

Strumentazione Biomedica - Electrosurgical unit

Davide Piaggio, Research Assistant and Teaching Fellow, *University of Warwick, UK*

Prof Leandro Pecchia, Professor of Biomedical Engineering, *University of Warwick, UK*
Innovation Manager, R&D Blueprint and COVID-19, World Health Organization (WHO)

Director, *Applied Biomedical Signal Processing and Intelligent eHealth lab*
Innovation Manager, R&D Blueprint and COVID-19, World Health Organization

President, *EAMBES (2021-23)*

Secretary General, *IUPESM (2018-2022)*

Treasurer, *IFMBE CED (2018-21)*

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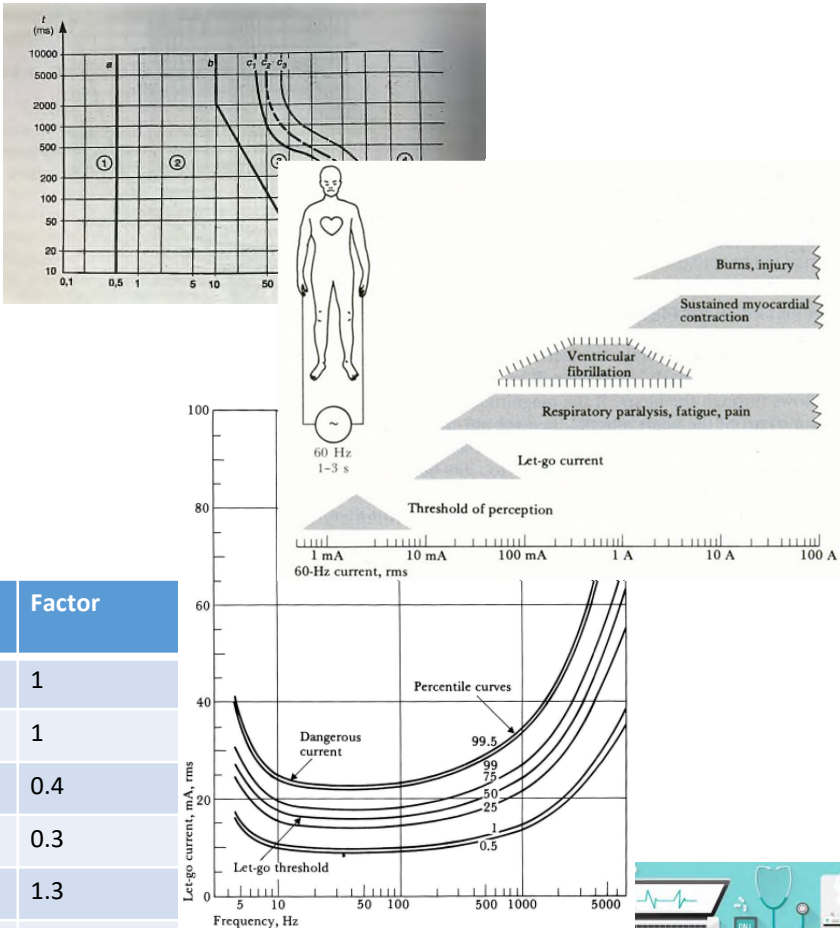
Effects of current on human body:

- 1) Thermal effects: the flux of electrical current generates heat which could provoke burns.
- 2) Electrophysiological effects: electrical current could generate action potentials in excitable tissues.

Such effects depend on:

- the intensity of the current;
- the characteristics of the current;
- the duration of the exposition to the flow of current;
- the path inside the human body.

Path of the electrical current	Factor
Left hand-foot	1
Two hands-feet	1
Left hand-right hand	0.4
Back-right hand	0.3
Chest-right hand	1.3
Chest-left hand	1.5



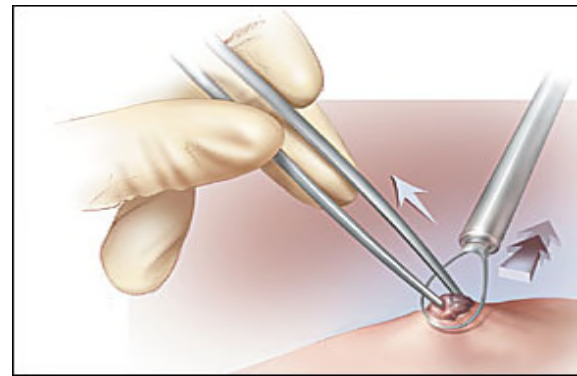
Electrosurgery:

The application of high-frequency (radio frequency) AC currents to biological tissues for thermal destruction of tissue through dehydration, coagulation or vaporization.

It allows to obtain very precise cuts with limited blood loss.

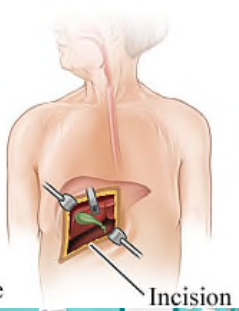
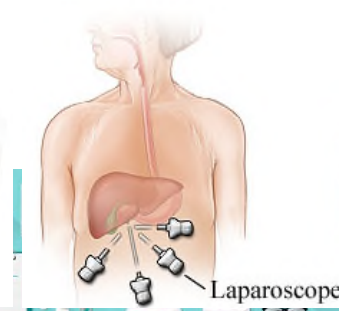
It can be used in general surgical procedures such as dermatological, plastic, spinal, orthopaedic etc. as well as in minimally invasive surgery.

Voltages around 200 – 10'000 V
Frequencies around 100 KHz – 5 MHz

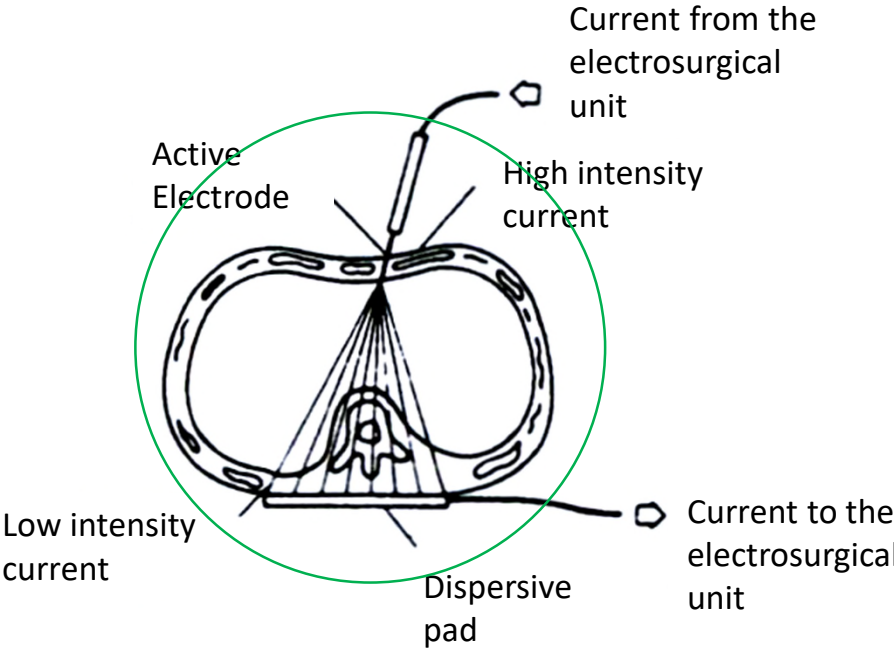
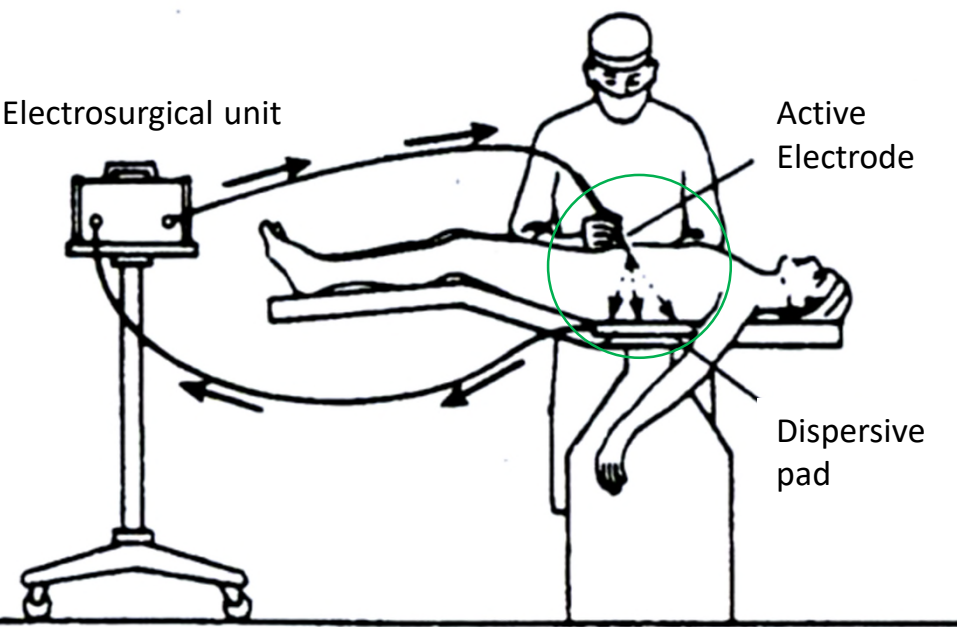


Laparoscopic
cholecystectomy

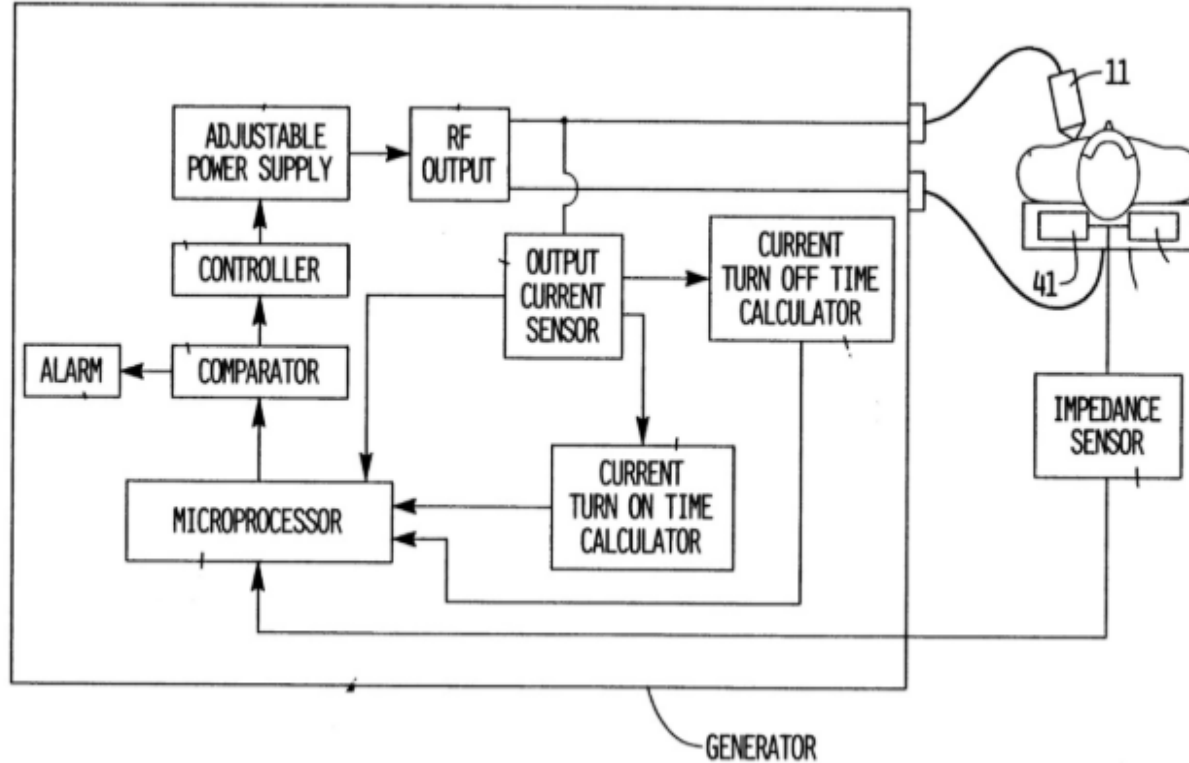
Open
cholecystectomy



Complete circuit of an electrosurgical unit



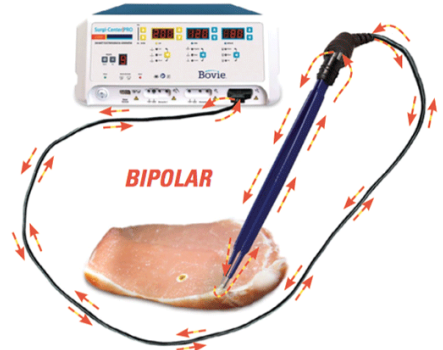
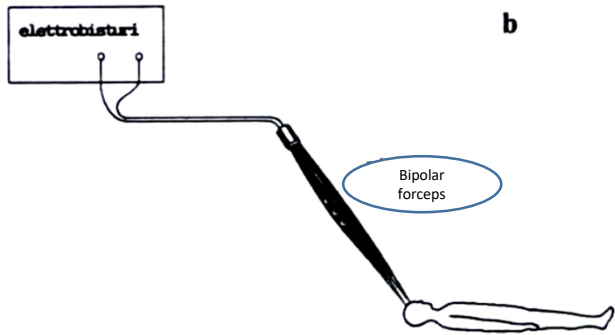
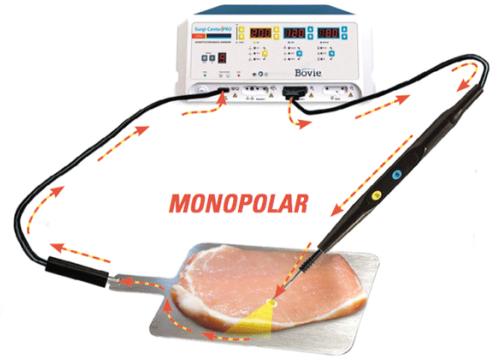
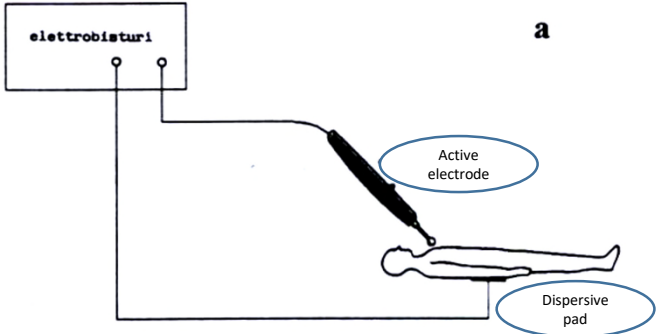
Block diagram

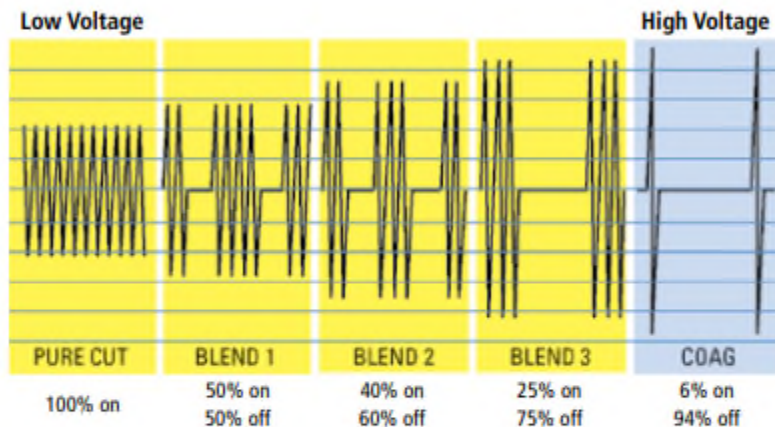


Tension: 500-2000 V
Current: 0.5-2 A
Power: 50-400 W
Frequency: 0.3-5 MHz
Modulation freq: 0.01-5KHz



Configuration a) monopolar, b) bipolar





Typical Example

TISSUE EFFECTS CHANGE AS YOU MODIFY THE WAVEFORM

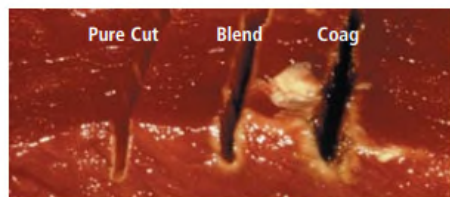
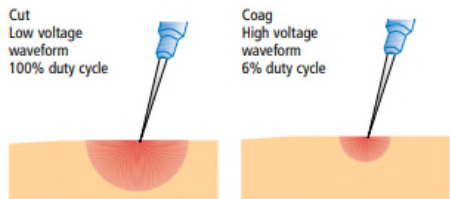
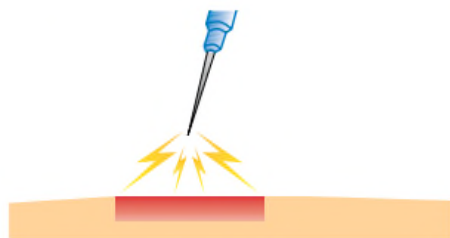
Electrosurgical generators are able to produce a variety of electrical waveforms. As waveforms change, so will the corresponding tissue effects. Using a constant waveform, like "cut," the surgeon is able to vaporize or cut tissue. This waveform produces heat very rapidly.

Using an intermittent waveform, like "coagulation," causes 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 is produced.

A "blended current" is not a mixture of both cutting and coagulation current but rather a modification of the duty cycle. As you go from Blend 1 to Blend 3 the duty cycle is progressively reduced. A lower duty cycle produces less heat. Consequently, Blend 1 is able to vaporize tissue with minimal hemostasis whereas Blend 3 is less effective at cutting but has maximum hemostasis.

The only variable that determines whether one waveform vaporizes tissue and another produces a coagulum is the rate at which heat is produced. High heat produced rapidly causes vaporization. Low heat produced more slowly creates a coagulum. Any one of the five waveforms can accomplish both tasks by modifying the variables that impact tissue effect.





Low ← Thermal Spread/Charring → High
Low Voltage High

ELECTROSURGICAL TISSUE EFFECTS

Electrosurgical Cutting

Electrosurgical cutting divides tissue with electric sparks that focus intense heat at the surgical site. By sparking to tissue, the surgeon produces maximum current concentration. To create this spark the surgeon should hold the electrode slightly away from the tissue. This will produce the greatest amount of heat over a very short period of time, which results in vaporization of tissue.

Fulguration

Electrosurgical fulguration (sparking with the coagulation waveform) coagulates and chars the tissue over a wide area. Since the duty cycle (on time) is only about 6 percent, less heat is produced. The result is the creation of a coagulum rather than cellular vaporization. In order to overcome the high impedance of air, the coagulation waveform has significantly higher voltage than the cutting current. Use of high voltage coagulation current has implications during minimally invasive surgery.

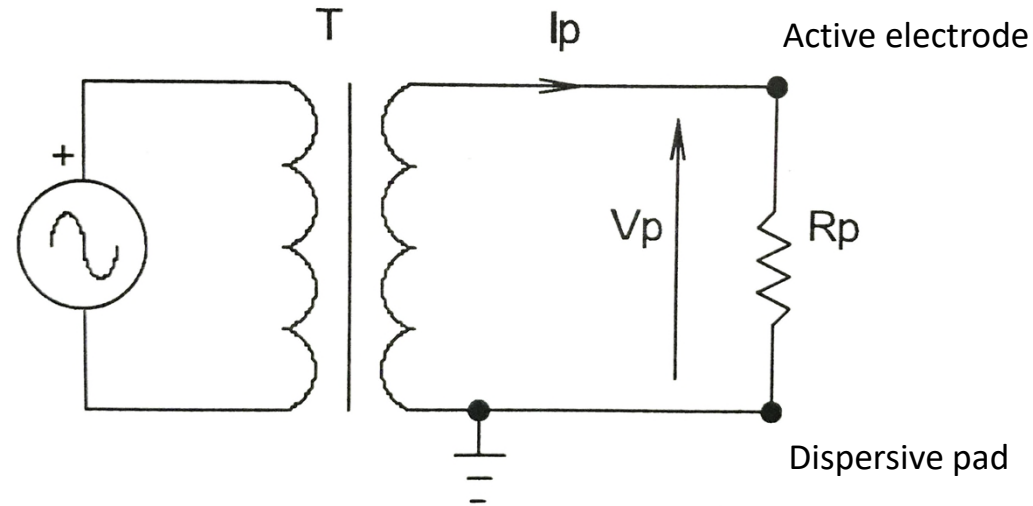
Desiccation

Electrosurgical desiccation occurs when the electrode is in direct contact with the tissue. Desiccation is achieved most efficiently with the "cutting" current. By touching the tissue with the electrode, the current concentration is reduced. Less heat is generated and no cutting action occurs. The cells dry out and form a coagulum rather than vaporize and explode.

Many surgeons routinely "cut" with the coagulation current. Likewise, you can coagulate with the cutting current by holding the electrode in direct contact with tissue. It may be necessary to adjust power settings and electrode size to achieve the desired surgical effect. The benefit of coagulating with the cutting current is that you will be using far less voltage. Likewise, cutting with the cut current will also accomplish the task with less voltage. This is an important consideration during minimally invasive procedures.



Output stage referred to the ground (Obsolete)



The transformer isolates the primary and secondary from low-frequency currents.

The secondary is referred to the ground, and low-frequency leakage currents coming from other devices can find their way to the ground through this.

Risk of ventricular fibrillation.

Risk of burns.

Risk of burns in different body regions.





For example:

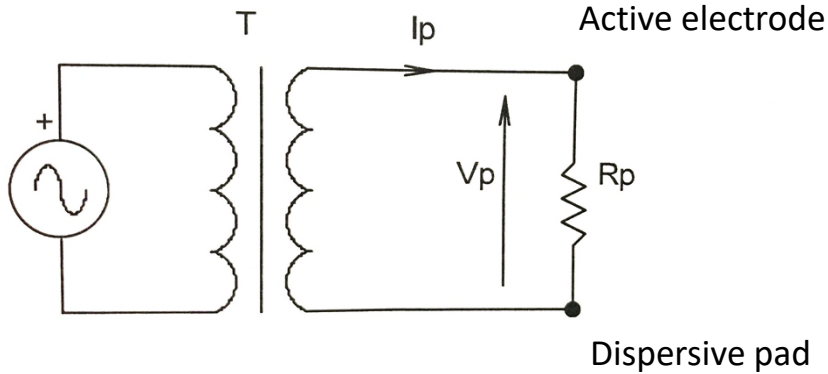
$$X_c = 1/(2\pi \cdot f \cdot C_1) = 9.9 \text{ Ohm}$$

Xc = 198.9 kOhm → 20000 times bigger!

Risk of burns.

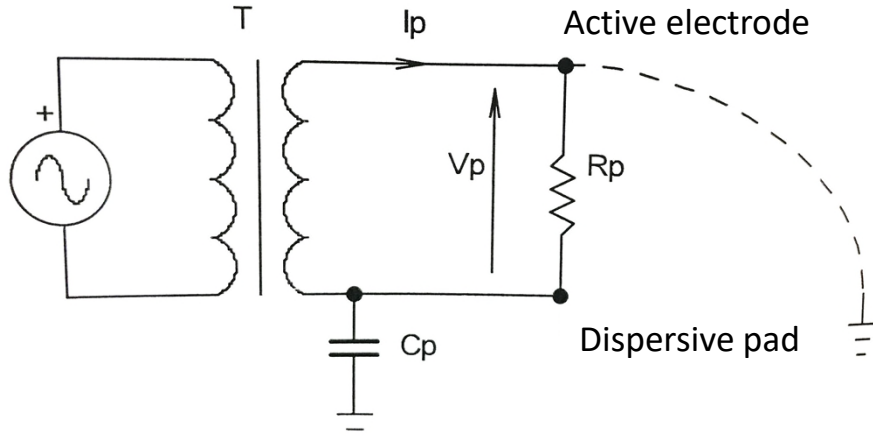
Risk of burns in different body regions

Floating output stage isolated (current solution)



Ideally there is isolation and no current can flow to the ground.

No risk.



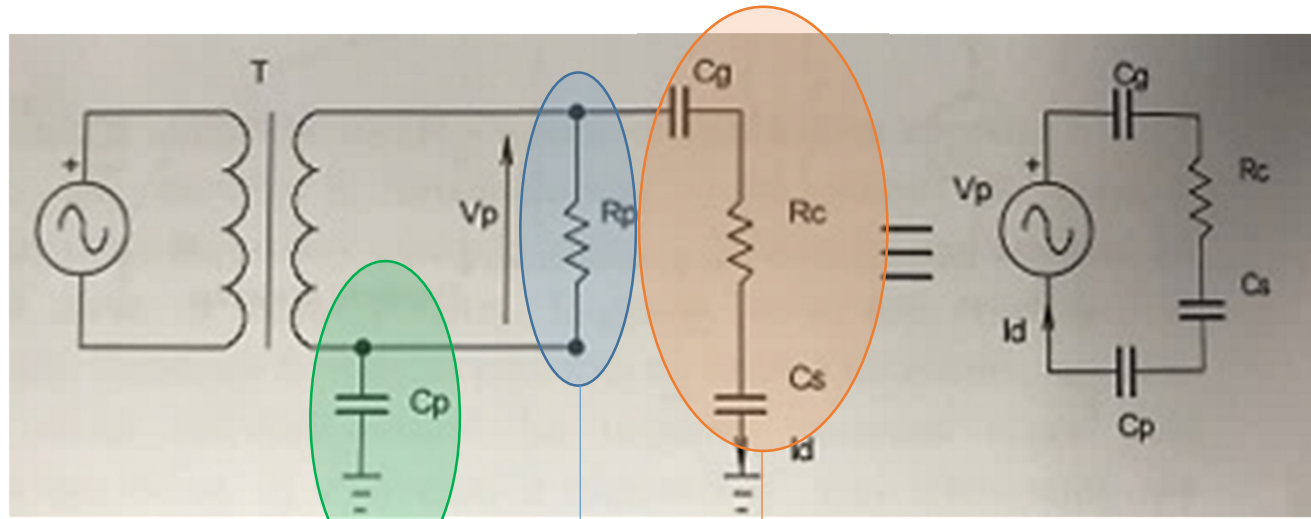
However, in a real world scenario there is a capacity coupling C_p with the ground.

There could be a link between the active electrode and the ground (for example the surgeon).

Risk of burns.



Current flowing towards the ground through the surgeon while the electrosurgical unit supplies power on the patient



Capacitive
coupling

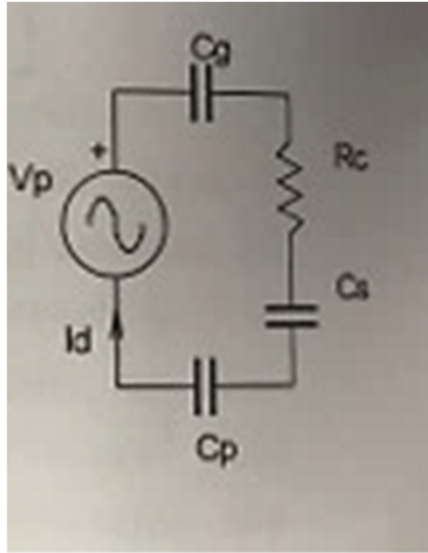
between patient
and ground

Patient

Surgeon

Buzzing technique: when the surgeon coagulates small vessels in a rapid way by pinching the tissues at the extremities of the vessel with tweezers and by touching the tweezers with the active electrode, so that the current will flow through the pinched tissues.

NB: the surgeon is not isolated by the gloves. In fact, the gloves behaves like a capacitor with AC voltages. It is important to have limited currents flowing through the surgeon.



$$C_g = 50 \text{ pF}$$

$$C_s = 1 \text{ nF}$$

$$C_p = 150 \text{ pF}$$

$$R_c = 500 \text{ Ohm}$$

Power supplied to the patient = 250 W

R_p resistance of the patient = 200 Ohm

$$f = 1 \text{ MHz}$$

What is the increase in the T of the fingers of the surgeon?

$$P = V_p * I_p = V_p * V_p / R_p$$

$$\rightarrow V_p = \text{Sqrt}(P * R_p) =$$

$$223.61 \text{ V}$$

$$C_{eq} = (1/C_g + 1/C_s + 1/C_p)^{-1} = 36.1 \text{ pF}$$

$$|z| = \text{Sqrt}(R_c^2 + (2 * \pi * f * C_{eq})^2) = 4413.3 \text{ Ohm}$$

$$I_d = V_p / |z| = 223.61 / 4413.3 = 0.051 \text{ A} = 51 \text{ mA}$$

This current increases the T of the fingers of the surgeon!

$$\Delta T = \frac{\rho}{\delta c} * \left(\frac{I}{S}\right)^2 * \Delta t$$

ΔT is the increase of temperature (K);

ρ is the resistivity of the material (Ohm*m) = **5000 Ohm*m**

δ density of material (kg*m⁻³) = **985 kg/m³**

c is specific heat of the material (J*kg⁻¹*K⁻¹) = **3500 J*kg⁻¹*K⁻¹**

I is the current intensity (A)

S is the section of the 3 fingers (m²) = **0.0004 m²**

Δt is the contact time = 2 s

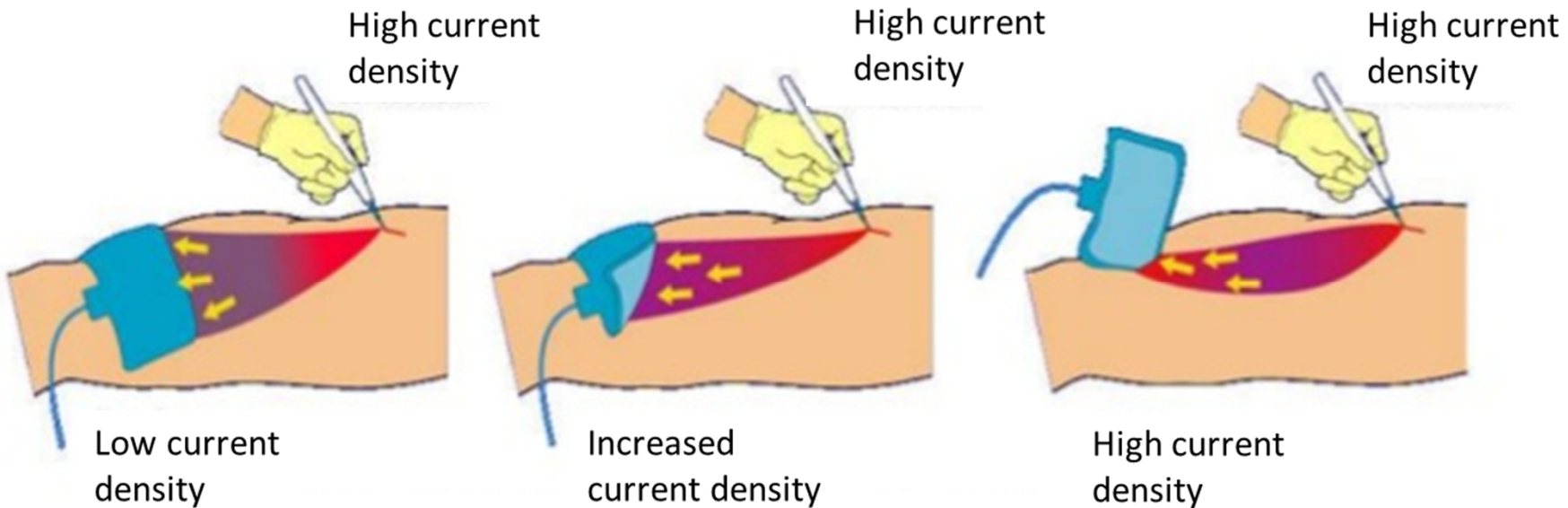
47.15 °C !!!

Risks

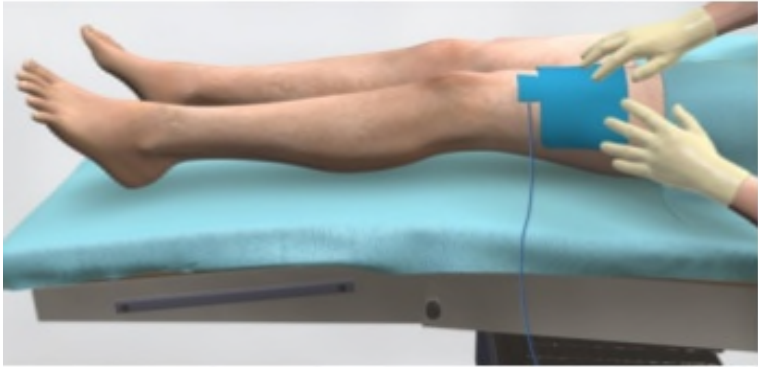
- Burns
- Neuromuscular stimulation
- Fire
- Interferences with other devices



Dispersive Pads – Current densities



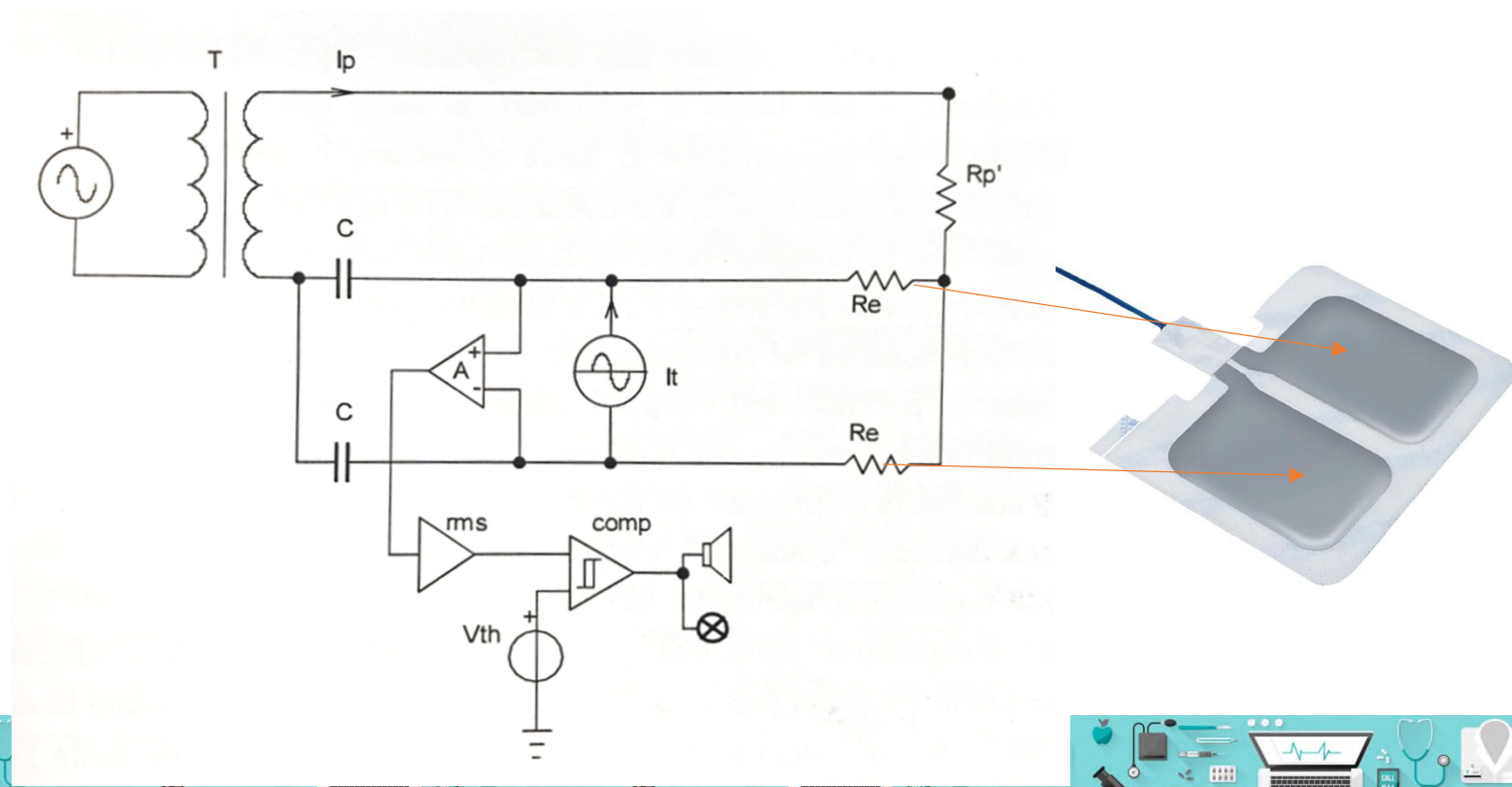
Best practices for dispersive pad positioning



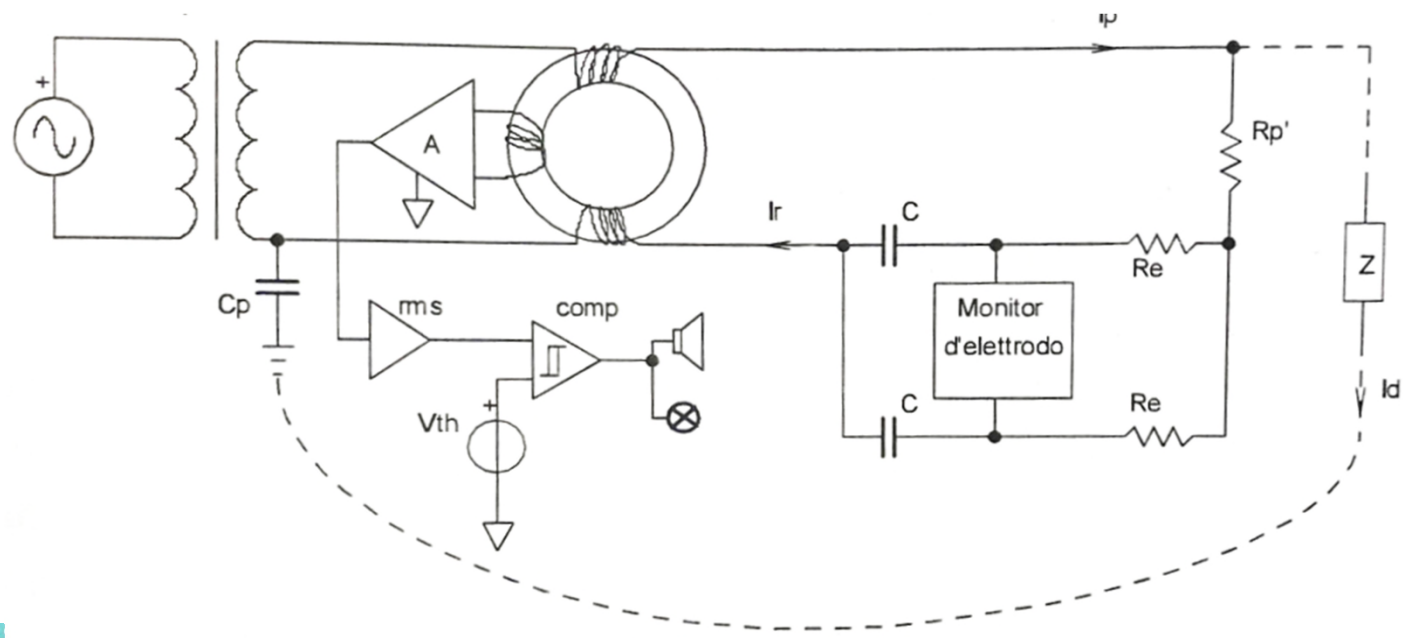
- Choose a well-vascularized muscle mass
- Choose a convex area
- Choose an area close to the surgical site



Electrode monitoring system to reduce the risk of burns



Patient monitoring system to reduce the risk of other site burns



Periodic Maintenance

- **Every 6/12 months measure low-frequency leakage currents: it could cause ventricular fibrillation if in contact with cardiac tissues (using a leakage current meter);**
- Measure high-frequency leakage currents (these usually have higher intensities than the low freq. ones);
- Measure the output power on the patient (200 Ohm resistor);
- Check the integrity of the security systems;
- Check the integrity of the cable insulation, the correct functioning of the switches and the foot pedal;
- Check the number and size of the return electrodes;
- Check the integrity of the chassis.

These measurements can be done with a tester for electrosurgical units, that allows to measure the output power, the duty cycle of the output signal and the high-frequency leakage currents.



The Electrosurgery TEAM

Together Everyone Avoiding Mistakes

Recovery staff

- ✓ Check for skin damage
- ✓ Discard single-use items after use
- ✓ Report adverse events identified in the recovery area to the operating surgeon and theatre manager

Theatre manager

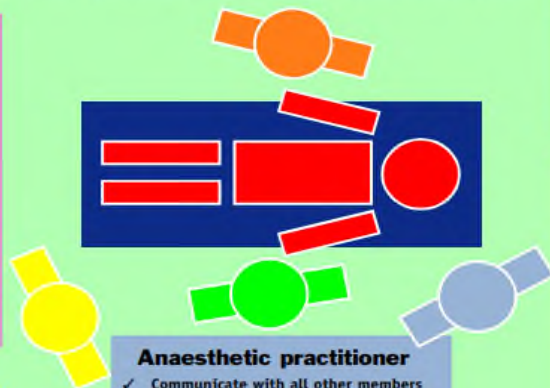
- ✓ Responsible for safe system of working as required by controls assurance/governance
- ✓ Ensure all staff have undergone general and product specific electrosurgery training
- ✓ Ensure systematic procurement of equipment, taking account of MDA guidance (DB9801) and evaluation reports (CEDAR)
- ✓ Liaise with medical engineering and sterile services departments to ensure appropriate systems of maintenance and reprocessing
- ✓ Report adverse events and near-misses to MDA and trust MDA liaison officer

Circulating staff

- ✓ Communicate with scrub nurse
- ✓ Understand generator and accessories
- ✓ Understand generator alarms and how to rectify problems
- ✓ Know where to find spare accessories

The Problem

Every year many patients and staff are injured needlessly by electrosurgical equipment (sometimes referred to as surgical diathermy). These injuries are often due to user error and poor systems of work, not the equipment design.



Anaesthetic practitioner

- ✓ Communicate with all other members of the electrosurgery team
- ✓ Understand generator and accessories
- ✓ Understand generator alarms and how to rectify problems
- ✓ Responsible for ensuring correct patient set-up including placement of the return electrode after clipping or shaving where appropriate

Scrubbed staff

- ✓ Co-ordinate theatre team and act as hub of communication
- ✓ Ensure that the patient and generator set-up are correct
- ✓ Ensure that the accessories such as forceps and leads are appropriate and functioning normally before and during procedure
- ✓ Ensure that electrosurgery equipment is used correctly at all times
- ✓ After surgery check reusable accessories for damage and prepare for central reprocessing
- ✓ Report adverse events to the theatre manager

Surgeon

- ✓ Responsible for clinical outcome
- ✓ Pre-operative assessment should consider relevant patient factors (see right)
- ✓ Select appropriate skin preparation (avoid using alcohol-based preparations as per MDA SN 2000(17))
- ✓ Select and check the appropriate mode, return electrode (if required), accessories and generator settings before use. Remember the pedicle effect
- ✓ Use the lowest power setting commensurate with the desired surgical effect
- ✓ If foot pedals are used check that they cannot be activated inadvertently by becoming trapped under the operating table
- ✓ Avoid activating generator if other staff are in direct physical contact with the patient
- ✓ Use quivers to store accessories when not in use
- ✓ Take particular care when 2 separate generators/systems are used by 2 surgical teams concurrently

Personal training

Do I understand?

- ✓ The patient's needs
- ✓ The different types of electrosurgery equipment needed to meet those needs
- ✓ The risks of electrosurgery and how to minimise them
- ✓ The principles of electrosurgery

Do I know how to?

- ✓ Set up the generator safely
- ✓ Prepare the patient properly
- ✓ Select and check accessories
- ✓ Avoid risks to theatre staff

Have I considered patient factors?

- ✓ Gender, weight and fat distribution
- ✓ Position return electrode taking account of patient position, the operating site, previous surgical scars and metal implants
- ✓ Active implants (pacemaker/internal defibrillator require extra pre-op/post-op checks by cardiology team)
- ✓ Consent for shaving
- ✓ Allergy to skin preps and return electrode

Have I considered equipment factors?

- ✓ Properly maintained and in good order
- ✓ Correct generator setting using lowest power practical to start procedure
- ✓ Correct accessories compatible with generator and required mode



Safeguarding Public Health

To find out more about the MDA and the electrosurgery equipment centre log onto www.medical-devices.gov.uk
CEDAR website at www.cedar.wales.nhs.uk

Published by MDA November 2002. Content ongoing.

*Remember that you are professionally responsible
for your own actions*

Safe working needs TEAM working

