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Important information

While Erbe Elektromedizin GmbH has taken the greatest possible care in preparing this brochure and compiling the recommended settings, we cannot completely rule out errors. The information and data contained in the recommended settings cannot be used to justify any claims against Erbe Elektromedizin GmbH. In the event of compelling legal justification for a claim, liability shall be limited to intent and gross negligence.

Although the information on recommended settings, application sites, duration of application and the use of instruments is based on clinical experience, individual centers and physicians also favor settings other than those recommended here. This information is intended only as a guideline and must be evaluated by the surgeon for applicability. Depending on individual circumstances, it may be necessary to deviate from the information provided in this brochure.

Medicine is constantly subject to new developments based on research and clinical experience.

This is another reason why departing from the information provided here may be appropriate.

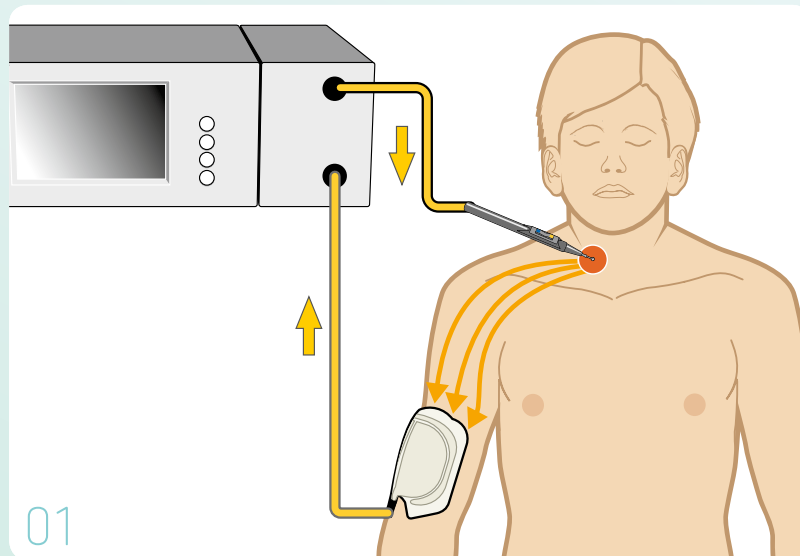


The technology of electrosurgery has become an indispensable component of interventional disciplines. Surgeons in all specializations use this method. The advantages of this technology reside primarily in the controllability of the electrosurgical effect, the versatile, partly new and unique applications, and the variety of supported instruments and instrument forms. Electrosurgery makes a valuable contribution to the efficient, gentle execution of procedures not only during conventional surgeries but also in particular during minimally invasive surgery.

The aim of this brochure is to help understand the principles of electrosurgery. It discusses tissue effects and the electrosurgical process, gives advice and background information pertaining to safe use, presents electrosurgical instruments, and provides an overview of the areas of application. A glossary at the end of the brochure summarizes the technical terms employed and their definitions.

The principle of electro-surgery

Electrosurgery is the application of high-frequency electric current on biological tissue with the goal of creating a thermal effect that is medically useful. This first chapter explains the physical principles of tissue heating with electric current. It provides an overview of the processes in the tissue that are generated by the heating, and lists important influencing factors for the electro-surgical tissue effect.



Principle of electro-surgery. The surgical effect arises due to tissue heating caused by current flow (yellow arrows)

PHYSICAL PRINCIPLES

01

The principle of electro-surgery is illustrated in Figure 01. The patient is connected to the electro-surgical unit through two electrodes. The device creates electrical voltage (see the "Basic physical terms" on page 6) between the electrodes. Because biological tissue conducts electricity, current flows between the electrodes through the patient's body. The electrical circuit is therefore closed. The current generates the required heat in the tissue for the electro-surgical effect. This is one of the important differences between electro-surgery and cautery: In electro-surgery the heating is not exogenous, e.g. caused by a heated instrument, but rather endogenous – generated by the flow of current in the tissue itself. In order to exclude chemical burns by the electrolysis process and prevent nerve and muscle stimulation, alternating current with a frequency of at least 200 kHz is used. This is why electro-surgery is sometimes known as high-frequency surgery.

The quantity and distribution of the heat released in the tissue are important factors for the electro-surgical effect.

The heat quantity is determined by the voltage and tissue resistance. The distribution of the heat results from the distribution of the tissue resistance and the geometry of the current path. This can be explained with just a few physical correlations, as explained below.

The quantity of the heat released in the tissue per unit of time is the electrical power, i.e. the product of current and voltage (see box, p.6). Current and voltage depend on each other via the electrical resistance. This applies both to the tissue between the electrodes overall as well as locally at each location in the tissue.

The current path denotes the route the current takes through the tissue from one electrode to the other (the yellow arrows in Figure 01). Here the current, voltage and resistance are distributed in different ways. To get a better understanding of this, one can imagine the current path divided into thin discs whose surface is the path cross-section. The same amount of current flows through each disc. The resistance can be different at each location of the disc. The current is distributed over the disc and prefers to flow in areas where the resistance is low. Here the current density is thus higher than in areas with greater resistance. The overall resistance of a disc results from the distribution of the local resistance on its surface, where the area with the lowest resistance is decisive. The local voltage on each disc is equally high at each location of the cross-section surface and is determined by the total current and the total resistance of the disc. The voltages and resistances of the individual discs add up to the total voltage and total resistance of the

tissue between the electrodes. The current strength is determined by the total voltage and total resistance.

A lot of heat is released at locations that exhibit a high current density or a high local voltage or both simultaneously. A high current density arises when the cross-section surface of the current path is small or if there are only small areas with low local resistance. A high local voltage arises when the current cannot circumvent areas with high local resistance.

Thus, the quantity and distribution of the released heat is determined by the voltage and the tissue resistance, and by the geometry of the current path.

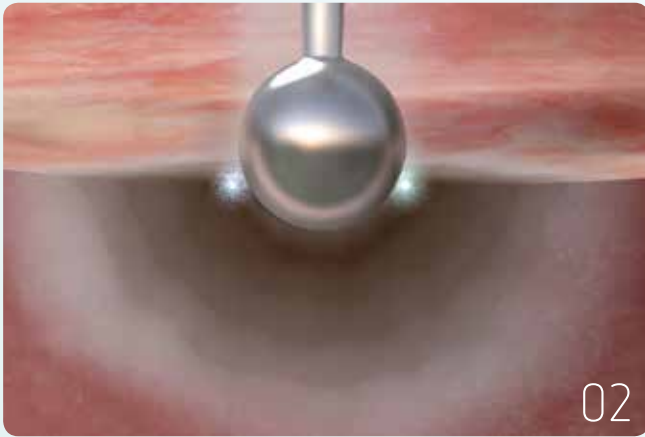
FUNDAMENTAL PHYSICAL TERMS

*Positive and negative electrical charges attract each other, thus exerting force on each other. In order to separate them from each other against this force, one has to use **energy (unit: joule)**. The **electrical voltage (unit: volt)** between positive and negative charges is the energy required for their separation per charge quantity. If there is an electrically conductive connection, then the charges move toward each other and **electrical current flows (unit: ampere)**. The current remains the same along the current-carrying conductor. The **current density** is the current per cross-section surface of the conductor. Every conductor has a **resistance** against the current (**unit: ohm**) which depends on the geometry and the material. If the resistance is higher, less current flows at unchanged voltages or unchanged current requires higher voltage. The total voltage and total*

resistance are the sum of the local voltages and resistances along the conductor, respectively. The higher the local resistance, e.g. due to changed material properties or a smaller cross-section surface, the higher the local voltage drop.

*Current flow creates **heat**. The energy that was required to separate the charges is released in the form of heat. The released energy per unit of time (second) is called **power (unit: watt)**. It is the product of current and voltage.*

***Direct current** always flows in the same direction. If the current and voltage periodically change their direction, then this is called **alternating current** and **alternating voltage**. One period contains two changes of direction. The number of periods per second is called **frequency (unit: hertz)**.*



Changes in biological tissue when using electrocoagulation
(schematic representation)

THERMALLY GENERATED TISSUE CHANGES

02

Various processes take place in tissue during heating (see Table right and Figure 02). They are primarily determined by the temperature achieved. Most important for electrocoagulation are denaturation of the proteins starting at about 60 °C (coagulation) and vaporization of the tissue fluid at about 100 °C. The rapidity and the completeness of fully these processes depends on the speed of the heating and the duration of exposure to the increased temperature.

THERMAL EFFECTS ON BIOLOGICAL TISSUE

37-40°C

None

From ~ 40°C

Hyperthermia:

initial tissue damage, edema formation, depending on the duration of application, the tissue can recover or die (devitalization)

From ~ 60°C

Devitalization (destruction)

of the cells, shrinkage of the connective tissue through denaturation

~ 100°C

Vaporization of the tissue fluid, depending on the speed of vaporization:

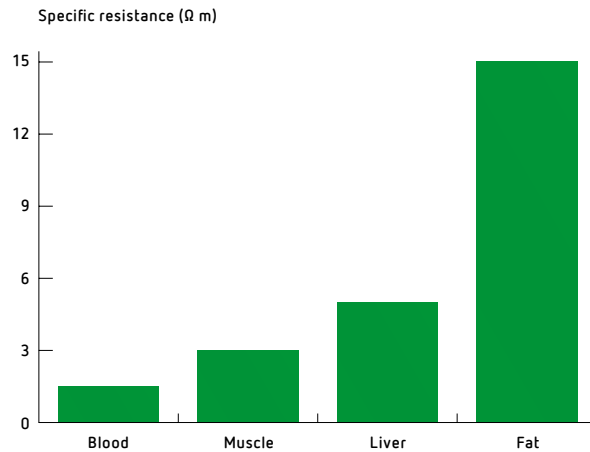
- Tissue shrinkage through desiccation (drying out) or
- Cutting due to mechanical tearing of the tissue

From ~ 150°C

Carbonization

From ~ 300°C

Vaporization (evaporation) of the entire tissue



03

Specific resistance (material-dependent part without geometry factor) for various tissue types at about 300 kHz

INFLUENCING FACTORS ON THE ELECTROSURGICAL EFFECT

03

The temperature achieved in the tissue and the time of exposure as well as the speed of the heating are decisive for the surgical effect. The speed of the heating and the time of exposure to the increased temperature are determined by the amount and time course of the power delivered to the tissue. Energy (power x time) is decisive for the temperature level achieved. The local distribution of the heating depends on the current density and the distribution of the tissue resistance. This results in various influencing factors on the electrosurgical effect:

Type of electrode and contact area:

Small contact areas between the electrode and tissue generate quick, intense heating due to the high current density. At the same power but with larger contact areas the current density is lower and the heating is slower and weaker. The most intense heating is achieved by the smallest area, i.e. a punctiform contact between the electrode and the tissue.

Speed of movement of the electrode and incision course:

The duration of the contact between the electrode and the tissue influences the temperature achieved and the time of exposure. The contact area can be changed through the electrode's movement, e.g. deeper insertion.

Tissue properties:

Different types of tissue, such as muscle, fat or vessels, can be heated to varying degrees due to their electrical and thermal properties and can also respond differently to heating. What is important here is the electrical resistance, which determines the delivered power. As the current flow occurs through ion movements in the electrolytic tissue fluid, the resistance depends greatly on the water content of the tissue, which differs depending on the type of tissue (see Figure 03). The resistance rises quickly when desiccation is initiated through vaporization of the tissue fluid. This can lead to more intense heating of desiccated tissue areas.

Operating mode of the electrosurgical unit:

Current and voltage depend primarily on the tissue properties, the size of the contact area and the properties of the generator in the electrosurgical unit. Under these conditions a reproducible effect is difficult to achieve. Erbe's introduction of regulated electrosurgery in the 1980s was a great advancement. Modern electrosurgical units continuously monitor current and voltage, derive parameters such as power and tissue resistance, and analyze them. Depending on the desired effect, these devices can keep the operating parameters constant or change them in a targeted manner through control and regulation. This enables them to compensate for differences between different types of tissue, react to changes in tissue properties, e.g. due to heating-induced desiccation, and ensure the reproducibility of the surgical effect.

Tissue effects of electrosurgery

The two classic effects of electrosurgery are tissue separation (cutting) and hemostasis, where hemostasis is often equated with coagulation. The operating elements and indicators of electrosurgical equipment are uniformly labeled with the colors yellow for cutting and blue for coagulation. From the process for hemostasis, processes for devitalization and ablation of tissue as well as for vessel sealing have been developed, which are also classified as coagulating effects and are allocated to the color blue.



Electrosurgical incision. The electrode is surrounded by a layer of vapor. The current is transferred by electric arcs

CUTTING

01

In order to separate tissue, it must be quickly heated to over 100 °C, so that the tissue fluid abruptly vaporizes and the tissue structure ruptures. The current density required for this is achieved by short electric arcs (sparks) which occur at peak voltages starting at around 200 V between the electrode and tissue. The electric arcs, tiny flashes, effectuate an almost punctiform feed-in of the current (see Figure 01). The cutting electrode is typically a spatula, a needle or a snare with a line-shaped leading edge. It does not directly touch the tissue during the cutting process because it is surrounded by a layer of vaporized tissue fluid. The arcings take place between the electrode surface, preferably at the edges, and the respective closest tissue location. This quickly scans and vaporizes tissue at the leading edge, thus creating an incision. The electrode can be advanced through the tissue without force. This procedure is also called electrotomy.

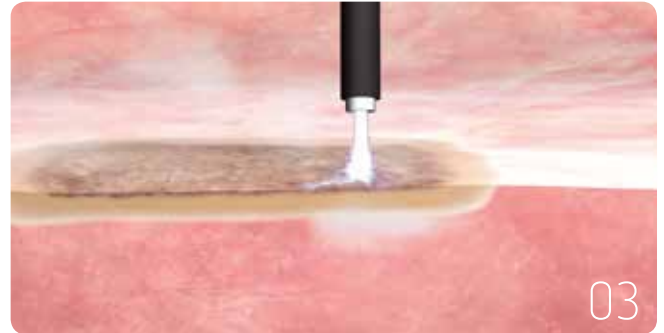
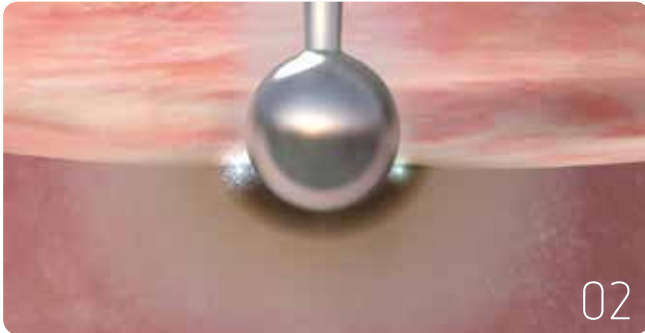
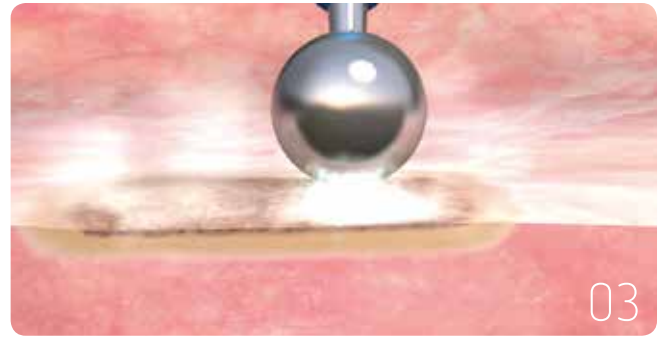
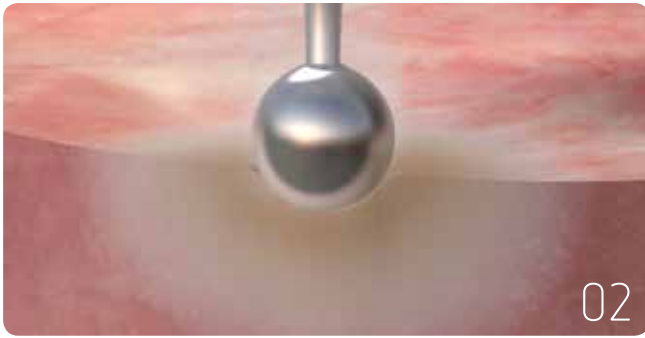
If the voltage is increased, the intensity of the arcings increases as well. A higher current flows than would be necessary for a simple incision. This leads to the vaporization of more fluid and to more intense heating of the neighboring tissue. Hemostatic coagulation occurs here; in the event of intense heating, undesired carbonization can occur as well. The nature of the incision, especially the size of the coagulation zone at the incision margin, is also known as the incision quality. The desired incision quality depends on the application. The incision quality can be influenced by the user through the incision speed – a

faster incision means less coagulation – and by the device through regulation of the operating parameters. The most common regulation processes are presented below.

Voltage regulation: The electrical voltage is decisive for the formation of arcings. Together with the electric resistance of the tissue, the voltage determines the current flow and thus the delivered energy for each arcing. Therefore, a voltage that is kept constant creates a constant incision quality that is independent of the incision depth. However, the incision quality depends on the incision speed and the tissue type. As an example, the same voltage yields a stronger effect in muscle tissue than in fatty tissue, since the resistance of muscle tissue is lower. This ensures a reproducible incision in the presence of constant tissue properties. At the same time, the tissue selectiveness of the effect can be used for the dissection of various tissue types.

Arc regulation: The intensity of the arcings is a measure of the incision effect. Modern electrosurgical units can measure this intensity and keep it constant by setting the voltage correspondingly. Arc regulation enables constant incision quality independent of the tissue type, cutting speed and type of electrode.

Modulation: Higher peak voltage is required for more intensively coagulating incisions. In order to prevent an excessive incision effect and carbonization, the mean power must be decreased. This is achieved by modulating the alternating current, i.e. its peak value is varied with



↑ Contact coagulation with low voltage
↓ and high, modulated voltage

↑ Non-contact coagulation: Fulguration
↓ Non-contact coagulation: Argon plasma coagulation

time. A frequent type of modulation consists in interrupting the current stream in brief time intervals. Normally, modulation takes place so quickly that the user only notices the changed tissue effect. An indicator of the extent of the modulation is the relationship between the peak value and the average value (quadratic mean or RMS value) of the voltage, which is called the crest factor.

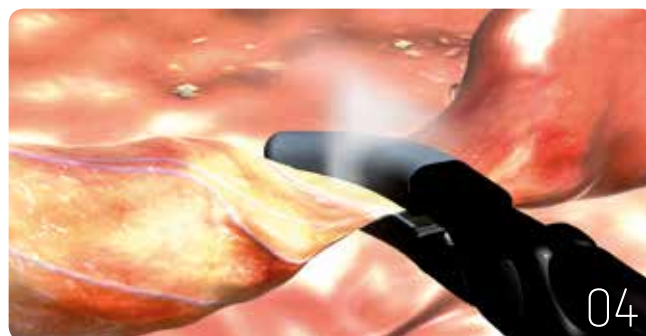
Power limitation: The delivered power can be limited to a maximum value. This ensures that not more power is delivered than is required for the desired effect and increases the safety of patient and physician alike.

Power regulation: The power can also be regulated to a constant value by adjusting the voltage. Similarly to the electric arc regulation, the power regulation brings about a largely tissue-independent incision quality, which does, however, depend more strongly on the size of the contact area.

HEMOSTASIS THROUGH COAGULATION

02,03

With sufficiently slow heating of bleeding tissue, the proteins in the tissue and blood that has seeped out coagulate first. The tissue shrinks and dries out due to the fluid vaporization which then occurs. The shrinkage of the tissue and the coagulation of the blood closes blood vessels and the bleeding stops. Coagulation can be performed in direct contact with the tissue (contact coagulation) or without contact. Contact coagulation is primarily suitable for coagulation of localized bleeding. It uses either low voltages (see Figure 02 ↑) or modulated forms of voltage with a higher peak value (see Figure 02 ↓). The higher voltages make it possible to work faster but can be associated with arcings and carbonization. In non-contact coagulation, the current is transmitted by electrical arcs under high voltages of several thousand volts. In contrast to the incision, the arcs are generally distributed over a larger area so that a broad coagulation zone is created. This way superficial, diffuse bleeding can be efficiently stopped. The conventional procedure works with arcings in air and is described as fulguration (see Figure 03 ↑). A more homogeneous and controllable result is provided by argon plasma coagulation (APC, Figure 03 ↓), which is described in the "Argon plasma coagulation" chapter on page 13.



*Vessel sealing through thermofusion.
The vessel is gripped with a bipolar clamp and sealed by means of coagulation*

DEVITALIZATION AND ABLATION

To treat tissue anomalies such as lesions or tumors, the tissue can be devitalized (destroyed), reduced or removed.

For devitalization, the tissue is irreversibly damaged by heating it to temperatures of over 60 °C. Argon plasma coagulation (APC) is best suited for superficial devitalization, while larger, deeper areas can be better reached with contact coagulation with ball or needle electrodes. Better penetration can often be achieved by applying lower currents for longer durations because tissue does not dry out as fast at the electrode and therefore does not lose its conductivity. The heat thus has more time to spread out into the depth of the tissue. This effect also occurs when modulated voltages are used. In addition, during current breaks fluid from adjacent tissue can diffuse back into the tissue directly at the electrode, thereby additionally delaying the drying out process. Devitalization of undesired tissue is often called high-frequency or radio-frequency ablation, although no direct tissue ablation takes place. The devitalized tissue is subsequently decomposed by the patient's intrinsic metabolic processes.

True, non-mechanical tissue ablation is difficult to achieve with electro-surgical procedures. APC with a high power setting can effectuate rapid vaporization, at least of the tissue fluid. However, carbonization of the remaining tissue also often occurs during this procedure. Slower heating can at least reduce the volume of the undesired tissue through shrinkage via vaporization of the tissue fluid and without carbonization.

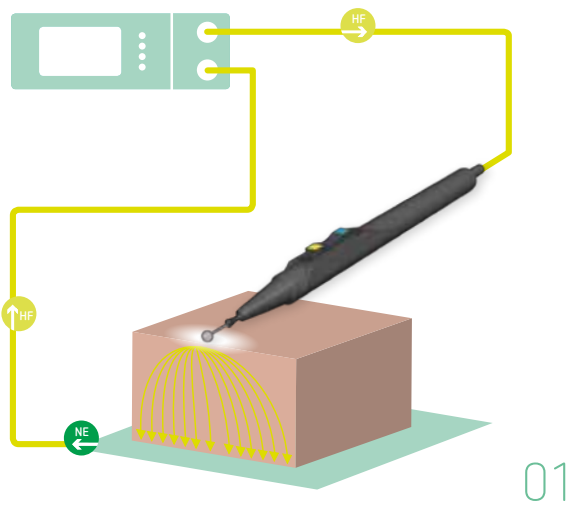
VESSEL SEALING THROUGH THERMOFUSION

04

Tissue supplied with blood or individual larger blood vessels can be sealed using coagulation before being cut. The walls of the vessel to be sealed are pressed together by a clamp, with current flowing between its two jaws. Due to the coagulation process, the denatured proteins of the vessel walls are fused together. The electro-surgical unit continuously monitors any changes of the tissue resistance between the jaws. Thanks to automatic regulation of the peak voltage and modulation, excessive thermal damage to surrounding tissue areas is prevented. The sealed tissue can then be cut through using a mechanical or electro-surgical incision. This procedure is increasingly replacing sealing by means of clip or suture.

Electrosurgical procedures

In electrosurgery a differentiation is made between monopolar and bipolar applications. In addition, there are contact procedures and non-contact procedures. Argon plasma coagulation is an important non-contact procedure. This chapter presents the monopolar and bipolar techniques as well as argon plasma coagulation.



Monopolar technique:

The surgical effect occurs at the active electrode (AE), where the current density is at its highest.

The current flows back through the large-area patient plate (neutral electrode, NE)

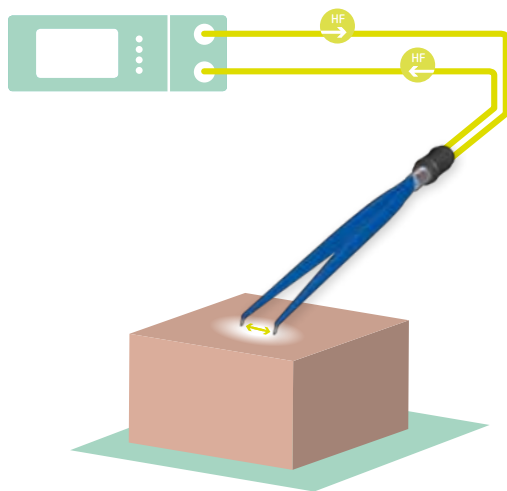
MONOPOLAR TECHNIQUE

01

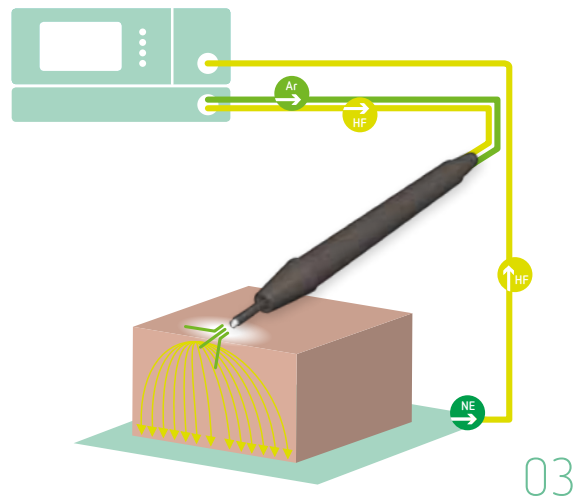
In the monopolar technique, the two electrodes between which the current flows have different shapes. The surgical effect occurs at the active electrode. It has a relatively small contact area so that the highest current density is reached at its surface. The second electrode is the large-area patient plate (neutral electrode or return electrode). It is applied to a suitable location on the patient's skin. The high-frequency current, which brings about an incision or coagulation at the active electrode, only minimally heats the tissue in contact with the large patient plate area and is barely perceptible to the patient. There is no surgical effect.

Burns can occur in the event of bad contact or too small contact area between the patient plate and the skin. Modern electrosurgical units, when used with dual- or multiple-surface patient plates, can measure the resistance between both electrode halves to detect a defective skin contact.

Because current can flow through the patient's body over longer distances with the monopolar technique, several things must be kept in mind to ensure safe use. The next chapter (page 14) discusses this in detail.



*Bipolar technique:
the current primarily flows between the two electrodes*



*Argon plasma coagulation (APC):
the current is transmitted through electrically conductive argon plasma between the active electrode (AE) and the patient plate (neutral electrode, NE)*

BIPOLAR TECHNIQUE

02

In bipolar electrosurgery, both electrodes are integrated in one instrument. The current flows primarily in the narrowly confined tissue area between the electrodes. A separate patient plate is not required. Often both electrodes are equal in regard to the surgical effect. In case of asymmetrical configurations with different contact area sizes, the effect only occurs at the small-area electrode.

The spatially confined current flow can be advantageous if safety aspects are taken into consideration. However, the bipolar technique cannot be used for every application. Due to its better handling properties, the monopolar technique has clear advantages, in particular as regards cutting electrodes.

ARGON PLASMA COAGULATION

03

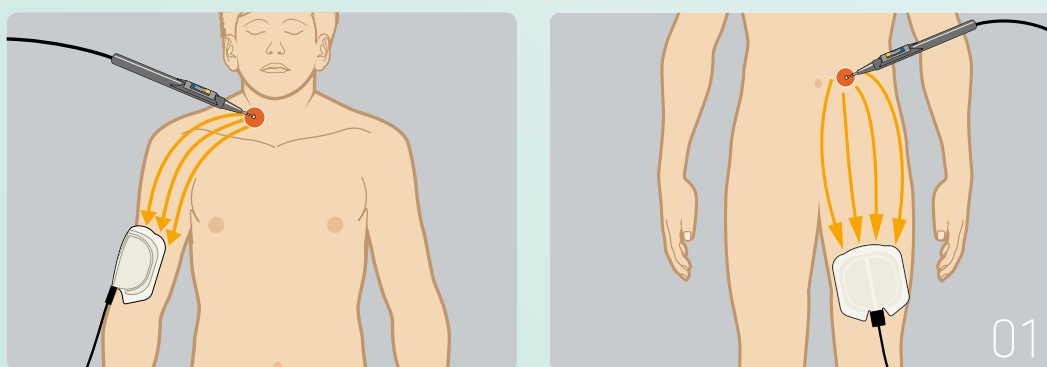
Argon plasma coagulation (APC) is a monopolar non-contact procedure. The current is transmitted by electric arcs through ionized (i.e. electrically conductive) argon gas – the argon plasma. APC is used for the coagulation of diffuse bleeding, for superficial devitalization of tissue and for volume reduction through vaporization and shrinkage. An important advantage of APC is that adhesion of the instrument and the resulting tearing open of coagulated tissue is excluded. The plasma also has the tendency to turn to not yet coagulated and therefore more conductive areas. With the appropriate low power setting, this produces a relatively even superficial coagulation with low penetration depth. Deeper coagulation can also be achieved with increased power.

Principles

of safe use of electrosurgery

Just as with all medical equipment, working with an electrosurgical unit is associated with certain risks for the patient, user and environment.

The information in this chapter is intended to help the user to understand the specific risks of electrosurgery and minimize these risks through proper use. This chapter is not, however, a replacement for reading and following the instructions and rules for safe use in the user manual nor for a briefing on the device itself. Many manufacturers also offer training and accompanying literature on their devices.



Current path through the patient (yellow arrows) between the active electrode (AE) and the patient plate (neutral electrode, NE) with monopolar application

HEATING EFFECT OF ELECTRICAL CURRENT 01

The effect of electrosurgery is based on high-frequency alternating current flowing through the patient's body between two electrodes, thereby generating heat in the tissue depending on the current density and tissue properties. High current density is desired at the surgical site in order to achieve the electrosurgical effect. However, aside from the operating field, bottlenecks in the current path can lead to undesired burns and/or coagulation sites. Some examples are small-area contact areas, such as between a patient's fingertip and thigh, or areas in which the tissue with good conductivity is thin, such as in joints. Therefore, the current path through the body should be as short as possible and have good conductivity as well as a large cross-section surface.

Burns can also be caused by electrical contact of the patient with the ground. The reason for this are so-called leakage currents, which can flow due to a technically unavoidable capacitive coupling between the high-frequency generator and the ground (see the "Capacitive coupling, ground and leakage current", right). Although these currents are limited to a relatively low value, they can cause burns in the event of small-area contact of the patient, e.g. with a grounded operating table, the table's metallic accessories or an infusion stand.

In bipolar applications most of the above-described risks are largely excluded due to the short current path between the electrodes. In monopolar applications these risks can be minimized by adhering to several principles regarding patient positioning and use of the patient plate.

Patient positioning:

The patient must be electrically well insulated when positioned on the operating table. As fluids are generally conductive, the area between the patient and the operating table should be as dry and impervious to fluids as possible. Skin to skin contact is to be avoided.

Patient plate:

The patient plate must have good contact to the patient's skin with its entire surface and should be applied as closely as possible to the operating field. The current path between the active electrode and the patient plate should be short and go through tissue that is well supplied with blood with the largest possible cross-section surface (see Figure 01).

FLAMMABLE LIQUIDS AND GASES

Electric arcs that transmit current arise during cutting and with some types of coagulation, especially APC. These are desired for generating the electrosurgical effect. However, they can also set fire to flammable substances like disinfectants in liquid or evaporated form as well as other flammable gases. Even gases which support combustion such as pure oxygen can be dangerous in this context. Therefore, such substances should be removed from the operating area – e.g., through aspiration – before performing electrosurgery.

DISRUPTING OTHER DEVICES

Electrosurgical units may disrupt other devices that are being operated at the same time. The reasons for this are very complex and the solution to the problem can require various measures. Therefore, only the most frequent disruptions and their causes can be listed here. Manufacturers of electrosurgical units generally have additional information available on this topic and assist with finding a solution.

Electrosurgical alternating currents can flow through devices that are connected to a patient and affect the functioning of these devices. Pacemakers and other active implants as well as devices for patient monitoring are some examples. These problems can be partly minimized by suitable placement of the patient plate, thus preventing unfavorable current paths. The bipolar technique is particularly preferable for operations on pacemaker patients.

Another frequent cause of disruption is capacitive coupling (see box, right) between cables that are located close to each other belonging to a high-frequency device and an ECG device, for example. This is why electrosurgical cables should be located away from the cables of other devices, if possible. In endoscopic procedures this is only possible to a limited extent; here transmission of image data can be affected by capacitive coupling between the electrosurgical cables and the data cables in the endoscope. These problems can generally be resolved with various measures. Information can be obtained from the respective manufacturers.

MISCELLANEOUS INFORMATION

Infants and children:

Special patient plates for infants or children can be used in cases when the standard patient plates cannot be used due to space reasons while employing the monopolar technique. This results in the current being distributed over a smaller area. In order to prevent burns caused by the higher current density, the total current must be limited. This can be achieved by using lower settings on the electrosurgical unit. Some devices have specially adjusted current monitoring for infant and children patient plates. Another measure is to decrease the contact area at the active electrode through careful cutting and/or by using small-area coagulation electrodes.

Pregnancy:

Although electrosurgical currents are not known to cause damage to the embryo or fetus, the bipolar technique is recommended for pregnant women.

Several instruments connected to one device:

Due to capacitive coupling between instrument cables, an alternating current can flow through the cable of a non-activated instrument, which can cause burning at the electrode. Therefore, instrument cables must be kept apart from each other. Instruments that are not needed must be placed in a safe place and in particular not on the patient.

Simultaneous operation of two electrosurgical units:

During simultaneous use of two electrosurgical units on a patient, a range of problems may arise, e.g. due to superposition of high-frequency currents. For more information on this topic, please contact the respective manufacturer.

CAPACITIVE COUPLING, GROUND AND LEAKAGE CURRENT

Alternating current can be transferred from one conductor to another even without an electrical conducting connection. This is due to the fact that the force between the electrical charges is also effective in non-conductive areas. If alternating voltage is applied between two conductors, then alternating current can flow in both. In contrast to direct current, a conductive connection is not required because in alternating current the electrical charge moves back and forth in the conductor and no net charge flow occurs. This phenomenon is called **capacitive coupling** and occurs between conductors – such as cables – that are located close to each other. The higher the frequency, the better the current can be transmitted. Therefore, capacitive coupling can occur increasingly in the frequencies used in electrosurgery, which are considerably higher than the frequency of the electricity network (50 or 60 Hz).

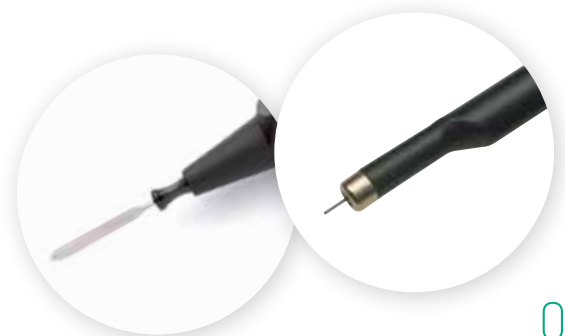
The voltage of the energy supply network lies between the current-carrying conductor (phase) and the **ground**. If one touches the phase, current can flow through the body to the ground. In order to exclude this danger in the event of a defect in the device, metallic housing is always directly connected to the ground through the grounded safety power outlet.

In electrosurgery the electrosurgical current must not flow directly to the ground. This is why the electrosurgical generator in the electrosurgical unit is insulated from the ground so that the electrical circuit can only be closed by the second electrode. However, one cannot prevent small currents from flowing over the ground due to capacitive coupling in the electrosurgical unit. These currents are called **leakage currents** and are technically confined to the greatest extent possible.

Instruments

Users of electrosurgery have a large number of instruments at their disposal for the various applications. This chapter provides an overview of these instruments.

In principle, there are cutting instruments and coagulation instruments – with some combinations of the two. One must also differentiate between instruments for monopolar and bipolar applications as well as for APC. The instruments can also be classified according to their area of application in regard to their design. Instruments for open surgery generally consist of a handle with an electrode attachment. For minimally invasive surgery, instruments with a shaft are required, which can be rigid or flexible depending on the kind of application, e.g. laparoscopic or flexible endoscopy. And lastly, many instruments have disposable (one-time use) versions as well as reusable versions.



Left: monopolar and right: bipolar cutting instrument

01

CUTTING INSTRUMENTS

01

Electrodes with a line-shaped leading edge are necessary for incisions. Typical forms of cutting electrodes are needles, spatulas, wire snares or hooks. These are available in a monopolar version as electrode attachments for handles and in monopolar or bipolar versions as instruments with a rigid or flexible shaft. Bipolar cutting instruments normally have a neutral electrode ring which must be brought into contact with the tissue during the incision. There are also bipolar scissors with two cutting electrodes. Figure 01 shows examples of monopolar and bipolar cutting instruments.



02

Monopolar ball electrode with large contact area



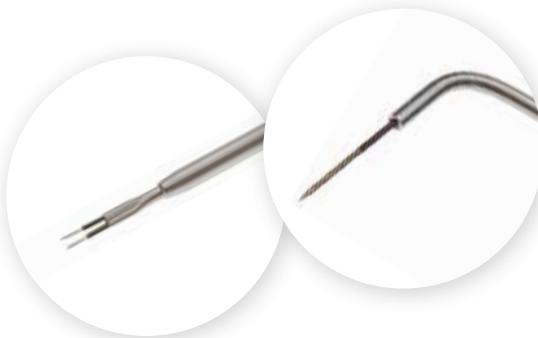
03

*Bipolar instruments for thermofusion.
Left: for open surgery, right: laparoscopic.*



05

Open surgery APC handle with screw-on applicator



04

*Puncture coagulation needles.
Left: bipolar, right: monopolar.*



06

APC probe for flexible endoscopy

COAGULATION INSTRUMENTS

02,03,04

There are special instruments for each of the following coagulation effects: hemostasis, vessel sealing, and ablation. Hemostasis in open surgery is generally a monopolar procedure using an instrument with a large contact area such as the ball electrode (see Figure 02). The flat side of a cutting spatula can also be used.

For vessel sealing, bipolar forceps and clamps of various sizes and shapes are used (see Figure 03). Monopolar or bipolar puncture needles are used for tissue ablation and devitalization (see Figure 04).

INSTRUMENTS FOR ARGON PLASMA COAGULATION

05,06

APC covers hemostasis as well as ablation through devitalization and shrinkage. APC instruments consist of an electrode and a feed pipe for the argon gas and are available in many shapes for the various areas of application (see Figure 05). Since its integration in flexible endoscopy (see Figure 06) by Erbe, use of APC has become widespread, above all in this field.

Applications

Due to its versatility, electrosurgery has a wide range of applications, from general surgery to gastroenterology, gynecology, urology, pneumology, ENT, dermatology and neurosurgery. An overview can be provided based on the characteristic properties and possibilities of electrosurgery:

- ✔ **Perform incisions effortlessly and with little bleeding using a blunt electrode**
- ✔ **Stopping localized and large-area bleeding**
- ✔ **Fusing tissue that is supplied with blood and making it separable without loss of blood**
- ✔ **Devitalization and shrinkage of tissue**
- ✔ **Removal of tissue through incision**

The following sections discuss typical applications for these surgical techniques. Please refer to the user brochures for more detailed information. Many manufacturers also offer training courses during which these techniques can be learned.

CUTTING AND HEMOSTASIS

Cutting and hemostasis are the classical tasks of electrosurgery. These effects are used in all surgical disciplines. Contact coagulation or APC is generally used for hemostasis. Contactless APC has some clear advantages in regard to the coagulation result and manageability, especially in minimally invasive surgery.

TISSUE SEALING

Bipolar forceps and clamps are used for sealing tissue structures that are supplied with blood and for larger blood vessels. Typical applications are the mobilization of the intestines or lymph node dissection in visceral surgery and the mobilization of the uterus for resection in gynecology.

DEVITALIZATION AND ABLATION

The treatment of tumors, lesions and hyperplastic tissue through devitalization and shrinkage is an important area of application of electrosurgery. The range of applications includes, for example, liver surgery, ENT surgery and pneumology. Contact coagulation with a ball electrode or puncture needle as well as APC are employed, which can be used both for superficial devitalization as well as for tissue reduction, e.g. for growths in the gastrointestinal tract.

TISSUE REMOVAL

Tissue reduction can also be done through electrosurgical removal using a snare electrode. This technique is used for removing intestinal polyps (polypectomy), for example. The electrosurgical unit automatically switches between cutting and contact coagulation in order to reduce the risk of bleeding. Another application is transurethral resection of the prostate (TURP). Here a monopolar or bipolar snare is introduced through a resectoscope together with an irrigation solution to remove the unwanted tissue. A similar procedure can also be used in orthopedics for smoothing down cartilage tissue.

Glossary

Ablation Removal, reduction or destruction of tissue

Active electrode The part of the electrosurgical instrument that transmits the electrosurgical current at the site of the intended tissue effect to the patient's tissue. Acronym: AE

Alternating current Current that regularly changes its direction

Alternating voltage Voltage that regularly changes its polarity

Argon plasma coagulation Monopolar, non-contact coagulation. Electrically conductive argon (argon plasma) transmits the current to the tissue via electric arcs. Acronym: APC

Bipolar electrosurgery Electrosurgical procedure in which both electrodes are integrated in one instrument

Burns under patient plate Burning of the skin due to excessively high heat generation through excessive current density under or at the patient plate

Capacitive coupling Contactless transmission of alternating current between two electrical conductors with alternating voltage applied between them

Carbonization Charring of biological tissue

Cautery Procedure for cutting and hemostasis using heated instruments. Sometimes erroneously used as a synonym for electrosurgery

Coagulation 1. Denaturation of proteins. 2. Electrosurgical effect during which proteins coagulate and the tissue shrinks

Crest factor The ratio of the peak value to the RMS value of a current or voltage curve; a measure of the signal's degree of modulation

Current Electrical charge quantity that moves past a certain point in one second. Unit: ampere (A)

Current density Current flow amount per cross-section area. The higher the current density, the more heat is generated

Cutting Electrosurgical effect during which the intracellular fluid is explosively vaporized and the cell walls burst

Desiccation Drying out of biological tissue

Devitalization Destruction of biological tissue

Diathermy Synonym for electrosurgery

Edema Water accumulation in the tissue

Electric arc Electrical discharge in the form of a tiny flash. During this process a gas, such as air or argon, is turned into an electrically conductive plasma through ion formation. Arcs are particularly needed for cutting procedures and APC

Electrical resistance / impedance Describes the electrical conductivity of a material. The greater the conductivity the lower the electrical resistance. The resistance of a conductor is the product of the material-dependent specific resistance and the length, divided by the cross-section area. Unit: ohm (Ω)

Electrode Conductor that transmits or receives current, e.g. active electrode, patient plate

Electrosurgery Application of high-frequency electric current on biological tissue with the goal of creating a surgical effect through heating. Synonyms: diathermy, radio-frequency (RF) surgery

Electrotomy Electrosurgical cutting

Endogenous from within

Energy Power x time. There are different forms of energy, e.g. electrical work, mechanical work and heat. Unit: joule (J)

Exogenous Derived or originating externally

Frequency Rate of periods per second during which the direction of, for example, the current changes twice. Unit: hertz (Hz). 1 kHz = 1,000 Hz

Fulguration Non-contact coagulation with arcing in air

Hemostasis Stopping of blood flow

High frequency In terms of electrosurgery (standard: IEC 60601-2-2): frequency of at least 200 kHz. Acronym: HF; also radio frequency (RF)

High-frequency generator Device or device component that converts direct current or low-frequency alternating current into high-frequency surgical current

Hyperthermia Heating of the tissue to higher than its normal temperature

Incision quality The nature of the incision, especially the extent of the coagulation at the incision margin. The desired incision quality depends on the application

Lesion Damage, injury or disruption to an anatomical structure or physiological function

Modulation Variation in time of the peak value of a signal varying in time (current, voltage)

Monopolar electrosurgery Electrosurgical procedure during which the active electrode is used at the surgical site and the electrical circuit is closed by a patient plate

Necrosis Pathological cell death

Neutral electrode Synonym for patient plate. Acronym: NE

Patient plate Conductive electrode which is attached to the patient during a monopolar application in order to receive the electrosurgical current. It feeds the current back to the electrosurgical unit in order to close the electrical circuit. Synonyms: dispersive electrode, return electrode, neutral electrode

Peak voltage Maximum value of a voltage varying in time, in positive or negative direction starting from zero (0)

Plasma Gas which has become electrically conductive through ionization

Power Energy per second. Electrical power is the product of current and voltage. Unit: watt (W)

Radio-frequency surgery Synonym for electrosurgery. Acronym: RF surgery

Root mean square value Square root of the mean square value of a parameter varying in time (current, voltage). In regard to the delivered power, the root mean square is the value with equivalent effect of a direct current or direct voltage. Acronym: RMS

Spark Brief electric arc

Thermofusion Fusion of tissue through coagulation

Vaporization Vaporization of the entire tissue

Voltage Energy for separating charges, relative to the charge quantity. Unit: volt (V)



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