

High Frequency Surgery: Mechanism of Action, Risks and Risk Minimization

The hands are man's most important tools. Gloves protect them from cold, dirt, contamination and injury.

In the medical field, special gloves are used to protect the patients and the staff. When used properly, medical gloves should prevent the transfer of pathogens from the medical staff to the patient and vice versa.

The best possible sense of touch, high elasticity and comfort are further product specifications that must be met. With a thickness of only 0.2 mm, these requirements are generally met. However, this raises the question of whether and how a surgical glove can offer protection from voltages of approx. 1,300 volts, such as they are applied in high frequency surgery.

1. General Aspects of High Frequency Surgery

Biological tissue can be cut and bleeding stopped with the help of electric energy that is transformed into heat.

Since this technology works with high voltages, there are certain risks involved. In order to minimize these risks, it is important to be aware of the method of operation.

1.1. Interaction Between Electricity and Biological Tissue

Three effects are important when electricity is applied to the organ-

ism: the Faraday effect, the electrolytic effect and the thermal effect.

1.1.1. The Faraday Effect

Nerve and muscle cells can be stimulated electrically. In human tissue, the stimulation effect is greatest with an alternating current of approx. 100 Hz, and it decreases constantly with increasing frequency, thus losing its damaging or life-threatening effect (Fig. 1).

1.1.2. The Electrolytic Effect

Electric current induces an ion flow in biological tissue. Ions are small electrically charged particles.

When direct current is applied, positively charged ions migrate to the negative pole and negatively charged

ions migrate to the positive pole, where they cause damage to the biological tissue. Therefore, direct current is not suitable for use in surgery.

If, on the other hand, alternating current with a very high frequency is used, the charged particles constantly change their direction of movement, i. e. they are made to oscillate and thus they do not have any damaging effect.

1.1.3. The Thermal Effect

Due to the effect of electric current, the tissue is heated, whereby the degree of heating

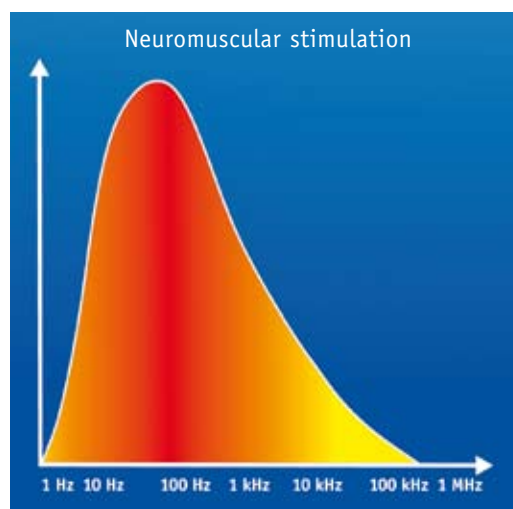


Fig. 1:
Relation between the frequency of alternating current and its stimulating effect on cells

depends on the following factors:

- the current density
- the specific resistance of the tissue
- the duration of action of the electric energy

The higher the current density, the greater the increase in temperature and thus the thermal effect is. The current density at the tip of the monopolar electrosurgical knife (active electrode) is increased, resulting in the formation of an electric arc and thus a very high local temperature. Tissue located at this site can be cut or coagulated.

On the large surface of the neutral electrode, on the other hand, the current density and temperature curve are so slight that there is no effect.

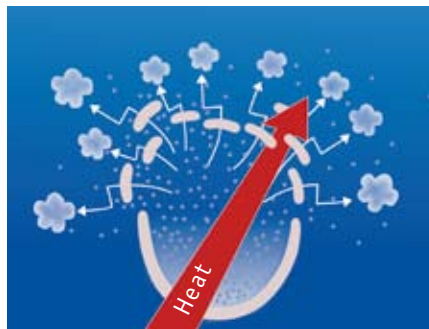


Fig. 2:
Process within the cell when cutting



Fig. 3:
Process within the cell when coagulating

2. Principle of HF Surgery

The principle of HF surgery is based on the processes described above. The tissue is cut and bleeding is stopped with the help of the thermal effect. In order to prevent damage to the tissue due to the electrolytic effect or stimulation of nerve and muscle cells by the Faraday effect, high frequency alternating currents of at least 100 kHz are used. Basically, HF surgery can be used in two ways: for cutting and for cauterizing.

2.1. Cutting Tissue

Current with a high density heats up the fluid in the body cells so quickly that the resulting vapor pressure causes the cell membrane to burst (Fig. 2). This principle is applied for cutting tissue and – to a lesser degree – for coagulation. Thereby, the adjacent small vessels are stenosed, which results in hemostasis.

2.2. Coagulation

If the tissue is heated slowly, the fluid inside and outside the cells evaporates without destroying the cell walls (Fig. 3). The tissue shrinks and the parts capable of coagulation are cauterized thermally. This results in hemostasis, even in larger vessels.

3. Techniques in High Frequency Surgery

Two methods are used in high frequency surgery, which differ depending on the path taken by the electric current: the monopolar and bipolar technique.

3.1. Monopolar Technique

In the monopolar technique, a strong thermal effect is produced at the narrow active electrode (tip of the electrosurgical knife) due to an increase in current density. This makes it possible to cut and coagulate in the adjoining tissue of the surgical field. In the more remote tissue, the current density is markedly reduced, and the current is discharged from the body as electric energy via the large neutral electrode without a thermal effect (Fig. 4).

Compared with the scalpel, this has the following advantages:

- prevention of bleeding
- prevention of pathogen transfer
- protection of the tissue

The degree of coagulation at the cut surface depends on the shape of the electrode and the type of cut; the depth of coagulation depends on the intensity of the HF current.

3.2. Bipolar Technique

The bipolar technique is used mainly in micro- and neurosurgery, and it can only be used for coagulation. A bipolar active electrode (forceps) is used, whereby both poles

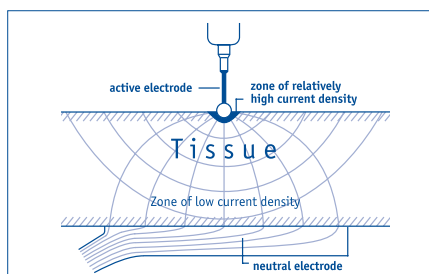


Fig. 4:
Method of operation in monopolar technique

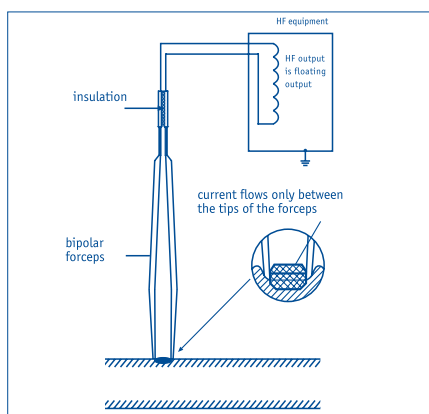


Fig. 5:
Method of operation in bipolar technique

have contact with the surgical field. A neutral electrode is not required. Electric energy is conducted into the forceps, and the thermal effect at the tips results in coagulation of the tissue (Fig. 5).

4. Safety in HF Surgery

High safety standards and technical innovations have made high frequency surgery a safe method of surgery when applied correctly. Simply being aware of the risks can help to avoid adverse effects such as an electric discharge at undesired sites. Surgical gloves are not necessary for protection, but naturally they have to be used for hygienic reasons.

4.1. Risk for the Patient

Contact with a grounded object (e. g. the operating table) between the surgical field and the neutral electrode can result in undesired discharges. Instead of flowing through the neutral electrode, the electric energy is discharged via this contact surface. The smaller it is (high current density), the greater the thermal effect and thus the risk of burns is.

4.2. Safety for the Patient

The following points should be observed for the patient's safety:

- Proper storage (dry and insulated)
- No contact with grounded objects
- No isolated skin-to-skin contact (between doctor/assistant and patient, between individual parts of the patient's body)
- Short wiring, no points of contact
- No looping of cables, no fixation with metal brackets
- Cautious handling of disinfectants (the alcohol contained can be ignited by electric

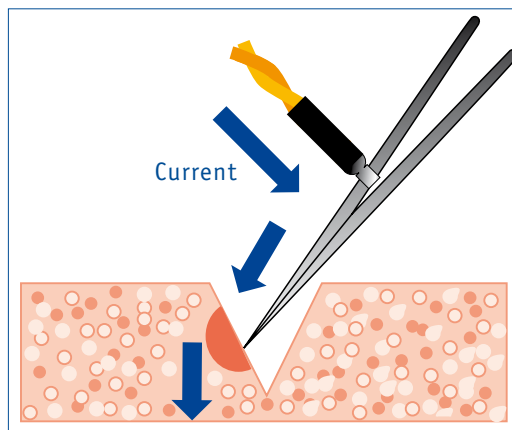


Fig. 6:
Desired "flow of current" in monopolar HF surgery

spark)

- Proper placement of the electrode handle
- Use of the lowest possible voltage
- Proper placement of the neutral electrodes

4.3. Risks for the User

Due to the effects described above, high-frequency surgery is a safe operating method for both the surgeon and the patient. However, undesired discharges of electricity are possible. If this happens at the surgeon's hand, we speak of a blowout. An electric arc between the surgical instrument and the surgeon's hand causes heat to develop for a short time. The high temperature released will destroy the film of the surgical glove and can also cause painful burns to the hand.

"Thermal blowouts" occur mainly when coagulating with a monopolar electrode and forceps. If the forceps are not in contact with the tissue yet or if the electrode is activated too soon, the current cannot flow to the neutral electrode via the patient. As a result, the current flows through the forceps into the hand instead of through the patient. If the surface of contact between the forceps and the surgeon's hand is very small (if the forceps are held very lightly) and the current density high as a result,

strong heat development will be caused. The effect is the same as the effect desired in HF surgery, but it occurs in the wrong place. The thermal energy is so great that blowouts occur – the latex film melts, leaving a hole in the glove and causing burns to the user's hand.

The strong development of local heat can destroy surgical gloves of both natural and synthetic latex.

4.4. Tips for the User

Like for the patient, there are measures that the user can take to avoid undesirable incidents:

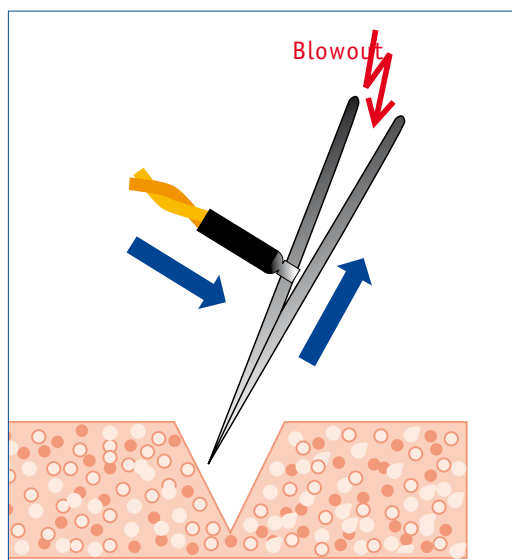


Fig. 7:
Coagulation against air

- Check the equipment before use: avoid cable loops, check for proper connection of the electrodes and switches, etc.;
- Always use the right accessories for the equipment;
- Use insulated forceps;
- Apply the active electrode to the tissue or, when coagulating, to the forceps first and then activate it;
- Change gloves regularly during the operation: due to grease from the skin and contact with liquids, the latex film will slowly swell and thus reduce the time-span during which the glove is properly functional.



Fig. 8:
Electrician's glove, surgical glove

ages (Fig. 8). To optimize the sensitivity and comfort of the gloves, the wall thickness of surgical gloves is only about 0.2 mm (1/10 of the thickness of an electrician's glove). Therefore, they can offer some protection from blow-outs, but by no means 100 % protection. However, it should be pointed out again that if HF surgery is carried out properly, gloves are not necessary for protection. The insulating effect of rubber depends not only on its

thickness, but also on its physical properties.

In longer surgery, the glove material tends to swell, i. e. it absorbs sweat and fluids from the surgical wound, thus reducing the insulating effect of rubber even more.

Fresh and dry surgical gloves can reduce the probability of blowouts. In his own interest, therefore, the surgeon should change his gloves at regular intervals during longer surgery.

In order to increase the safety even further, the use of two pairs of gloves is recommended. This doubles the thickness of the rubber layer, and the layer of air between the rubber surfaces provides an additional insulating effect.

5. Does a Surgical Glove Offer Efficient Protection when used in HF Surgery?

A surgical glove is expected to protect from injuries resulting from HF currents.

Basically, rubber is an insulator. The insulating effect depends on the physical composition of the rubber film, and on its thickness. The thicker the rubber film, the greater the insulating effect is.

Specific resistance of different materials in [$\Omega \cdot \text{cm}$] with alternating current in the range from 0.3 to 1 megahertz [MHz]

Biological Tissue		Metal	
Blood	$0,16 \cdot 10^3$	Silver	$0,16 \cdot 10^{-5}$
Muscles, kidney	$0,2 \cdot 10^3$	Copper	$0,17 \cdot 10^{-5}$
Liver, spleen	$0,3 \cdot 10^3$	Gold	$0,22 \cdot 10^{-5}$
Brain	$0,7 \cdot 10^3$		
Lung	$1,0 \cdot 10^3$		
Fatty tissue	$3,3 \cdot 10^3$		

Surgical glove of natural latex: $10^{10} - 10^{13}$ [$\Omega \cdot \text{cm}$]

In HF surgery, average voltages of 1,200 V with peaks of up to 4,000 V are used. According to EN 60903, electrician's gloves of safety class II with a wall thickness of 2.3 mm are necessary to protect against such high volt-

6. Summary

Basically, it can be said that gloves are not necessary for protection in HF surgery, and that they can therefore not be regarded as protective gloves for this purpose. A discharge of electric current through the surgeon is unlikely, if the HF generator is applied properly and without errors.

However, should there be any "misrouted" currents and blowouts as a result, measures to ensure safety and additional insulation, such as e. g. special forceps or the wearing of two pairs of surgical gloves can be helpful and can minimize the risk of blowouts.