ENERGY SYSTEMS IN SURGERY
ENERGETSKI SISTEMI U HIRURGIJI

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Summary

Introduction. The systems of energy in surgery are applied in order to achieve better and more effective performing of procedures. Whereas various energy sources, including electricity, ultrasound, laser and argon gas, may be used, the fundamental principle involves tissue necrosis and hemostasis by heating. Electro Surgery. Electro Surgery is a surgical technique by which surgical procedures are performed by focused heating of the tissue using devices based on high-frequency currents. It represents one of the most frequently used energy systems in laparoscopy: Ultrasound Energy. The basic principle of operation of the ultrasound surgical instruments is the usage of low-frequency mechanic vibrations (ultrasound energy within the range of 20-60 kHz) for cutting and coagulation of tissue. Laser. Laser is the abbreviation for Light Amplification by Stimulated Emission of Radiation, aimed at increasing light by stimulated emission of radiation and it is the name of the instrument which generates coherent beam of light. Argon Plasma Coagulation. It has been in use since 1991 for endoscopic hemostasis. It uses high-frequency electric current and ionized gas argon. The successful application of devices depends on the type of surgical procedure, training of the surgeon and his knowledge about the device. Surgeons do not agree on the choice of device which would be optimal for a certain procedure. Conclusion. The whole team in the operating room must have the basic knowledge of the way an energy system works so as to provide a safe and effective treatment of patients. The advantages and shortcomings of different systems of energy have to be taken into account while we use a special mode.

Key words: Gastrointestinal Stromal Tumors; Leiomyosarcoma; Diagnosis, Differential; Diagnosis; Immunohistochemistry; Morphological and Microscopic Findings; Signs and Symptoms; Combined Modality Therapy; Tumor Markers, Biological; Actins; Desmin; Proto-Oncogene Proteins c-kit

Sažetak

Electro Surgery

Electro surgery is a surgical technique by which surgical procedures are performed by focused heating of the tissue using devices based on high-frequency currents. It represents one of most frequently used energy systems in laparoscopy. It is usually wrongly identified with electrocautery. Cautery uses the heat conductibility of the test probe which heats directly using alternating current, while electro surgery uses high-frequency current which directly heats the tissue itself. Electrocautery is an electro surgical instrument which heats the focused tissue and cuts it by the high-frequency generator with the frequency of 2MHz, the output power from several tens to several hundred Watts and voltage of 15 kV [3, 4]. Electro surgery shortens the duration of surgical procedures, reduces hemorrhage and destruction of the tissue, has a good cosmetic outcome, and alleviates the postoperative pain when compared to the conventional surgeries performed by scalpels. At the same time, it provides the comparable postoperative healing of wounds and percentage of infections [5–7]. When electricity flows through the biological tissue, one of the three effects appears depending on the type of electricity and its frequency: electrolytic, Faraday’s or heat effect. Electrolytic effect: when we use the direct current or the low frequencies of alternating current, the electrolytic effect will dominate, which means that the ions in the tissue will move. The positive ions will move towards the negative electrode (cathode) and the negative ions move towards the positive electrode. This effect is used in ionosphere which is used to introduce different types of medicines to an organism. However, the electrolytic effect is not desirable in electro surgery because it may cause the damage of the tissue. Faraday’s effect: it is created when alternating current with the frequency of 20 MHz flows through a human body. With this frequency level, electricity stimulates the nerve and the muscle cells and, for example, it can cause muscle contractions. The maximum of excitation will happen at the frequencies from 10 to 100 Hz. The Faraday’s is successfully used in a form of electric stimulation in diagnostics and therapy [8]. As well as the electrolytic effect, the Faraday’s effect is not desirable in electro surgery because muscle contractions are unpleasant, problematic for doctors and can even be dangerous for the patient. Thermal effect: The application of high-frequency direct current in human tissue prevents the appearance of the electrolytic and Faraday’s effect to a great extent and makes the thermal effect dominant. The frequency of direct current is usually at least 300 kHz and that is why it is called the high–frequency surgery, radio frequency surgery or generally, electro surgery [9, 10] (Table 1). The basic principle for all electro surgeries is the thermal effect which is caused by the electric current flowing through a body. The thermal destruction of the tissue is used for cutting or coagulation in the area of the operation. If the tissue is heated long enough to the temperature of 100°C using the high-frequency direct current, the evaporation of the internal and external cellular fluid will be caused with the resulting coagulation and decreasing of the tissue. There are several types of coagulation: soft, urgent, draining, and spray coagulation [11]. The high-frequency direct current can also be used for quick heating of the target tissue by temperatures higher than 100°C, so the pressure of the vapor causes the explosive rapture of the membrane. The large number of these small ‘cell explosions’ create an incision, i.e. cause the cutting. There is a difference between the auto cut, dry cut and high cut. The electric current flows only though a closed system. That means that both active and neutral electrode, if connected correctly, create the electro surgical unit when the monopolar mode of operation is applied [12]. The neutral electrode, which is larger, must be correctly placed on the patient’s thigh. When the doctor touches the tissue with the active electrode, the electro surgical unit is on and high-frequency electricity flows through the patient. Electricity flows through the patient and then it returns to the electro surgical unit through the neutral electrode. In bipolar surgery, the active and neutral electrodes are on the place of operation, inside the instrument. These are, actually, the forceps with the tweezers or scissors. The flow of electricity is limited between these two poles which are very close one to another, so the neutral electrode on the patient’s body is not needed. Since the poles are very close one to another, the low voltages are used to achieve the tissue effect. Bipolar mode is very safe for electro surgery. Maximum thermal lateral span is less than 5 mm [13]. The shortcomings of bipolar electro surgery are the longer periods needed for coagulation because of low electricity, carbonization and unpredictable

Table 1. The heat effect on the tissue

<table>
<thead>
<tr>
<th>Temperature/Temperatura</th>
<th>Process/Proces</th>
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<tr>
<td>42°C</td>
<td>Reversible tissue damage/Reverzibilna ćelijska trauma</td>
</tr>
<tr>
<td>49°C</td>
<td>Irreversible tissue damage/Ireverzibilna ćelijska trauma</td>
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<tr>
<td>70°C</td>
<td>Coagulation/Koagulacija</td>
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<tr>
<td>100°C</td>
<td>Dessication/Isušivanje</td>
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<tr>
<td>200°C</td>
<td>Carbonization/Karbonizacija</td>
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<tr>
<td>500°C</td>
<td>Vaporization/Vaporizacija</td>
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Breaking of neighboring blood vessels. Three tissue effects are possible when using modern electro surgical units: cutting, draining and coagulation (fulguration). The achievement of these effects is influenced by the following factors: density of electricity, time, size of an electrode, tissue conductivity and the waveform of electricity. The clean cut (evaporating) uses the waveform of electricity which is continuous, non-modulated and unamortized. The blend waveform is a modification of cutting waveform and it is used when we need the hemostasis during cutting. It is a combination of cutting waveform and coagulation [11, 14](Graph 1). The devices for obturation of blood vessels caused a revolution in modern laparoscopy. They can be divided into two categories: advanced bipolar and ultrasound instruments. The advanced bipolar devices for obturation/cutting blood vessels use adaptive technology, which is a part of modern electro surgical units, to deliver the controlled energy of low voltage with minimal lateral thermal span. The most important element of this technology is usage of bipolar electro surgery which is based on generators of tissue response. To be more precise, electricity of great strength and low voltage causes denaturation of collagens and elastins in the walls of blood vessel by treating target tissue and the mechanical pressure of the instrument enables denatured proteins to form coagulum [15]. Blood vessels not wider than 7 mm and large tissue strings can be surgically ligated. Moreover, heat distribution decreases when compared to traditional bipolar surgical systems. Nowadays there are several types of advanced bipolar devices on the market: Plasma Kinetics system, LigaSure, EnSeal and Cayman. Each of these types is licensed to be used for obliteration of the tissue not more than 7 mm wide. Some of these include the Thnderbeat platform by Olympus which integrates both ultrasound and advanced bipolar technologies. LigaSure includes both advanced bipolar and monopolar technologies. Cayman 12 offers articulated 12 mm instrument [16]. Binding (ligating) of veins is very difficult because of very thin walls and that is why the so-called thermo fusion can sometimes be useful. When thermo fusion is applied, veins do not have to be separated from the surrounding tissue. They are coagulated together with the connecting tissue around the blood vessel. Shrinking of tissue helps ligation of a blood vessel to form the natural ring (collar). Thermo fusion must not be used near the important structures such as the ureter [17]. The number of reported electro thermal injuries is 1-5 injuries per 1000 cases. The majority of electro thermal injuries of intestine (75%) are not recognized when they happen [18]. The consequences of these unnoticed injuries are usually very serious and often cause long-term complications. The organ which is injured most is the small intestine (ileum), but these injuries can neither be noticed clearly and immediately nor cause the abnormal laboratory values. Generally speaking, the symptoms of the intestine perforation are usually noticed 4 to 10 days after the procedure. The symptoms of direct traumatic perforation of intestine usually appear within 12 to 36 hours, although there have been a few cases when they appeared in the period of 11 days. The electric injuries are caused by surface coagulation necrosis [11, 19]. Electro thermal injuries often appear in the following situations: direct application, direct coupling, weakening of the isolation and capacitive coupling. Direct application appears as a consequence of the unintended activation of the electro-surgical probes when the probe is, for example, moved from the operating field to the thigh artery. Direct coupling ensues when the electro surgical unit is activated unintentionally, while the active electrode is very close to another metal instrument. Electricity in the active electrode flows through the neighboring instruments following the path of the least resistance and it potentially damages the organs which are out of the field of view, but which are in the direct contact with the instrument. It can be prevented by visualization of the electrodes when they are in contact with the target tissue and by avoiding contact with any other conductible instrument before activating the electrodes. Unsuccessful isolation (weakening of the isolation) is considered to be the main cause of electro surgical injuries. It is defined as an interruption or a defect in isolation which covers the instrument. It is caused by extended, long time use of the instrument, especially by its multiple passing through the trocar and by its repeated sterilization. The instruments for one use only have lower frequency of isolation damage when compared to the instrument for multiple usage. The distal third of the laparoscopy instruments is the part which is the most problematic. Capacitive coupling is the electric current which flows through the tissue or in metal instruments which are parallel, but not in the direct contact with the active electrode. This happens when electric...
current is transferred from one conductor (the active electrode) through untouched isolation to the neighboring conducting material, for example the intestine, without direct contact. In monopolar mode, the alternating current flows through the active monopolar electrodes and then flows back to the electro surgical generator through the patient and the return plate induces undesirable electricity in all the conductors in the vicinity. The strength of induced electricity will depend on how far the conductor is. It will also depend on the voltage and isolation. Every conductor in the operating room is in danger of the electricity which flows in the wrong direction because it can become capacitively coupled with the electricity which comes from the active electrode. If an injury appears, it is usually out of the field of view of the surgeon and includes body structures. Ironically, the use of metal trocars can actually decrease this risk, enabling the stored energy from capacitors to discharge through the large surface of the patient’s skin, which makes electric energy less concentrated and less dangerous. The problems connected to the capacitive coupling can be eliminated by using the active system to monitor the electrodes and limit the time during which high voltage can be used [9, 20, 21]. To prevent electro surgical complications the following protective measures are used: the thorough checkup of isolation, application of the weakest possible strength, usage of short, interrupted activation, usage of low-voltage waveform (cutting out), avoiding usage in either closed circuit or in the vicinity or direct contact with another instrument, using bipolar electro surgery when it is appropriate. Choose completely metal canile system as the safest choice. Apply the available technology (generator of tissue response, active monitoring of electrodes) to eliminate problems which are caused by weakening of isolation and capacitive coupling. For the effective electrosurgery, the surgeon must be able to check the equipment and settings at first sight [1, 4].

Ultrasound Energy

Ultrasound energy in medicine was first applied in 1960 to cure the Meniere’s disease and then in the late 1980s it was used for coagulation and cutting the tissue. The basic principle of operation of ultrasound surgical instruments is the usage of low-frequency mechanic vibrations (ultrasound energy within the range of 20-60 kHz) for cutting and coagulation of tissue. A harmonic scalpel is an ultrasound instrument for cutting and coagulation of tissue and it uses the frequency of 55.5 kHz. It has no electro surgically generated energy. The combination of mechanical energy and heat which is generated causes the denaturation of proteins and forming of coagulum which seals small blood vessels. Vibrating of the top of the blade makes large changes of pressure and causes cellular liquid to evaporate on low temperatures which causes cells to rupture and it is used for highly precise cutting and dissection. Another mechanism of cutting by harmonic scalpel is the real cutting power coming from a relatively large knife which vibrates at the frequency of 55.5 kHz. The friction temperature of the tissue is usually about 80°C, which decreases the tissue carbonization, and causes drying and reduction of the zone of the wound. It is characterized by the lateral thermal spreading from 1 – 4 mm, the ability for obturation (ligation) of the blood vessels not wider than 5 mm. The shortcoming of this technology is the appearance of small, greasy drops from the tissue being treated and this can disturb the visualization through the laparoscope [22].

Laser

Laser is the abbreviation from Light Amplification by Stimulated Emission of Radiation, which means to increase light by stimulated emission of radiation and it is the name of the instrument which generates coherent beam of light. It is a ray, actually a wave, which transfers oscillation of light photons of certain frequency at a certain wavelength and in a certain direction of polarization. In a small space, laser beams enable big amount of energy to focus in one point which potentiate a large quantity of radiation energy to focus and thus the temperature could reach 7000°C in a very small space. In the area effected by laser beams, any substance can evaporate. As all other forms of light therapy, the effect of laser beams depends on their absorption. The absorption of radiation is different with different kinds of tissue. Differences in tissue absorption ability are closely related to the wavelength and content of fluid in the tissue [23]. The usual laser system in gynecological practice includes carbon-dioxide laser as well as Nd YAG laser. Both types of beams are invisible. There are four categories of lasers. The majority of medical lasers belong to categories 3B or 4, which require protection. Radiation of laser which penetrates the eye is focused on the retina, so that the strength of energy can dramatically decrease which can damage retina. Fire also represents threat when laser of category 4 is used. The retina of the eye is very sensitive to the effect of laser beams, therefore the eyes of both patients and doctors who work with it must be protected when this kind of beams is applied. Special protective glasses having a special optic filter are usually worn. Under any circumstances, protection must be complete, which means laterally as well, because otherwise the retina and sclera can be damaged. An eye can be damaged at the temperature of 0.24 – 7 J/cm². The eye must be protected when laser beams are used. Surgical effect produced by laser and electro surgery is the result of generating heat in the tissue. Since water heats to the extreme temperatures, inter-cellular pressure rises, which results in the cell explosion. In the situation like this, vapor has to be released and spread in the air. At the same time, microscopic particle is released into the air. That particle represents biological, contaminating substance in smoke which consists of oxidized tissue, blood and possibly contagious viruses and bacteria. Infection risk exists and is caused by exposure to the
living viruses of the infected deoxyribonucleic acid (DNA) and bacterial contaminates. Moreover, chronic irritation caused by surgical smoke can cause skin problems (dryness and rushes) as well as inflammation of respiratory tract (bronchitis). Mucosa along the nasal-pharyngeal area can be irritated. Those who wear contact lenses should be informed that small lenses absorb the contents of surgical smoke. In addition to biological substances, there are also the chemical contaminating substances which include toxins (carcinogens) such as Acroleyn, Benzene, Formaldehyde and Toluene, together with polycyclic aromatic carbon-hydrogen (PAH). It is necessary to provide effective elimination of smoke close to the surface on which surgery is performed in order to remove the vapor before operating room stuff (doctors and nurses) inhale it. Filtrating is only used for particles [24]. Masks do not filtrate gases which are chemical contaminating substances. Standard masks have the range of effective filtrating from 0.6 to 5 microns. Masks with a wide range of filtrating (when used properly) can filtrate 0.1–0.5 microns. These masks make breathing difficult. Integral system of approach, AirSeal(R) has sensors for flow of gases and pressure. It combines trocar and pipe system with a filter which enables fixed pneumo-peritoneum with the constant discharging of smoke, as well as the approach to venter without a vent hole [25]. Its holders can be 5, 8 and 12 mm wide in diameter. By the system of automatic and constant elimination of smoke, surgical smoke is prevented to get out. Constant filtering has been carried out and it provides circulation of CO₂.

Argon Plasma Coagulation

It has been in use since 1991 for endoscopic hemostasis. It uses high-frequency electric current and ionized gas argon. Besides lasers, this is noncontact method in which argon, being a good conductor of electricity, is used to transfer electricity from an instrument to the tissue. The result is quicker coagulation when compared with conventional devices and it provides coagulation on a wide surface and shallower coagulation of treated tissue, which results in quicker dispersion, decreasing the damage of tissue. Moreover, it produces less smoke than conventional systems. It is applied in hemostasis of the surface diffusion hemorrhages from parenchyma organs [26]. The most significant limitation of the usage of argon plasma system is a possible danger of emboloy by argon [27].

In spite of the advances, search for the ideal energetic device which will result in perfect hemostasis with minimal damage of the surrounding tissue in the most effective way with minimal possibility of complications has not been completely successful.

Every energetic system has its advantages and shortcomings. It is necessary to be very well acquainted with every device in order to be able to decide which source of energy will be used. Generally speaking, the majority of studies suggest that the effect of any procedure depends on skillfulness of the surgeons and their ability to use a certain device.

Conclusion

The whole team in the operating room must know basic information on how to apply sources of energy which represents the crucial point for the safety of patients. In addition, it helps to notice and prevent potential complications. The advantages and the shortcomings of different systems of energy have to be taken into account while we use a special mode. We have to use the most modern technologies with effective hemostatic characteristics whenever it is possible.

References