, so-called "dispersive" electrode makes good contact with the skin itshould offer a passage of least resistance for safe exit of the RF current from the patient. The large surface area generates little heat. A generator supplies RF to the active electrode. Current passes through the patient, exiting by way of the return electrode. It returns to the generator to complete the circuit. Without complete circular path, from generator to patient, back to the generator, the current should not flow.

ESU waveform:

ESU generators are able to produce a variety of electrical waveforms. As a waveform change, so will the corresponding tissue effect. Using a constant waveform, like "cut", the surgeon is able to vaporize or cut tissue. This waveform produces heat very rapidly. Using an intermittent waveform like "coagulation", cause the generator to modify the waveform so that the duty cycle "ON time" is reduced. This interrupted waveform will produce less heat, instead of tissue vaporization, a coagulum produced.



ESU circuits:

Spark gap circuits: the first electrosurgical instrument used spark gap technique and figure 4 shows the principle of work of spark gap instrument. Consist of high voltage transformer and electric spark gap and C1/L1 circuit. The transformer will increase the voltage from 220 v to 3000-4000v which is able to ionize the air in the gap between the two points of tungsten. When the gap start to spark during production of electric arc by alternating pattern, it will produce currents which radio frequencies which start to oscillate in the circuit (C1/L1). This circuit is coupled "connect" with output circuit (L1/L2) by induction. The output energy which gone to the patient can be control its intensity through taken different level of energy from L2 through switch S2 which is connect with the active electrode. Depending on the type and design of the instrument the power is between 25 watt and few hundred watts. The coils RF1 and RF2 are used for protection and prevent the effect or return back of radio frequencies to the input power.

In some instrument the capacitor is used parallel with the secondary coil of the transformer T1. These generators are used in cauterization and coagulation to stop the bleeding from blood vessels. Most of these instruments exist in two mode cut and coagulate. The rough foot selector switch. The wave for cutting is pure sinusoidal wave while the coagulation wave is damped oscillation wave according to the type and technique of the instrument.

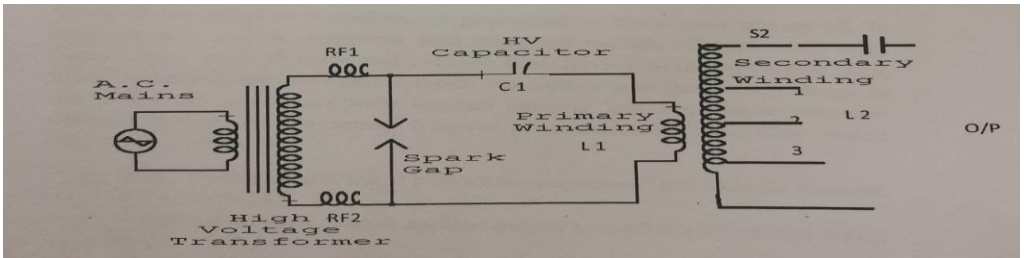


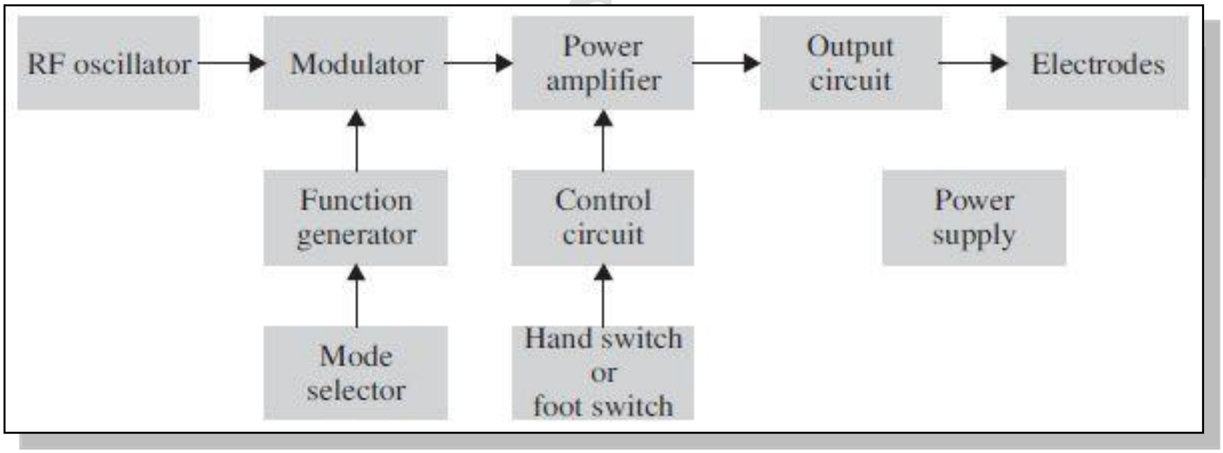
Figure 4: Spark Gap circuit

Design of electrosurgerical unit

Many different designs for the electrosurgerical units have evolved over the years. Modern units generate their RF waveforms by means of solid-state electronic circuits. Older units were based on vacuum tube circuits to generate the waveforms.

A block diagram of a typical electrosurgical unit is shown in the next figure. The RF oscillator provides the basic high frequency signal, which is amplified and modulated to produce the coagulation, cutting and blending waveforms.

A function generator produces the modulation waveforms according to the mode selected by the operator. The RF power output is turned ON and OFF by means of a control circuit connected either to a hand switch on the active electrode or to a foot switch that can be operated by the surgeon. An output circuit couples the power generator to the active and dispersive electrodes. The entire unit derives its power from a power-supply circuit that is driven by the power lines. The entire unit derives its power from a power-supply circuit that is driven by the power lines.



Testing Electrosurgery machine:

The methods of testing electrosurgery machine for checking the O/P RF Power are:

1-Toroid transformer oscilloscope output:

This act as shown in figure (2) uses a dummy load resistor (R1) to simulate the patient and an (RF) ammeter to measure the current through (R1) the resistor should have a resistance between 200-500 the ammeter should have a (0, 2A) full scale range and must be thermocouple RF meter.

The thermocouple (RF) ammeter is inherently an (rms) reading device so it provides a true picture of the actual O/P level Peak reading devices are also sometimes used.

There are two disadvantages with the RF meter they are more expensive than other types of movement meter the other problem is the matter of linearity. The thermocouple (RF) meter does not have a liner scale it is more crowded on the low end of the range than the top so it is difficult to read low power levels.

Transformer (T1) in circuit used to sample the (RF) wave from for display on the oscilloscope.

2. **Voltage divider circuits:**

This circuit uses resistor voltage divider (R2/R3) and diode rectifier (D1) to develop a (D.C) level to drive a (,|A) de meter movement. The circuit here is essentially a peak reading deviser so it can be calibrated in watt only.

3-Toroid current transformer:

This circuit is another peak reading test it used a toroid current transformer but with two windings one winding is connected to J2 for display of the wave form on an oscilloscope while the other devices a de meter through rectifier diode (D1).

This circuit useful when testing electronsurgery machine of low power rating.

Note: the heating of tissue is due to the RF power dissipated in the tissue:

P = PV * Id^ 2

p = resistivity of tissue

V = cubic volume (m ^ 3)

I_{d} = current density (A / (m ^ 2))

Ex: calculate the R.F power 0.2m ^ 3 of tissue with p=1.6^ * 10^ 3 rm. Id 0.36 A / (m ^ 2)

Solution

P = PV * I_{d} ^ 2

P=(1.6^ * 103)(0.2) (0.36)2 = 41.6