Technical Note

Electricity in Interventive Endoscopy

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Electricity is the most popular form of power used in Interventive Endoscopy. The electrosurgical generators, or diathermies as they are more widely known, produce high-frequency alternating current, which is transferred through special instruments (loops, forceps, sphincterotomes, etc) to the tissue, causing the excitation of molecules, which leads to the production of heat.

Many different terms are used to make reference to diathermy, such as monopolar-bipolar, cutting-haemostasis current, etc, whose understanding is vital to take full advantage of the devices' capacities, with safety (Fig 1).

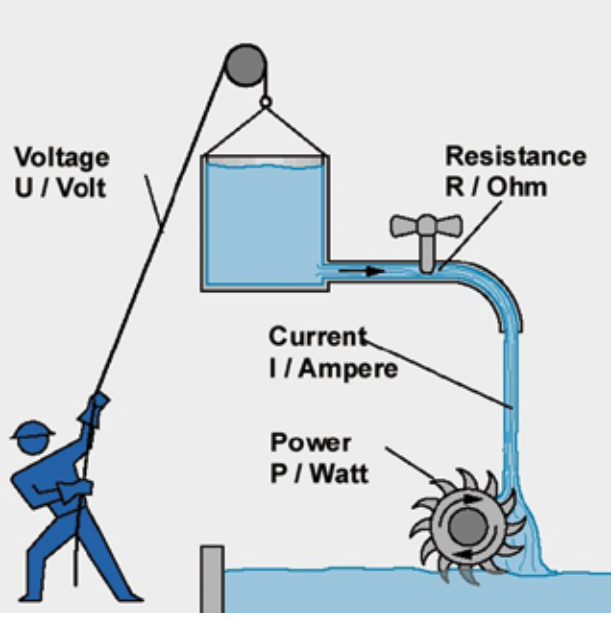

Figure 1.

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Current (I) is the volume of electrons flowing in the circuit in a set period, measured in Amperes.

Resistance (R) is the resistance of the circuit (in this case the tissue) to the flow, measured in Ohm.

Voltage (V) is the power forcing the current to pass through the circuit, measured in Volt. In Physics, the relationship between the above is described by Ohm's Law V = I x R, which states that a higher voltage is needed, to maintain the same flow (I) in a circuit of increasing resistance.

Current density (J) is the quotient of the current divided by the size of the surface through which it is flowing, measured in Amperes/m^2.

Power (P) is the product of current by voltage (P=I*V), measured in Watt and finally

Energy (E) is the product of power by time (E = P x t), measured in Joule.

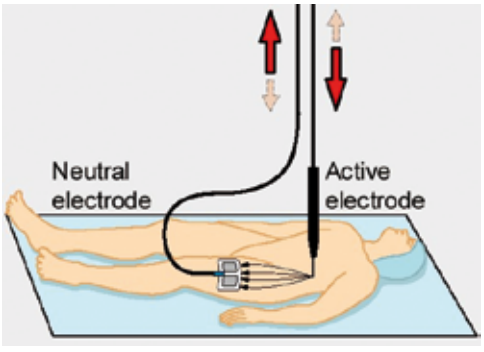

Figure 2.

Modern electrosurgical generators use two types of circuits, **monopolar** (Fig 2) and **bipolar** (Fig 3). In monopolar circuits, the current passes the active pole, which is the instrument, through the patient's body, to the return electrode. In this type of circuit, the active pole is significantly smaller than the return electrode, which, as we will see later, is extremely important for safety.

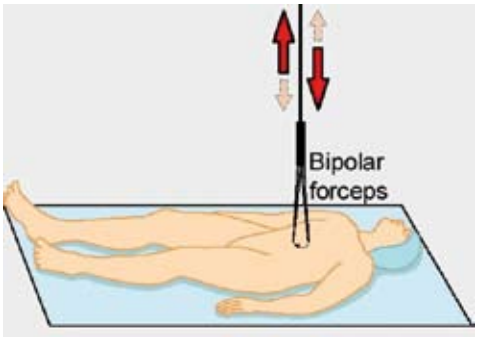

Figure 3.

In bipolar circuits, the instrument has two contact points with the tissue; one acts as an active pole and the other as the return electrode.In this way, the current flows only through the two poles, as thus the depth of the affected tissue is minimal.

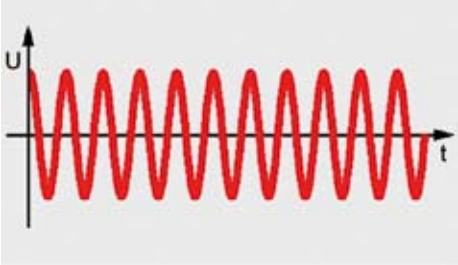

Figure 4.

The term alternating current arises from the current's property of changing its polarity during a unit of time. Its graphic representation forms a sinusoidal curve (Fig 4), whose density and wave height is differentiated depending on the frequency (Hz) and voltage (Volt) of the current through time. The larger the frequency of the alternating current, the smaller the bio-excitation caused to neurons and muscular fibres; this phenomenon was a major problem during the first applications of diathermy. Studies however found that bio-excitation vanished at frequencies over 100,000 Hz (100 KHz). Today, generators produce currents with frequencies from 350,000-1,000,000 Hz (350 KHz-1MHz), creating an exclusively thermal result.

In total, there are three main types of monopolar alternating current: **continuous**, **intermittent** and **interrupted or blended** current. What we should understand at this point is that when we talk about continuous monopolar current, we actually refer to an alternating, high-frequency current, which flows constantly while the diathermy is activated. Similarly, when we talk of intermittent monopolar current, we refer to an alternating, high-frequency current, which flows for short periods, interrupted by period with no current flow, usually at cycles of 6% ON and 94% OFF. Finally, when we talk of interrupted or blended monopolar current, we refer to an alternating, high-frequency current, like intermittent current, but with different cycles – usually between 50% ON and 50% OFF and 80% ON and 20% OFF.

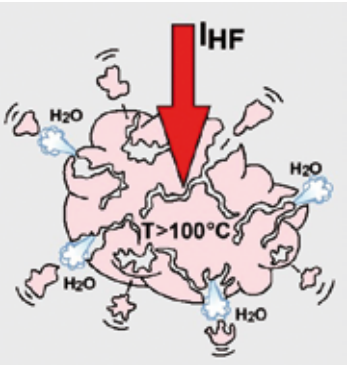

Figure 5.

The actions achieved through the selective use of the above types of current are the **Cutting** and **Coagulation** of tissues. Cutting of tissues is achieved with the application of high-voltage continuous current (>200V). It begins with the achievement of maximum current density, the creation of small sparks and the rapid increase of temperature (T>100ºC) (Fig 5), which ultimately lead to the almost immediate evaporation of intracellular liquids and the dissociation of the cellular membrane along the cut.

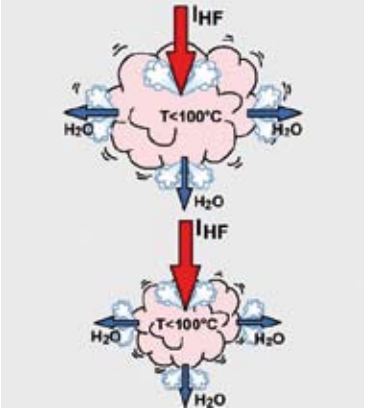

Figure 6.

No mechanical force is required to achieve this. Haemostasis is achieved with the use of intermittent current or low-voltage continuous current (<200V). This takes place through the gradual increase of temperature (T < 100ºC), which causes the gradual evaporation of intracellular fluids, without however dissociating the cellular membrane, which leads to their drying and shrinkage (Fig 6). This results in the necrosis of tissues and the obstruction of vessels.

Intermittent / blended current combines the above actions, depending on the selected cycle:

It is important to know that the width of the necrotic zone during haemostasis is affected by voltage, power, time and type of current, through the following relationships:

- The increase of voltage causes a widening of the necrotic zone (Fig 7).

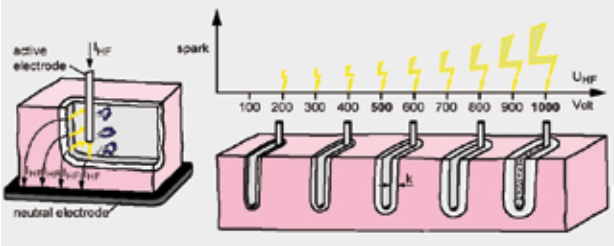

Figure 7.

- Continuous current causes a smaller necrotic zone than intermittent and interrupted current, with an increase of the necrotic zone in proportion of the OFF time (Fig 8).

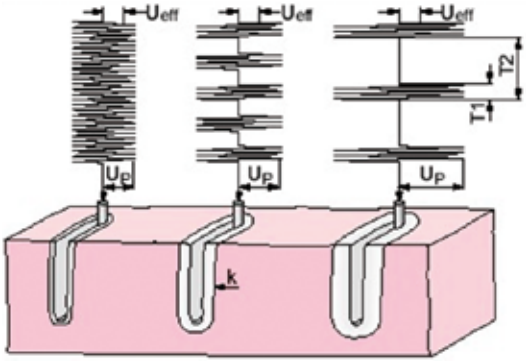

Figure 8.

- A high voltage with a short application time causes a smaller necrotic zone than a low voltage with a long application time.

The various diathermies produce monopolar current in one of the following modes:

- **Conventional mode**, where the produced voltage reduces rapidly, when the tissue's resistance increases.
- **Fixed-wattage mode**, where the produced wattage is maintained by a generator when the tissue's resistance increases, increasing the wattage accordingly.
- **Fixed-voltage mode**, where the wattage and power produced are reduced when the tissue's resistance increases.

In addition, modern diathermies have special programs to achieve a specific result, as for example, a system that achieves the section of tissues producing low-voltage continuous current followed by periods of cutting current, enriched with periods of haemostasis current, in a fixed-voltage mode (Fig 9).

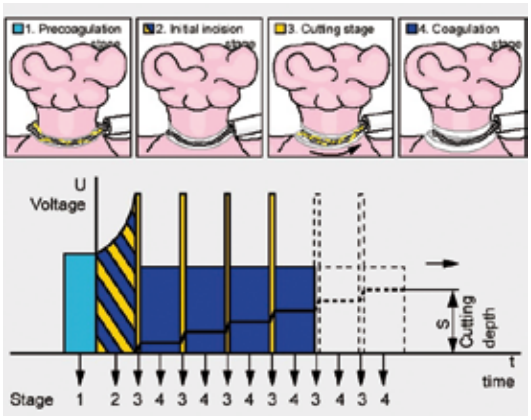

Figure 9.

Another key component in the operation of diathermies is safety. Most complications arise from the incorrect use of the return electrodes, which are often erroneously referred to as "grounding", thus being attributed an inactive role.

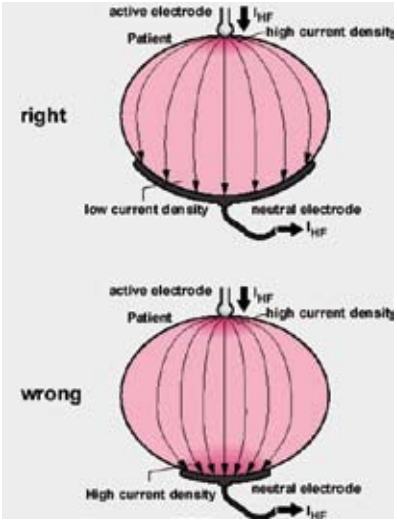

Figure 10.

It is important to understand that exactly the same quantity of current flows in the return electrode as in the active electrode (Fig 10); the only difference is the much smaller current density, which is due to their huge difference in size. Thus, we understand that it is of great importance to always ensure the full connection of the return electrode with the patient's body. If the contact surface decreases, the current's density will automatically increase, leading to thermal injuries.

For this reason, all modern generators have an integrated system to monitor the contact quality of the return electrode, which, upon detection of a decrease of the contact surface below a certain limit, interrupts its operation.

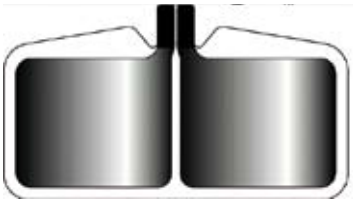

Figure 11.

These systems use double-surface return electrodes (Fig 11).

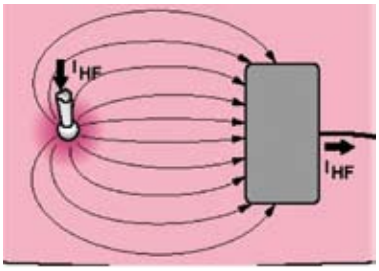

Figure 12.

The correct placement of the return electrode is with its large surface vertically to the flow of the current from the active electrode (Fig 12). The golden rule for the placement of the return electrode is in a muscular, well-vascularised tissue, at the shortest possible distance from the point of application (Fig 13, 14).

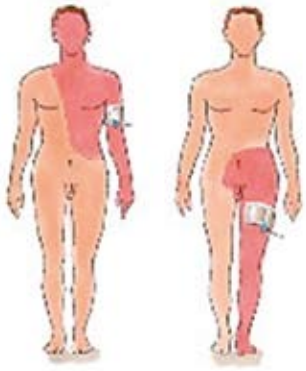

Figure 13.

Figure 14.

The most common use of diathermies in interventive endoscopy concerns the excision of polyps, sphincterotome and hot biopsies.

Based on the above, the correct selection for all applications requiring excision of tissues (excision of polyps, sphincterotomy) is the use of continuous or interrupted current, unless the diathermy has a special program for this operation, whereas intermittent current is used for cases requiring haemostasis. As a general rule, the diathermy should be set at relatively low wattages and the area should be cleaned of blood before the application of diathermy.

As regards the literature on medical complications from the selection of the types of current in the excision of polyps, the ASGE Guidelines on the use of diathermies (May 2003) state that the excision of polyps with the use of intermittent current led to twice as many incidents of significant haemorrhages (6/727) than the use of continuous or interrupted current (3/758). In addition, these haemorrhages appeared at a much later point (2-8 days instead of 12 hours). Concerning sphincterotomies, the same Guidelines show that the use of continuous current, despite the relatively higher risk of direct haemorrhage, entails a much smaller risk for the appearance of pancreatitis (3/86 compared with 11/84 or 3.2% compared with 12.9% in another study) than interrupted current. The use of intermittent current in sphincterotomies is clearly counter-indicated. The use of diathermy in patients with pacemakers does not create any problems, as long as the pacemaker does not interrupt the flow of the current. In the case of patients with automatic defibrillators, it is advisable to use diathermies only upon the opinion of a cardiologist.

In conclusion, we should stress that electricity can be used safely in interventive endoscopy. It is however necessary for the endoscopist to be fully proficient in the principles regarding it use, so as to be able to perform various operations at minimum risk for the patient.

REFERENCES

- Electrosurgical generators, Technology status evaluation report ASGE, May 2003
- The use of electricity in laparoscopic surgery, Applications and dangers, G.A Pistofidis, October 1999
- (All images are property of ERBE Electromedizin GmbH, Tubingen, Germany)