High frequency electrosurgery

Among surgical equipment the electrosurgical devices are probably the most commonly used and also most useful. High frequency electrosurgery is a surgical technique related to Diathermy, which is a clinical method that uses high frequency electromagnetic currents for clinical therapy and has surgical applications. Electrocauterization is a different concept from electrosurgery, but is still an important medical application of diathermy. The two are often mistakenly confused because of the use of the electrocoagulation (electrosurgical method). Electrosurgery uses alternating current to directly heat the tissue itself. Unlike electrocauterization that uses direct current to heat a probe to a glowing temperature to cauterize the tissue through heat conduction.

Biophysics in high frequency electrosurgery

Electrosurgery has been described as high-frequency electrical current passed through tissue to create a specific clinical effect. The frequency used must be sufficient to cross the tissues but without activating the muscles, such case would cause muscles contraction preventing the surgeon to work and it is likely to cause the patient's heart to stop. Electrical current in biological tissues is due to connectivity of ionic interstitial fluids. To have an electric current there must be an electric circuit, which is an uninterrupted pathways of flowing electrons.Transition between the electronic and ionic conduction is governed by electrochemical processes at the electrode–electrolyte interface.

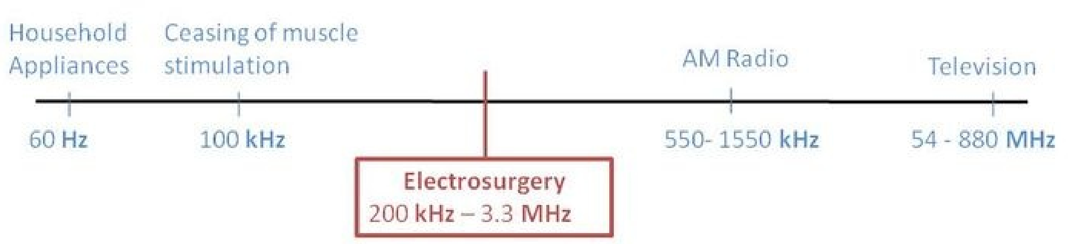

Figure 1: Applications of different current frequencies

Ohm’s Law describes the actions of a given circuit:

$$V = I \times R,$$

where I is the intensity of the current, V is the Voltage (force driving the current against the resistence) and R is the resistence of the circuit. This unities are measured in volt, ampere and ohm respectively. In electrosurgery, voltage is provided by a generator (which can be monopolar or bipolar – see instruments and it’s aplications) and current is delivered to the tissues through the electrode tip of the instrument. Resistance to the current is inherent to all human tissues, if the inherent resistence is higher, than the given voltage also needs to be higher for the current to pass. The current goes thro the patient’s body to a return electrode, which is connected to the generator, completing the circuit.

The current flowing through a resistor causes the generation of heat (Joule heating). This means that the electric energy of the voltage source is converted into thermal energy by the resistance of the human tissues, causing their temperature to rise.

The transformation of electric energy into heat occurs in acordance with Joule’s Laws, which can be related to Ohm’s Law. Joule's first law states that the rate of heat dissipation in a resistive conductor is proportional to the square of the current through it and to its resistance

$$P = I^2 \times R \; P = Q / (t_f - t_i),$$

where P represents electric power (watts), I is the intensity of the current (amperes), $(t_f - t_i)$ is the period of time (s) and R represents the resistence (Ohms).
By substituting Ohm’s Law formula for current into one or both factors of current in Joule's law, the power dissipated can be written in the equivalent forms:

$$P = V \times I = V^2 / R$$

In absence of heat conduction, the rate of temperature rise (dT/dt) in a heated object is proportional to the deposited power (P) and inversely proportional to which is in turn proportional to the mass (m) of the object and its specific heat capacity (c):

$$(dT / dt) = P / (c \times m)$$

This means that a larger amount of heat is required to increase the temperature of a heavier object. However, when heat is generated in a small region of an object, the temperature will rise faster than if the same amount of heat is evenly dispersed over the entire object. Therefor, a larger electrode require longer periods of current application to achieve the same heat production.

The heating effects produced are central to the desired function of the electrosurgical instrument. The rate ate which tissues are heated plays a crucial role in determining clinical effect. The amount of thermal energy delivered and the time rate of delivery will dictate what effects it will have on the tissues. If the temperature is below 45^{0}C, the thermal damage to the tissues can be reversible. If the temperature exceed 90 °C, the liquid in the tissues evaporates, if the heat is delivered rapidly than it will vaporize, if slowly it will result in desiccation. If the temperature reaches 200 °C, the solid part of the tissues will be reduced to carbon.

Instruments and applications of the method

Monopolar instrument

The *monopolar* instrument has three parts: the **active electrode**, the **conductive adhesive grounding pad** and the **generator**. The current leaves the generator and is conducted to the active electrode. Then the active electrode conducts it to the body. The conductive adhesive grounding pad is attached to the patient's body and will conduct the current back to the generator. The *monopolar* instrument doesn't work in a liquid medium, like blood, because this way the current is dispersed. For that reason, this instrument was enhanced with the incorporation of a argon beam, this way, when the gas becomes ionized by the energy of the electrosurgical device, it wipes away the blood. Since argon is a noble gas it makes possible for the current to arc, following the way of the gas column, creating a superficial coagulation, ideal for using in large surface areas.

Bipolar instrument

The *bipolar instrument* has three parts aswell: the **active electrode** and the **return electrode**, which are located in a device similar to surgical forceps, and the **generator**. After leaving the generator the current goes to the active electrode (in one tip of the tweeser-like device), goes to the patient's body and comes back for the other tip of the device, to the return electrode. The return electrode leads the current back to the generator. This instrument was initially used for coagulation of tissue, but evolved to be used in complete fusion of intimal layers of tissue, like vascular structures. This creates the opportunity for the surgeon to seal vessels without suture, staples or traditional clips.

Applications of the method

- **Cut** - to make an incision
- **Coagulate** - which is a way for the surgeon to facilitate the formation of clots in blood, therefor stop the bleeding in some damaged blood vessels;
- **Dessicate** - extraction of water of tissues or incisions;
- **Fulgration** - method that aloows the surgeon to destroy tissue, like malignant tumor, hemangiomas or even warts:
- **Sealing** - to fuse together layers of tissue (as referred above).

Risks and advantages

Risks

Risk of 3rd degree burns in monopolar modalities if the contact with the return electrode is insufficient, or when a patient comes into contact with metal objects serving as an unintended leakage path to Earth-ground. This risk can be dimished by cleaning the skin and applying a conductive gel to enhance contact with the return electrode. A modern electrosurgical unit should be used to continuously tests for reliable and safe patient contact with return electrode. Return electrodes should always be placed close to the body part where the procedure is occurring. The toxic surgical smoke produced by electrosurgery is also a big desadvantage of this tecnic. It contains chemicals which may cause harm by inhalation to the patients, surgeon and operating theatre staff.

Advantages

Some studies say that this type of surgery allows less operating time and limited bleeding.

The low cost (comparing to laser surgery) is also evident, and also the less post-operative time for recovery.

This is a field in medicine which is always evolving, as emphasized by the following article: "Instead of the classic scalpel, surgeons can also operate with an electroscalpel. A significant advantage to this technique is that while a cut is being made, blood vessels are closed off and hemorrhaging eliminated. Now another advantage may be added as well: a German-Hungarian research team has developed a mass-spectrometry-based technique by which tissues can be analyzed during a surgical procedure."

Links

Related articles

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Bibliography

TAKÁTS, Zoltán. *New Prespectives on Cancer Surgery* [online]. Wiley, ©29-9-2009. The last revision 29-9-2009, [cit. 2012-12-07]. <http://phys.org/news173431237.html>.