WOUND HEALING BY THE USE OF SCALPEL AND VARIOUS RADIO-FREQUENCY CUTTING DEVICES (A RANDOMIZED EXPERIMENTAL STUDY)

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ABSTRACT

An experimental study was performed on Wistar rats with the purpose of histological evaluation of the surgical wounds state and the processes of their healing using a conventional surgical scalpel and three radio wave devices with different operating frequencies (2.2 MHz, 2.64 MHz, 3.8 MHz). It has been established that in animals with wounds inflicted by the radio-wave at the highestworking frequency, there were statistically significant differences both in terms and in the mechanisms of wound healing. These benefits were in the absence of a blood clot in the wound after the incision, also in minimal necrosis of the operating wound and adjacent tissues, in the absence of leukocyte infiltration in the wound; early (from 3 days) reparation and epithelialization of tissues. These features contributed to a reduction in the timing of wound healing and the absence of scar formation.

Keywords: wound, wound healing, radiosurgery, plastic surgery, radio-knife, scalpel, repair, epithelization, healing time, scar.

INTRODUCTION

The last decades are characterized by a rather intensive development of surgical technologies and appropriate equipment for rapid, gentle and bloodless tissue dissection during surgical interventions, especially in plastic surgery1-4. The most widespread expansion gains electrosurgical devices, the history of which has been counting for more than a century5-7. The equipment, based on the principle of electrocoagulation, is constantly being improved, which is largely due to the intensive development of laparoscopic and endoscopic interventions, where this method is widely used and is the main for tissue dissection and hemostasis provision. However, this method is associated with thermal damage of surrounding tissues, since the skin has poor conductive properties for the electric energy flow, as a result, this energy is accumulated and converted into heat. For plastic surgery, especially the face area, such electrosurgery phenomena are highly undesirable. The results of a randomized blinded control trial showed that the use of monopolar electrosurgery in 10, 20 or 30 W cutting modes improved haemostasis and shortened the operation time for skin cutting in 15 dogs, but delayed healing and increased complications during the first 7 days in comparison with the cuts of a metal scalpel8. In addition, in the latest Cochrane review (2017) of randomized controlled trials involving 2,769 patients whoseincision, during open abdominal surgery, was performed either with a scalpel or an electron knife, it was shown that there is no clear difference in wound infections between electrosurgery and a scalpel, there is no clinically relevant the time difference in the incision, the blood loss level9. Consequently, with comparable results, the use of a scalpel remained the method of choice, which was associated with the least economic and technical costs. Inadequate bleeding control while using a scalpel, as well as a desire to reduce the postoperative scar, prompted surgeons to look for new alternative methods. One of the search areas was the use of radio waves of high frequency to create a local effect of coagulation and tissue dissection. Unlike electrosurgery, the radio knife works at the expense of an electric current flow at a much higher frequency (in the megahertz range), which minimizes the heating of tissue in the cut zone. The radio-frequency scalpel, which is a minimally invasive tool, allows cutting and coagulating tissues in the mostatraumatic manner and causes precise concentration of thermal energy in the target area10. The radio signal transmitted by the active electrode causes dehydration of the cells and, as a result, tissue dissection or their coagulation (depending on the waveform), without heating the electrode. A histological comparison of dog skin biopsies (n = 4) collected using monopolar electrosurgery, CO2 laser, radio wave radiosurgery [cut edges of biopsy specimens and adjacent peripheral skin were assessed using light microscopy to compare dermis
penetration due to tissue carbonation) showed that mixed radio waves in the mode of cut coagulation led to less lateral thermal damage to the skin than monopolar electrosurgery and a CO2 laser. This allows us to pin great hopes on this method in plastic surgery. Thus, J. Niamtu published a 30-year experience in the use of radio wave surgery (4 MHz) for the aesthetic removal of head and neck nevi and related benign lesions. The surgeon has shown that the technique of radiofrequency ablation is safe, removes nevi with minimal and often inconspicuous scars. At present, all new devices based on the use of radio waves in the megahertz range appear on the market, but they differ considerably by the specific length of the waves used. It remains unclear how these differences in the frequencies of the radiosurgical instrument affect the state of wounds and what are the features of the repair processes in the field of their application. The aim of the study was to carry out in the experiment a comparative evaluation of the quality of surgical wounds and the processes of their healing with the use of various types of radio-frequency cutting devices and a metal scalpel.

Materials And Methods
A double-blind experimental study was carried out on 21 Wistar (male) rats weighing 250-300 g (274.6 ± 19.3 g) to assess the quality of surgical wounds and their healing processes using modern radio wave devices and a conventional metal scalpel assessing their effect on the skin and soft tissues, as well as with a histological evaluation of the degree of tissue damage and the degree of their healing. The experimental procedure was carried out under general anesthesia (ketamine in a dose of 20 mg / 100 g of weight). The animal was fixed in the position on the abdomen. The back portion from the subscapular line to the lumbar region was carefully shaved and treated with a 70% solution of ethyl alcohol. In sterile conditions in the paravertebral zone at a distance of 5 mm on both sides of the spinous processes line, each animal under the uniform scheme was applied four longitudinal sections of the skin and subcutaneous tissue strictly to the fascia. The incisions had a length of 15 mm and were located parallel to the line of the spine one after another at a distance of 10 mm. The incisions were applied using a conventional metal disposable, bellied scalpel, as well as radio wave devices using different fixed wavelengths. Thus, each animal was inflicted upon four types of incisions, two incisions on each side of the spine at an equal distance, which ensured the identity of the dissected tissue. The resulting wounds were sutured with separate sutures (vicryl 4/0) on theatraumatic needle. To ensure the objectivity of research at all stages of the experiment, each type of surgical knife was coded and not known to all researchers. The incisions were numbered according to the type of surgical knife: type 1 - metal surgical scalp; type 2 - radio-knife Radiosurg 2200 "m", operating frequency 2.2 MHz (Meyer-Haake GmbH, Germany); type 3 - Fotek E80, operating frequency 2.64 MHz (Fotek, Russia); type 4 - Surgitron EMC, operating frequency 3.8 MHz (Ellman International, Inc., USA). After 1, 3 and 7 days, seven animals were taken from the experiment at each point of study. Sections of skin and subcutaneous tissue with wounds were excised by a 2 × 3 cm block and placed in a 5% formalin solution for subsequent histological examination. On the serial paraffin sections, stained using the usual method of hematoxylin and eosin, the dynamics of histological changes was evaluated according to the following criteria: 1. the presence and nature of the clot; 2. the presence and nature of hemorrhages; 3. severity of damage in the form of tissue necrosis and its depth; 4. severity and type of cellular infiltration; 5. neoangiogenesis in different wound areas; 6. completeness, severity and nature of reparative processes (granulation, epithelialization). All changes were assessed on a point system from 0 to 3 points for each feature of the drug (0 - absence of sign, 1 - mild severity, 2 - medium grade, 3 - pronounced changes). After the statistical processing of the parameters, the types of cuts were decoded.

Results
The first phase of the wound process, evaluated in the operating wound after 1 day, was characterized by the formation of a blood clot that performed a tissue defect with necrosis of adjacent tissues, vascular fullness up to the development of hemorrhages and leukocyte infiltration. When using a surgical scalpel, as well as radio knives 2.2 MHz and 2.64 MHz, these changes did not differ (p > 0.05). A radio knife with a frequency of 3.8 MHz caused significantly less pronounced changes (p < 0.05): the edges of the wounds were practically closed, the clot was small and the range of scores varied from 1 to 2, vasoremia, a narrow zone of injury, cases of signs of necrosis were absent, in other specimens the severity of necrosis was minimal. In all fourspecimens, single leukocytes in injured tissues have been recorded (Table 1, Fig.1), which indicates a reduction in the phase of exudation of postoperative wounds when using the radio knife with the highest operating frequency.
Table 1: Assessment Of The Nature And Speed Of Cutaneous Wounds Healing On The 1st Day Of The Experiment Using Different Types Of Radio-Frequency Cutting Devices And A Metal Scalpel.

<table>
<thead>
<tr>
<th>№ type of the knife</th>
<th>Clot</th>
<th>Necrosis</th>
<th>Effusion of blood</th>
<th>Leukocyte infiltration</th>
<th>Neoangiogenesis</th>
<th>Incarnation</th>
<th>Cuticularization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 type – scalpel</td>
<td>2,14±0,49 [1-3]</td>
<td>1,14±0,24 [1-2]</td>
<td>0,43±0,4 1</td>
<td>1,29±0,4 9 [0-1]</td>
<td>0,14±0,24 [0-1]</td>
<td>0,0</td>
<td>0</td>
</tr>
<tr>
<td>Score: 0</td>
<td>0; 29%</td>
<td>86% 14%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>29% 43%</td>
<td>29% 43%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2,14±0,49 [1-3]</td>
<td>2,14±0,49 [1-3]</td>
<td>1,57±0,4 9 [1-2]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MHz, Score: 0</td>
<td>0 29% 43%</td>
<td>0 29% 43%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2,29±0,61 [1-3]</td>
<td>2,29±0,61 [1-3]</td>
<td>2,43±0,4 9 [2-3]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MHz, Score: 0</td>
<td>0 14% 43%</td>
<td>0 14% 43%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1,43±0,49 [1-2]</td>
<td>0,71±0,41 [0-1]</td>
<td>1,0±0* [1]</td>
<td>0,14±0,24 [0-1]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MHz, Score: 0</td>
<td>0 57% 43%</td>
<td>0 29% 71%</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The data are presented as the mean value [the top line], the interquartile range is the deviation of the expression of the characteristic (the second line in the brackets) and the percentage of each attribute score (the third line is 0-1 points and the fourth line is 2-3 points).

* p <0,05 - the reliability of the difference in the indicator of the 4 types of the cut as compared to the other types studied.

Fig. 1: Microscopy Of Histological Sections In The First Day After The Operation (Staining With Haemotoxelin-Eosin) Of 4 Types Of Wounds In The Same Animal.
Stupin et al / Wound Healing By The Use Of Scalpel And Various Radio-Frequency Cutting Devices

On the third day after the operation, the wounds inflicted by the surgical scalpel, the radio knives of 2.2 MHz and 2.64 MHz retained the signs of inflammation, most pronounced when using radio knives. At the same time in some specimens, the appearance of reparative processes is registered. Thus, when the wound was applied with a scalpel, the severity of necrosis and leukocyte infiltration increased insignificantly compared with the 1 day, but the clot level decreased insignificantly, the hemorrhages with activation of the processes of neoangiogenesis and the appearance of granulation epithelization in 14% and 29%, respectively, were eliminated. When the wounds of type 2 and type 3 were applied, the signs of clot, necrosis and leukocyte infiltration increased in comparison with the studies performed on the 1st day after the operation, along with the appearance of mild reparative processes in the form of neoangiogenesis in 14% and 71%; processes of epithelization in 14%. It is important to note that there were no statistically significant differences on the 3rd day with the use of 1, 2 and 3 types of knives (p > 0.05). In animals with cuts of radio-frequency type 4 (3.8 MHz), the wounds were characterized by signs of cleansing from a blood clot and necrotic masses. In 29% of animals, the appearance of a scab is registered - a crust covering the surface of the wound, formed by inflammation products, which protects the wound from the exofactors and disappears as the wound epithelium. There were signs of wound repair in the form of granulations with epithelialization of tissues and restoration of the dermis with neoangiogenesis in 100% of cases, the severity of the repair processes was more significant than in the 1, 2, 3 types of wounds (p<0.05) (Table 2; Fig.2).

Table 2: Assessment Of The Nature And Speed Of Healing Of Cutaneous Wounds On The 3rd Day Of The Experiment Using Different Types Of Radio Frequency Cutting Devices And Surgical Scalpel.
The data are presented as the mean value (the top line), the interquartile range is the deviation of the expression of the characteristic (the second line in the brackets) and the percentage of each attribute score (the third line is 0-1 points and the fourth line is 2-3 points).

* p <0.05 - the reliability of the difference in the indicator of the 4 types of the cut as compared to the other types studied.

Note: 2a - a section of type 2 (signs of inflammation with the presence of leukocyte infiltration and a blood clot); 2b - a section of type 3 (signs of inflammation with the presence of leukocyte infiltration and a blood clot); 2c - incision of type 4 (recovery of epithelial tissue under the scab occurred more rapidly); 1d - section type 4 (complete repair).

On the 7th day, signs of tissue repair in the form of neoangiogenesis, epithelialization, and collagen scar formation in wounds prevailed. The flat epithelium creeps on the wound from its edges, a coagulant scab is placed on top of it, in the derma, a scar with a small number of cellular elements and vessels is formed at the site of the former lesion. However, in a part of animals with wounds inflicted with knives of types 1, 2 and 3, incomplete reparation of cutaneous surgical wounds and signs of inflammation in individual individuals persisted. The indices of healing of a wound inflicted with a knife of type 2 were not significantly better than those of types 1 and 3. When applying 3.8 MHz (type 4 knife) to 7 days, the wound healed with complete repair of a section of type 4 (complete repair).

<table>
<thead>
<tr>
<th>Type of the knife</th>
<th>Clot</th>
<th>Necrosis</th>
<th>Effusion of blood</th>
<th>Leukocyte infiltration</th>
<th>Neoangiogenesis</th>
<th>Incarnations</th>
<th>Cuticularization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 type - scalpel</td>
<td>86%</td>
<td>0.14±0.24</td>
<td>0.86±0.24</td>
<td>1.86±0.24</td>
<td>2±0</td>
<td>2±0</td>
<td>1.86±0.24</td>
</tr>
<tr>
<td>2 type</td>
<td>Crust</td>
<td>0.14±0.24</td>
<td>0.86±0.49</td>
<td>2±0</td>
<td>2±0</td>
<td>2±0</td>
<td>2.29±0.24</td>
</tr>
</tbody>
</table>

*Fig. 2: Microscopy Of Histological Sections On The 3rd Day After The Operation (Staining With Haemotoxel-Eosin).*

Table 3. Assessment of the nature and speed of skin wounds healing on the 7th day of the experiment using different types of radio frequency cutting devices and surgical scalpels.
Wound Healing By The Use Of Scalpel And Various Radio-Frequency Cutting Devices

<table>
<thead>
<tr>
<th>Type</th>
<th>Crust (%)</th>
<th>0-1 [0-1]</th>
<th>0-2 [0-2]</th>
<th>[2] 1±0* [1]</th>
<th>[2]; Mature 92%</th>
<th>[2-3] 3±0* [3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 type</td>
<td>2,2 MHz,</td>
<td>100%</td>
<td>0,29±0,41</td>
<td>2,29±0,24</td>
<td>1,86±0,24</td>
<td>2±0</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>[0-1]</td>
<td>[0-1]</td>
<td>[2-3]</td>
<td>[1-2]</td>
<td>[2]</td>
</tr>
<tr>
<td>4 type</td>
<td>3,8 MHz,</td>
<td>Crust 86%</td>
<td>0</td>
<td>1±0*</td>
<td>1±0*</td>
<td>3±0*</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>[0-1]</td>
<td>0</td>
<td>[1]</td>
<td>[1]</td>
<td>[3]</td>
</tr>
</tbody>
</table>

The data are presented as the mean value (the top line), the interquartile range is the deviation of the expression of the characteristic (the second line in the brackets).

* p <0,05 - the reliability of the difference in the indicator of the 4 types of the cut as compared to the other types studied.

Fig. 3: Microscopy Of Histological Sections On The 7th Day After The Operation (Staining With Haemotoxelin-Eosin).

Note: 3A - incision of type 1 (incomplete repair); 3B - incision of type 2 (incomplete repair); 3C - incision of type 3 (incomplete repair); 1D - section type 4 (complete repair).

When analyzing the depth of tissue necrosis in the wound at the 1st, 3rd and 7th day of the experiment, it was revealed that the depth of necrosis in the wound differed clinically and morphologically when different cutting devices were used. The roughest depth was when using a surgical scalpel (Fig.4).

Fig. 4: Depth Of Necrosis In The Wound (In Mm) At The 1st, 3rd, And 7th Day Of The Experiment In Animals With Different Types Of Wounds (Medians).
Unlike a mechanical scalpel, when using the radiosurgical method, the incision is done without pressure or other manual influence on the tissue and is not accompanied by mechanical destruction of the cells and necrosis of the surrounding layers. Mechanical and thermal injury of tissues when applying radiosurgical instruments is minimal. At the same time, the smallest depth of necrosis was recorded in applying the device with the highest operating frequency of 3.8 MHz at all studied points (p < 0.05) and by the 7th day of the experiment the wound applied by this type of knife was epithelialized. In animals with wounds inflicted by 2 and 3 types of radio knives, the depth difference of necrosis in the wound for the 1-3 days was statistically unreliable (p > 0.05), complete epithelization of the wound by the 7th day in all animals did not occur. This may be due to the varying operating frequency of the instruments used. The maximum tissue damage and maximum depth of necrosis occur when using the lowest operating frequencies of radiosurgical knives of type 2 and type 3 (2.2 MHz and 2.64 MHz), most clearly in the first three days of the study at the level of the epidermis and dermis, when the depth of tissue necrosis was 70-80 m, there was no significant difference in these instruments with respect to the degree of necrosis depth (p > 0.05). At the same time, using the type 4 device (3.8 MHz), the depth of necrosis was minimal and on the 1st day averaged 35 m, on the 3rd day it was 18 m and completely regressed to the 7th day.

**Discussion**

Less pronounced tissue damage is certainly a favorable factor, as the healing time and the size of the postoperative scar directly correlate with the size of the wound and tissue trauma (in our study all simulated wounds were of the same size). The absence of a blood clot in the wound potentially prevents secondary infection, and the earliest appearance of a scab contributes to a faster regeneration. The results of the study showed that wounds inflicted at a frequency of 3.8 MHz had a shorter healing time. In addition, more active and advanced wounds inflicted by other types of radio-knives and a metal scalpel, processes of neoangiogenesis, and growth of granulation tissue (already by the 3rd day) were recorded in these wounds. The processes of formation of a large number of vessels along the edges of the wound after radiosurgical action were associated with epithelialization processes. The high frequency of marginal necrosis after the use of a surgical scalpel is probably due to additional manipulation to stop bleeding. Due to the formation of a large number of vessels along the edges of the wound after the radiosurgical action, optimal conditions for its epithelization are created, which also shortens the time of its healing. The healing mechanisms also differed in all 4 types of knives. In the wounds inflicted by a surgical scalpel and radio knives with a working frequency of 2.2 MHz and 2.64 MHz, healing was accompanied by the formation of a scar by substitution (incomplete repair) in areas of marginal necrosis, then in wounds inflicted by a radio knife at a working frequency of 3.8 MHz - by restitution (complete reparation) almost without scar formation.

**Conclusion**

Experimental studies showed that animals with wounds inflicted by a radio knife deposited with the greatest frequency of 3.8 MHz had statistically significant differences both in timing and in the mechanisms of wound healing, demonstrating the advantages of this device to a surgical scalpel and other radio knives with lower operating frequency. These advantages are expressed in fewer damaged tissue adjacent to the edges of the wound defect, less pronounced inflammatory vascular reaction, at a depth of damage (absence of a blood clot in a wound after cutting, minimum marginal necrosis operative wound and the surrounding tissues, lack of leukocyte infiltration in the wound, and consequently, reduced risk of inflammation, early (from 3 days) repair and epithelialization of tissues). All this contributed to a reduction in the timing of wound healing and the absence of scar formation.

**References**


Skin Incisions Made with Monopolar Electrosurgery versus Scalpel Blade. *Veterinary Surgery, 44*(6), E67.


