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The basics of diathermy

By the perioperativeCPD team

Introduction

Electrosurgery or diathermy is the passage of a high-frequency alternating current through the body to produce a desirable surgical effect. It has allowed faster operating, reduced blood loss and new surgical techniques. It does have its dangers and its safe use in operating theatres requires a grasp of its mechanisms of action and potential pitfalls.

Electrocautery or Electrosurgery?

The terms electrocautery and electrosurgery have often been confused. Electrocautery is an old system for haemostasis which is no longer used. It uses direct current (DC) to generate heat to the tip of a metal instrument, thereby causing blood to coagulate. During electrocautery, current does not enter the patient's body. Only the heated wire comes in contact with tissue. Electrosurgery uses modern instruments that harness alternating current (AC) and the patient is included in the circuit.

Diathermy circuits

Historically, diathermy used mains voltage referenced to earth and the patient return electrode or pad was earthed. If this pad became loose, was incorrectly applied, or the current found an alternative path to earth (e.g. via a limb in contact with the table) burns would result.

Since the 1980's modern monopolar diathermy generators use an isolated circuit with output voltages referenced to the generator itself (figure 1). This requires current to flow back to the generator to complete a circuit. If this circuit is broken (e.g. if the patient return electrode is not connected), current will not flow. Therefore in modern theatres calling the patient return pad/electrode an earthing or grounding pad it is not correct. Only the metal casing of the diathermy machine is earthed in case of insulation failure.

Modern monopolar circuit **bipolar circuit**

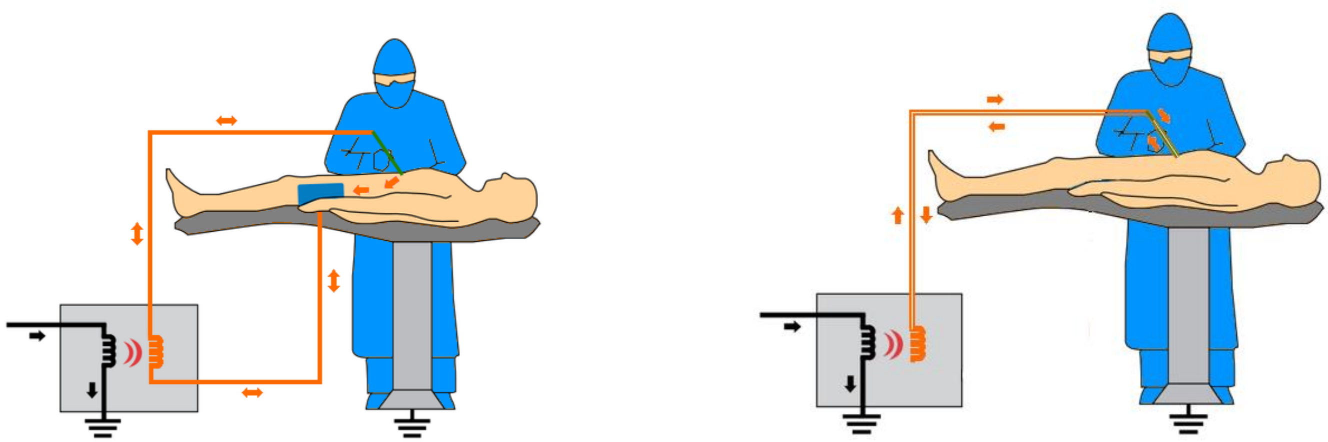


Figure 1: The electricity circuit from a monopolar and a bipolar circuit

Frequency

Standard electrical current alternates at a frequency of 50/60* cycles per second (Hz). Diathermy systems could function at this frequency, but as the current would be transmitted through body tissue at 60 cycles, excessive neuromuscular stimulation and perhaps electrocution would result. Nerve and muscle stimulation cease at 100,000 cycles per second (100 kHz), therefore diathermy can be performed safely at frequencies above 100 kHz (Figure 2). These are sometimes called the "radio" frequencies.

An electrosurgical generator takes the 50/60 cycle current and increases the frequency to over 200,000 cycles per second (200 kHz). At this frequency electrosurgical energy can pass through the patient with minimal neuromuscular stimulation and no risk of electrocution. The electrical energy is converted to heat and tissue temperatures at the active electrode tip can be as high 1000^0C.

*some countries use 50Hz (U.K.) and some 60Hz (U.S.A)

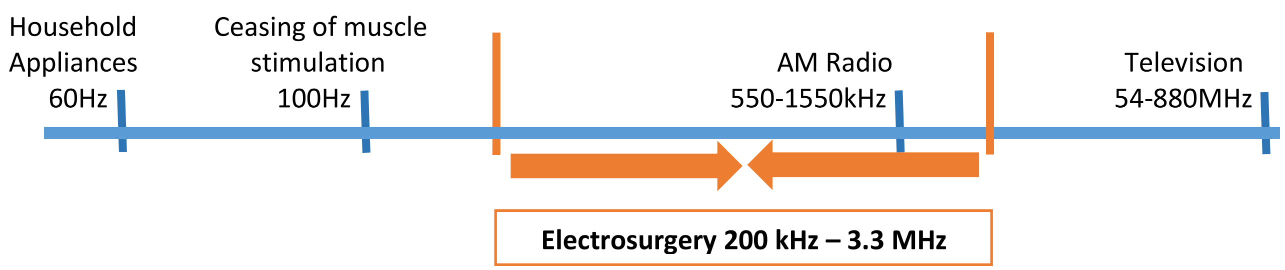


Figure 2: Frequencies of electrosurgery

Monopolar diathermy

Monopolar is the most commonly used electrosurgical modality, due to its versatility and clinical effectiveness. In monopolar diathermy, the active electrode is in the surgical site. The dispersive or patient return electrode is somewhere else on the patient's body (figure 1). Monopolar diathermy should also never be used on endarterial organs which include fingers, ears, the nose and the penis. If the main supplying artery is thrombosed, it can result in necrosis and self-amputation.

Bipolar

In bipolar electrosurgery, both the active electrode and return electrode functions are performed by a pair of forceps at the site of surgery (Figure 1). Only the tissue grasped is included in the electrical circuit. It has limited ability to cut and coagulate large bleeding areas, and it is more ideally used for those procedures where tissues can be easily grabbed on both sides by the forceps electrodes.   Because the return function is performed by one tine of the forceps, no patient return electrode is needed.

Modern devices are capable of sealing vessels up to 7 mm in diameter by a combination of mechanical pressure and diathermy. Microprocessors use tissue response generators to adjust current and voltage based on the sensed tissue impedance, so vessels can be reliably sealed to withstand three times normal systolic pressure.

Patient return pad safety

Historically, patient return electrode burns have accounted for 70 percent of the injuries reported during the use of electrosurgery. Patient return electrodes are not "inactive" or "passive." The only difference between the "active" electrode and the patient return electrode is their size and relative conductivity.

The active electrode (i.e. diathermy tip) has a small surface area for contact with the target tissues; all of the current is forced to flow through the tiny area where the active electrode makes contact with the tissue. At this point, the current flow is concentrated intensely. The heat at the site is great enough to achieve cutting and coagulation (figure 3).

Current leaves the body via a dispersive electrode or patient return pad. The pad has a large surface area thus the current density is low. It is typically applied to the thigh, buttock or back. As long as the surface area is large, (i.e over 100cm^2) and the electrode makes good contact with the skin it will offer a passage of least resistance for safe exit of the current from the patient. An incorrectly applied pad can cause burns due to the reduced surface area increasing the current density and heat.

Things to consider in placing the return pad include avoiding areas of vascular insufficiency, irregular body contours and bony prominences. The plate must also be placed away from any metal implants to avoid the current passing into this and causing heat damage.

More modern machines actively monitor the amount of impedance at the patient/pad interface because there is a direct relationship between this impedance and the pad contact area. The systems are designed to deactivate the generator before an injury can occur if it detects a dangerously high level of impedance caused by a pad becoming partially detached(split pads).

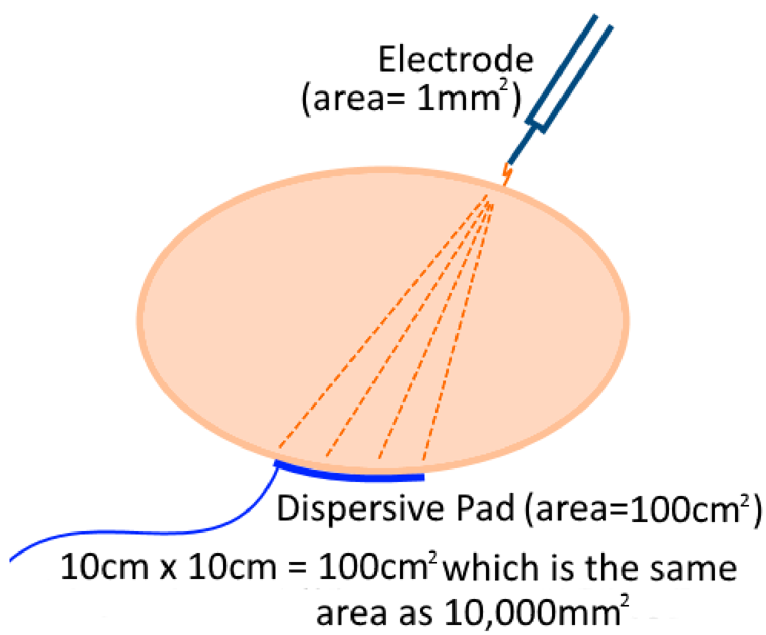


Figure 3: Current density diagram

Modes

Diathermy generators are able to produce a variety of electrical waveforms. As waveforms change, so will the corresponding tissue effects.

Cut (Yellow button or pedal)

The cutting action of monopolar is achieved by a continuous low voltage electric current waveform action which vaporises the tissues on contact (Figure 4). This waveform produces heat very rapidly and allows the cutting of tissues without coagulation and the effect is similar to being cut with a scalpel. The electrode does not need to be in contact with the tissue. Although it can be used for the initial skin incision a scalpel is still preferred. On the skin a scalpel reduces tissue damage, produces neater wound edges and reduces infection rates.

The 'Cut' setting sometimes has extra settings called 'Blend' depending on the levels of energy involved. A "blended current" is not a mixture of both cutting and coagulation current but rather a cut mode with a modification of the duty cycle. A lower duty cycle produces less heat.

Coagulation or 'Coag' (Blue button or pedal)

This uses a higher voltage AC current but the waveform is only on 6% of the time (see Figure 4). This interrupted waveform will produce less heat and instead of tissue vaporization, a coagulation effect is produced. 'Coag' can be used directly through the active electrode or through a conducting device such as insulated forceps to direct the coagulation more accurately. As with 'Cut' there are two modes: desiccation (also called 'forced coag') and fulguration ('spray coag').

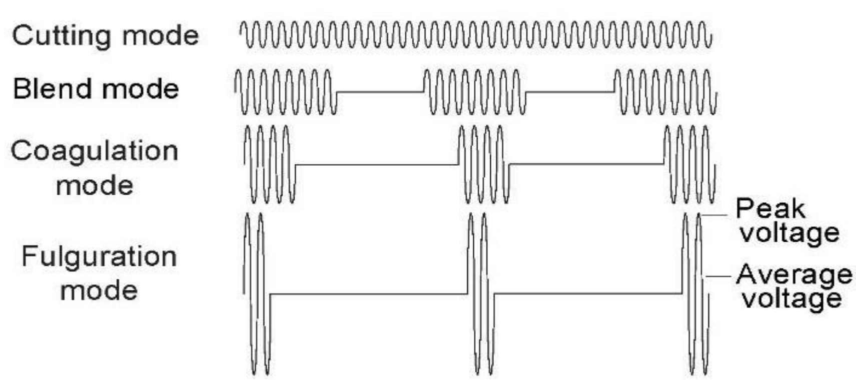


Figure 4: Differences in electricity currents between cutting and coagulation mode of diathermy

Desiccation ('Forced Coag')

This allows more precise coagulation and the electrode needs to be in touch with the target tissue. The voltages are somewhat lower in desiccation mode compared to Fulguration but with slightly higher currents (0.5W vs 0.1W).

Fulguration ('Spray Coag')

This is good for haemostasis and 'sprays' a shower of sparks a few millimetre away from the targeted tissue. It is achieved by using very high voltages (around 6000V) with lower currents. It should be avoided on delicate organs like bowel and near large vessels as the effect is less controlled than desiccation and can cause thermal injuries.

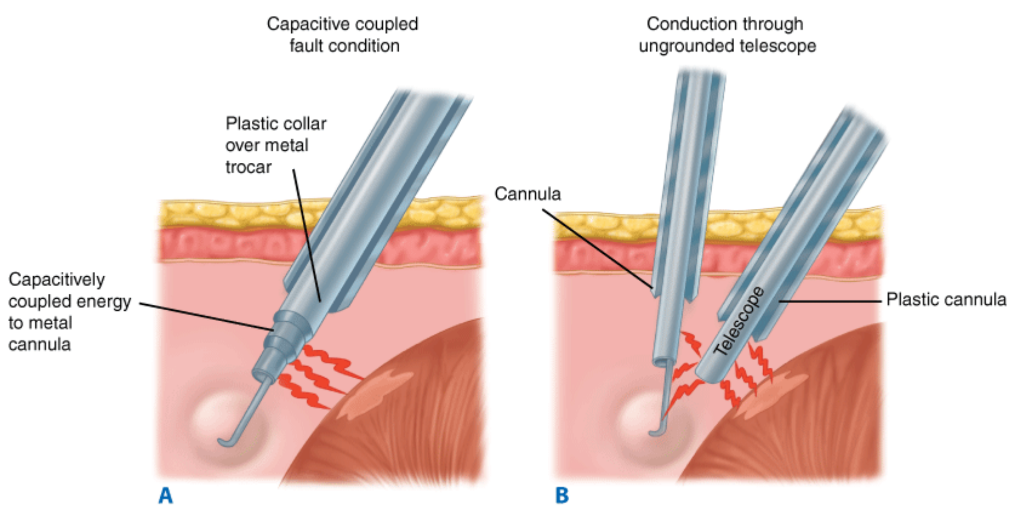
Other precautions

Fire

Most flammable anaesthetic gases have been eliminated from the operating theatre but alcohol preps and other flammable vapours can ignite if present when an active electrode is used in the same area. Care should be used if using alcohol preps and if they need to be used then avoid pooling. The inadvertent activation of an active electrode positioned on sponges, drapes, or in an oxygen-enriched atmosphere can also result in fires.

Capacitive coupling

A capacitor is simply two conductors (one of which may be the active electrode) separated by an insulator such as air. High frequency currents flow through a capacitor since an electrostatic field is created between the two conductors, and when the insulating capacity is exceeded, a current is induced in the other conductor. If this current is high enough it can cause a burn at sites of patient contact. This is a hazard during laparoscopic surgery between the active electrode and a metal trochar or scope. (Figure 5)



Source: Brunicardi FC, Andersen DK, Billiar TR, Dunn DL, Hunter JG, Matthews JB, Pollock RE: *Schwartz's Principles of Surgery, 9th Edition*: http://www.accessmedicine.com

Figure 5: two types of capacitive coupling

Electromagnetic interference (EMI)

Diathermy can interfere with both EEG and ECG monitoring electrodes. Of greater consequence is the interaction between EMI and cardiac pacemakers or implantable defibrillators. Bipolar is safer than monopolar, but can still cause interference. The effects are unpredictable and include inappropriate pacing, damage to the device, inappropriate defibrillation, and myocardial heat damage. Modern pacemakers have a titanium shell and interference monitor to protect them from EMI. The use of a magnet to reset pacemakers to asynchronous continuous pacing can be unpredictable. Current advice suggests limiting the use of diathermy to short low-power bursts and avoiding monopolar where possible. Placement of the dispersive electrode away from the device increases safety. Where appropriate the device should be checked and reprogrammed to monitoring mode prior to surgery.

Diathermy surgical smoke

Diathermy smoke consists of 95% steam and 5% cellular debris, with a mean diameter of 0.07 m, containing a variety of toxic mutagenic chemicals including hydrogen cyanide and benzene.

To prevent viruses and viable cancer cells being transmitted in surgical smoke and diathermy machines should now contain a surgical smoke evacuator with a 0.1-m filter, attached to the diathermy pencil less than 2 cm from the site of smoke production.

Similar devices

Ultrasonic surgical tools are not diathermy devices. They operate by containing elements that vibrate at 55.5 kHz. No electrical energy flows. The cutting and coagulation effect occurs at lower temperatures than diathermy, by a combination of mechanical and heat energy that denatures proteins.

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