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RAPID COMMUNICATION

Experimental and clinical study of influence of high-frequency electric surgical knives on healing of abdominal incision

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Abstract

AIM: To study the influence of high-frequency electric surgical knives on healing of abdominal incision.

METHODS: Two hundred and forty white rats were divided into 10^0, 10^2, 10^5, and 10^8 groups and rat models of abdominal operation were induced by using electric surgical knives and common lancets respectively. Then they were respectively given hypodermic injections of normal saline and 0.2 mL quantitative mixture of *Escherichia coli*, *Staphylococcus aureus* and *Pseudomonas aeruginosa* at a concentration of 10^2, 10^5 and 10^8. On the basis of the animal experiment, 220 patients undergoing abdominal operations (above type Ⅱ) were randomly allocated into one of following three groups: electric knife (EK, 93 cases), electro-coagulation (EC, 55 cases) and control (72 cases). High-frequency electric surgical knives were used to dissect abdominal tissues and electro-coagulation for hemostasis in EK group. Common lancets and electro-coagulation were applied in EC group. Common lancets and tieing silk suture were used in the controls.

RESULTS: In all the groups except group 10^0, infection rate of incisional wounds made by electric surgical knives were remarkably higher than that with common lancets. Furthermore, there were significant differences in groups 10^2, 10^5, and 10^8 ($P < 0.05$), but not in group 10^0 ($P > 0.05$) between EK and EC groups. Clinical studies showed a delayed wound healing in 16 cases (17.20%) in EK, 11 cases (16.36%) in EC and 2 cases (2.86%) in the control groups. A significant difference between EK and the control groups ($\chi^2 = 8.57$, $P < 0.01$), and between EC and the control groups ($\chi^2 = 5.66$, $P < 0.05$) was observed, but not between EK and EC ($\chi^2 = 0.017$, $P > 0.05$).

CONCLUSION: High-frequency electric knives may remarkably delay abdominal incision healing. Its application should be minimized so as to reduce the possibility of postoperative complications.

Key words: High-frequency electric surgical knives; Abdominal incision; Healing; Infection

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INTRODUCTION

The high-frequency electric surgical knife is one of the common instruments in surgical operations. It has many advantages such as easy operation and good hemostatic effect, *etc*. In our clinical practice we found, however, the poor healing rates as well as high infection rate of incision made by electric knife (EK) were remarkably increasing. In order to approach the influence of high-frequency electric surgical knives on healing of the abdominal incisions, we carried out animal experiments with white rats from May to Dec 1999, and also conducted clinical trials on 220 patients undergoing abdominal operations (above level II) from Dec 1999 to Sept 2001. Our study shows that high-frequency electric knives may remarkably delay abdominal incision healing.

MATERIALS AND METHODS

Animal grouping

Experimental animals of Wistar white rats, weighing 150-180 g, were divided into experimental group (EG) and control group (CG) at random, 30 each. Every group was subdivided into 10^2, 10^5, 10^8 groups according to the number of vaccinated bacteria, and 10^0 group using normal saline instead of vaccinated bacteria.

Preparation of bacteria solution

Standard strain sources: Based on WHO recommendation, frozen, dry and pure *Escherichia coli* ATCC (25 922), *Staphylococcus aureus* ATCC (25 923) and *Pseudomonas aeruginosa* ATCC (27 853) were supplied by the Clinical Trial Center of Ministry of Health.

Bacteria suspension solution preparation: The standard strains were vaccinated into plating culture of goat's blood, cultured at 35℃ for 24 h to obtain the bacteria suspension solution with a concentration of 0.5 U (equal to 10^8 cfu/mL), then the bacteria solutions were made into 10^5 cfu/mL and 10^2 cfu/mL bacteria suspension solution for stock use.

Quantitative culture of bacteria suspension solutions: Ten microliters of the 10^2 cfu/mL bacteria solution were subjected to culture by pour plate method. The results showed that *Escherichia coli* was 130 cfu/mL, *Staphylococcus aureus* was 125 cfu/mL, and *Pseudomonas aeruginosa* was 110 cfu/mL. The 3 kinds of standard bacteria strain suspension solutions were mixed at equal amount, the colonies were counted, and its bacteria content was 12.67 cfu/mL. Thus bacteria content of 10^2 group was 24.33 cfu/0.2 mL (actual bacteria content was about 0.24×10^2).

One microliter of 10^5 cfu/mL bacteria solution was taken for pour culture. The results showed that *Escherichia coli* was 14 500 cfu/mL, *Staphylococcus aureus* was 115 000 cfu/mL, and *Pseudomonas aeruginosa* was 95 000 cfu/mL. The 3 kinds of standard bacteria strains were mixed at equal quantity, and the bacteria content was 224 500 cfu/mL. Therefore, bacteria content of 10^5 group was 44 900 cfu/0.2 mL (actual bacteria content was about 4.49×10^4).

The 10^8 cfu/mL bacteria solution was diluted to 1/50 of its concentration, and 1 μL of it was taken for pour culture, the colonies were counted after 24 hours. The results showed that *Escherichia coli* was 130 000 000 cfu/mL, *Staphylococcus aureus* 125 000 000 cfu/mL, and *Pseudomonas aeruginosa* 115 000 000 cfu/mL. The 3 kinds of standard bacteria strains were mixed at equal quantity, and the bacteria content was 123 333 333 cfu/mL. Therefore, bacteria content of 10^8 group was 41 111 111 cfu/0.2 mL (actual bacteria content was about 4.11×10^7).

Experimental procedures

After the animals were anesthetized by ether, the experimental groups were operated with EK through midline incision of abdomen, while the control group with common surgical knives. The No 4 silk thread was used to suture peritoneum. According to the group division, 0.2 mL of the mixed bacteria solution was injected subcutaneously. The skin was sutured, and animals were marked and raised in different cages.

Observational parameters

Criteria for incisional healing: According to Surgery[1]: The healing is classified as A: first-grade healing, B: second-grade healing, and C: third-grade healing.

Table 1 Comparison of operative incision of 3 groups

Group	*n*	Type Ⅰ incision *n* (%)	Type Ⅱ incision *n* (%)	Type Ⅲ incision *n* (%)
EK	93	6 (6.45)	83 (89.23)	4 (4.30)
EC	55	3 (5.45)	50 (90.91)	2 (3.64)
Control	72	5 (6.94)	63 (87.50)	4 (5.56)

Grading of incisional infection: Non-infection (Grade Ⅰ): presence of some granulation tissues in the section. Slight infection (Grade Ⅱ): presence of a few neutrophil diffuse infiltration, the inflammatory area is smaller than 10% of the section. Moderate infection (Grade Ⅲ): presence of much neutrophil infiltration, the inflammatory area is between 10% to 30% of the section. Severe infection (Grade Ⅳ): presence of severe neutrophil infiltration, the inflammatory area is larger than 30%.

Criterion for grease liquefaction: All those that have bad incision healings and meet the following descriptions could be diagnosed as grease liquefaction: (a) Incision has serum-like solution on the surface of incision. (b) Fat drops are observed with naked eyes or microscopy. (c) No purulent secretion is found. (d) Redness and swelling around the incision. (e) No growth in bacteria cultural medium.

Clinical studies

Patient grouping: A total of 220 patients were randomly divided into EK group, EC (electric coagulation) group, and common surgical knives group (control group). EK group consisted of 93 cases, including 57 males, 36 females, with age ranging from 21 to 80 (average 53.70) years. Fifty-seven underwent biliary system operation, 17 colorectal operation, 8 gastric operation, 5 portal hypertension cutout operation, 3 pancreatic operation, 3 respectively splenectomy, resection of small intestine and intestinal tuberculosis operation. EC group consisted of 55 cases, including 30 males, 25 females, with age ranging from 28 to 67 (average 51.54) years. The patients underwent biliary system operation (including one case for subtotal gastrectomy) (30 cases), gastric operation(11 cases), colorectal operation (4 cases), appendicitis exploratory laparotomy (3 cases), small intestine operation and portal hypertension cutout operation (2 cases each), enterolysis, pancreatic operation and liver operation (1 case each). Control group consisted of 72 cases (38 males, 34 females), with age ranging from 22 to 78 (average 55.09) years. Patients underwent biliary system operation (40 cases), gastric operation (10 cases), colorectal operation (7 cases), small intestine operation (5 cases), portal hypertension cutout operation and appendicitis exploratory laparotomy (3 cases each), abdominal mass operation (2 cases), hepatorrhexis with hepatorrhaphy and splenectomy (1 case each).

There were no remarkable differences in sex, age, and types of operative incision among all 3 groups. Table 1 shows the comparison of types of operative incision.

Surgical operation methods: The ways of preoperative preparation and operative disinfection and dressing in the 3 groups were the same. Operative incisions were mostly transrectus incisions, with a few other incisions. EK group

Table 2 Infection of incisional sites for the experimental animals

Group	*n*	EG's incision healing			Infection	*n*	CG's incision healing			Infection
		A	B	C	rate (%)		A	B	C	rate (%)
10^0	30	23	2	5	23.33	30	28	0	2	6.60
10^2	27	17	3	7	37.04	30	26	1	3	13.33
10^5	30	15	5	10	50.00	29	22	3	4	24.14
10^8	30	11	4	15	63.33	30	19	2	9	36.67

Table 3 Pathological examination results of experimental animals

Group	*n*	EG				Infection	*n*	CG				Infection
		I	II	III	IV	rate(%)		I	II	III	IV	rate(%)
10^0	30	14	4	9	3	23.33	30	16	7	4	3	6.60
10^2	27	5	5	10	7	37.04	30	13	5	5	7	13.33
10^5	30	6	7	6	11	80.00	29	13	3	6	7	55.17
10^8	30	5	5	8	12	83.33	30	13	3	5	9	56.67

used EK to resect tissues, and EC for hemostasis. EC group used common surgical knives to dissect tissues, and EC for hemostasis. Control group used common surgical knives, and silk thread suturing for hemostasis. Antibiotics were routinely used, and dressings were changed to observe the healing state of the incisions on the 3rd and 7th d after operation.

Instruments

EK group and EC group used GD350-D high-frequency electric surgical knives, made by Shanghai Hutong Electric Instrument Factory. Power of electric current was set at 40 W. Control group used common surgical knives.

Statistical analysis

Statistical analysis used chi-square test (χ^2). P < 0.05 was taken as significant.

RESULTS

Results of the animal experiments

Four white rats died of anesthesia accidents. The other 236 rats were put to death by cut-cord operation. On the 8th post-operative day, infection of incision sites was recorded, and then the 1 cm tissues around the original incision site were fusiformly excised for pathological examinations.

The comparison of incisional sites infection due to different density bacteria between the EG and CG are shown in Table 2.

Statistically significant differences in 10^2, 10^5, and 10^8 groups (χ^2 = 4.31, 4.22, 4.27, respectively P < 0.05), but not in Group 10^0 (χ^2 = 3.28, P > 0.05) were observed.

The comparison of pathological infection of incision due to different density bacteria is shown in Table 3.

Statistically significant differences in groups 10^2, 10^5 and 10^8 (χ^2 = 4.05, 4.23, 5.08, respectively P < 0.05), but not in group 10^0 (χ^2 = 0.27, P > 0.05) were observed.

All the above results showed there were differences in the infection rate based on either experimental observation or pathological examinations. However, both of them indicated that the bacterial contamination would increase the operative infection rate of EK, while the aseptic operation showed no significant difference .

Clinical study results

Second grade or 3rd grade healing (cacoethic healing) accounted for 16 cases (17.20%) in EK; 11 cases (16.36%) in EC, and 2 cases (2.86%) in the control. A significant difference between EK and the control was observed (χ^2 = 8.57, P < 0.05). Furthermore, significant differences were found between EC and the control (χ^2 = 5.66, P < 0.05), but not between EK and EC groups (χ^2= 0.017, P > 0.05).

DISCUSSION

Common reasons for postoperative incisional site infection in laparotomy

Postoperative incisional site infection is a common complication in laparotomy. There are various reasons for infections, for example, without tight hemostasis on operative incisions, incisional contamination, and less strict aseptic operation. In spite of use of large doses of broad-spectrum antibiotics, this problem still has not been satisfactorily solved.

In 1917s, a French doctor Doyen invented EK[2]. Since then, surgeons have been in favor of wide use of EK, merely because EK can make hemostasis quick and satisfactory, save the operative time and decrease bleeding during operation. In recent years, EK is more and more widely used in surgical operations. Because of unlimited and incorrect use of it, the injury of tissues is worsened and postoperative complications are increasing. Our experiment also testified this. In addition to incision site infection, there are also some grease liquefaction[3] and abdominal incision deliscence, which are called delayed incision healing.

Early in the 1970s, *Link et al*[2] proposed that EK could delay incision healing. The histological reports showed that the injury of electrocauterized tissue was worsened and the incisional site infection rate was increased. Studies by Soballe[4] and Kumagai[5] also indicated that EK could decrease the threshold of the infection in abdominal incisions.

Our animal experiments demonstrated that in each subgroup, the infection rate of incisional wounds made with EK was remarkably higher than that in the control group. There were significant differences in groups 10^2, 10^5 and 10^8 (χ^2 = 4.31, 4.22, 4.27, respectively P < 0.05), except for group 10^0 (χ^2 = 3.28, P > 0.05). Since experimental pathological examination results were the same was experimental observational results, it indicated that EK could increase the infection rate of non-sterilized incisions, but not increase the infection rate of aseptic incisions.

Although clinical data were controversial on this issue, our current study demonstrated that there was a significant difference between EK and the control (χ^2= 8.57, P < 0.01). In addition, significant differences were observed between EC and the control (χ^2 = 5.66, P < 0.05), but not between EK and EC (χ^2 = 0.017, P > 0.05). It was proved that EK may delay abdominal incision healing, while EC may not. Therefore, we suggest avoiding use of EK, and recommend use of common surgical knives when opening abdomen, and tieing or EC for hemostasis.

Reasons for increased rate of incision cacoethic healing by EK

Local hyperthermy: When the temperature is higher than 45℃ to 50℃, it can cause tissues and cells to denature; when the temperature is higher than 60℃, it can cause tissue necrosis. As the local temperature caused by EK can reach 200℃ to 1000℃, if tissue is burnt under a big power again and again, a large number of histiocytes can be destroyed, which can cause incision wound hydrops and cacoethic healing.

Local tissue ischemia: When EK is being used, electric current and thermal energy are dispersed radiatively along the incisive margin, thereby causing denaturation and vascular occlusion in tissues on both sides of the incisive margins, and also the disturbances of local blood supply, thus affecting incisional healing. How *et al*[2] have proved that tissues without blood vessels are more likely to be infected than those that have blood vessels.

Condition favorable for bacteria growth: The high temperature of EK can destroy the histiocytes, and lipocytes are more sensitive to thermal energy. A great amount of lipocytes destruction which can cause grease efflux, and coagulational tissues are good culture media for bacteria. Bacterial infection can cause incisional infection. That is why EK may increase the infection rate of non-sterilized incisions while has little effect on aseptic incisions.

Local hyperosmotic state: When the lipocytes are destroyed, micromolecular material makes the incisions in the hyperosmotic state, which accelerates subcutaneous hydrops, leading to incisions cacoethic healing.

Suggestions on application of EK

In our view, we should strictly follow the indications for use of EK. For complicated operations or operations of serious patients, such as reoperated patients, malignant tumor, in order to avoid excessive blood loss of patients, save operative time, we should limitedly use EK. In another word, when opening abdomen, EC should be preferable to electrotomy and the electric current should be under control while using EC for hemostasis. When using electrotomy and EC in abdominal cavity operation, we also should control electric current to decrease tissue destruction, and the incision cacoethic healing rate. However, Kuzon[6] failed to find any significant difference in the rate of the incisional complication between the high electric current volume and low electric current volume. Another point to be mentioned is, use of gauze before the operation is finished also has some positive effect on preventing incision liquefaction by getting rid of lipid and adipose tissues.

There are various causes for the infection of abdominal incision. Therefore, we should strictly follow the aseptic operating principle in the operation, protect incisions, avoid bacteria contamination, and make tight suturing for hemostasis. Meanwhile, prophylactic use of antibiotics in preoperative and postoperative periods is an effective way to decrease the infection rate of incisions.

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