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TISSUE STRUCTURAL PHASES OF GUT ANASTOMOSIS FORMATION BY RADIOFREQUENT ELECTRIC WELDING SUPPLY

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Abstract

Introduction. The preferences of radiofrequency-based tissue fusion of intestinal anastomosis are based on its uncompleted healing and vital restructuration during the welding variant. But the radiofrequency fusion process monitoring still is sophisticated, so further researches are mandatory to create new settings.

Aim. To study the phases of tissue changes that occurs in gut wall tissue during the welding anastomosis creating, as its estimating criteria.

Material and methods. The same voltage, form and duration of the welding impulses' tissue effects, based on radio frequency 440 kHz were studied. The swine organ complex was delivered to laboratory during 6 hours at 4 ºC, and then was heated to 28-32 ºC into 0.9% NaCl. Two intestine walls having human sizes were positioned on electrodes inside the anastomotic device prototype. 120 experiments were provided using pressure values 2.1, 3.0, 3.9 and 5.0 N/mm^2 for tissues thinning. After completion of the welding supply, anastomosed tissues were taken for morphological studies.

Results. We established the 4 common phases of welding-provided tissue restructuration inside gut organ walls, starts from oedema and widening of connective tissue septums with slight collagen fibres denaturation, throw loosing of layers integrity with attaining wave-like periodical deformation, next to the start of two organ walls merging in local points into fissured tissue substrate, and the merging process spreads along the whole

organ walls finally. Simultaneously, the formed tissues common substrate becomes solid structure, homogeneous density and coagulation depth.

Conclusions. The structural phases of gut organs' tissues welding merging into homogeneous anastomosis substrate are: i) initial mucous epithelium destruction; ii) tissues loosening, partial fragmentation and orientation; iii) sealing of collagen fibres to smooth muscle cells; iv) derivation of walls merging points; v) forming continuous solid but structured tissue substrate, is dense and armoured by multi-point collagen fibres to smooth muscle cells sealing.

Discussion. As for similarity of welding-provided restructuration phases, inside investigated gut organs, having so different walls, the welding anastomotic process could be uniform for surgical needs.

Key words: intestine, electric welding, anastomosis tissue structure, pig, muscle cell, collagen fibres, sealing, impulses, experiment, stomach, current.

Introduction. The preferences of radiofrequency-based tissue fusion of intestinal anastomosis are based on its uncompleted healing [1, 2] on the ground of vital restructuration during the welding variant [3]. But the radiofrequency fusion process monitoring, based on thermal measuring as common, is increasingly sophisticated, multimodal, and consists the real time tracking of a multitude of parameters [4]. Beside this, no significant difference was found between burst pressure of fused and staplered anastomoses, so further researches are mandatory to create new settings [5].

Aim. To study the phases of tissue changes that occurs in gut wall tissue during the welding anastomosis creating, as its estimating criteria.

Materials and methods

This research was carried out at the laboratory of Welding and Related Technologies for Medicine and Environment Department of the E.O. Paton Electric Welding Institute. The effect of welding impulses supply upon tissue was investigated. The same voltage, form and duration of the welding impulses, based on radio frequency 440 kHz were studied. The clinical welding device EKWZ-300 "Patonmed" was used as the impulses source. The electric parameters were fixed using the analogue-digital converter LCard E20-10, the PC monitoring program and the oscilloscope Tektronix TDS 3014C.

The biologic tissues material used for study was the swine intestinal complex. It was taken from agricultural animal, 5 months old pig of "Ukrainian Big White" breed**,** intestine of which has human-sized diameter and thickness of the gut organ's walls, so could be an

appropriate bioimitator for human organ. For present investigation, the intestine and stomach were used.

The organ complex was taken at farm immediately after pig slaughter, which was planned with non-experimental reasons, and was carried out in compliance with the Ukrainian Law requirements on animals protection against cruel action, the latter have been harmonized with the relevant requirements of EU legislation.

The bioimitator was cooled to +4 ^{o}C, and then delivered to the laboratory within 6 hours. Then, in the laboratory, it was prepared for experiment, by immersing in a warm (28-32^{o}C) solution of 0.9% NaCl for 10-20 minutes, until the tissues temperature equalized with that of the solution. The temperature of the organ surface and solution was controlled by the infrared contactless device GM 300 (Benetech).

The prepared bioimitator was placed between the circular electrodes, which were the element of electric welding anastomosis device's model. It was produced at the Electric Welding Institute as clinical prototype as well as the element of the experimental electric welding bench.

The intestinal or stomach walls were oriented to each of the two electrodes by their mucosal surface inward, copying typical location in the surgical stapler, and then fixed to centre axis of the instrument.

In total, 120 experiments were conducted. We put to the electrodes previously calibrated mechanical load. Its value has been calibrated in accordance with certain pressure value between the electrodes: from 1.1 to 6.0 N/mm^2 (1.1-6.0 × 10^6 N/m^2). The pressing effect was applied during 60 or 120 seconds. The optimal pressure ranges were established in our previous study. When the pressure preparing finished, the electric welding impulses were initiated.

After completion of the welding impulses sequence, welded organ' tissue samples were taken for morphological studies. The paraffin fixing, hematoxylin and eosin colouring were used.

Results. We established the 4 common phases of welding-provided tissue restructuration inside gut organ walls, beside its thickness and organ type.

The first tissue structural changes after the initial welding impulse includes: partial damage of mucosa epithelium, oedema and widening of connective tissue septums and membranes in muscular layer (Fig. 1), and slight collagen fibres denaturation, mostly in the subserosal layer.

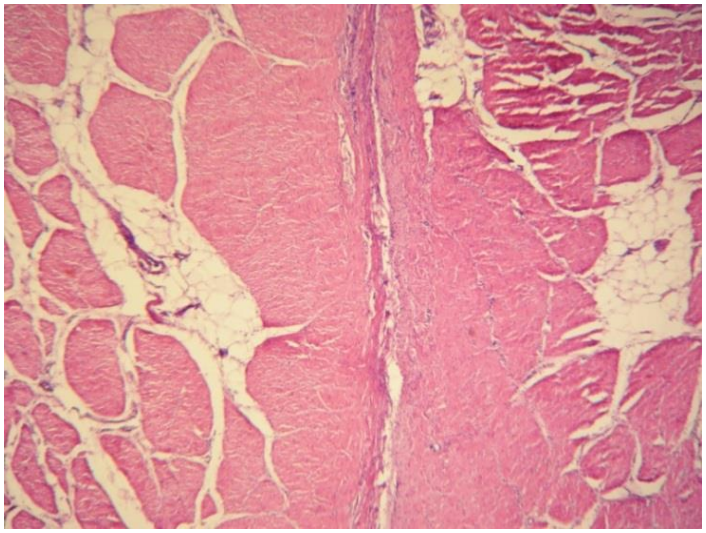

Fig. 1 The slight denaturation of subserosal collagen fibres, oedema and widening of connective tissue membranes of the muscular layer. Hematoxylin and eosin. X 100

Despite the appearance of electric coagulation damage signs in several smooth muscle cells' and fibroblasts' cytoplasm, the contours of the cell's and their layer membranes, as well as their cores, staying complete.

During the second phase, we achieved the effect by the 2-3 impulses action, resulting in changes of the over layers form. Impulses caused the destruction of mucous layer integrity. Subsequently, all collagen fibres and smooth muscle cells presented slight coagulation changes at the welding zone. The muscle layer attained wave-like periodical deformation along the strings, which is oriented transversely to the electrodes plane. It leads to fissuring inside the layer, and to disruption of several single smooth muscle cells contours (Fig. 2).

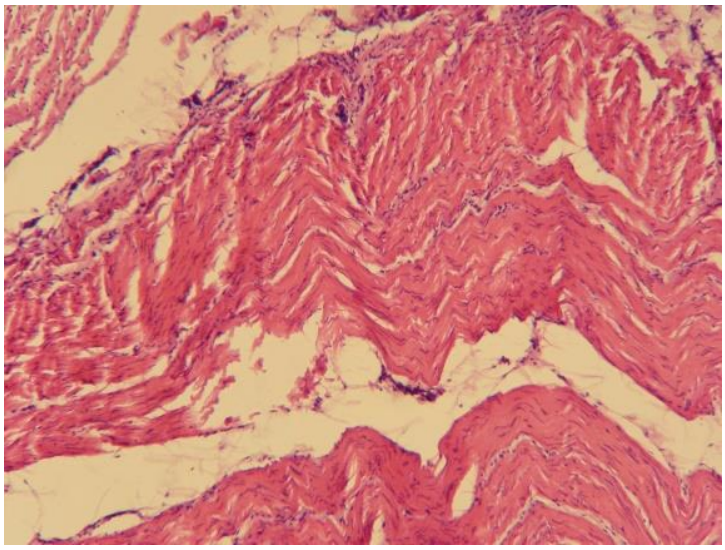

Fig. 2. Periodical orientation of the muscle wires fibres, destruction of the smooth muscle cells contours in several points. Hematoxylin and eosin. X 100

The third restructuration phase achieved by 10-12 voltage impulses supply, mean the start of two organ walls merging in local points into continuous tissue substrate, having a number of small fissures. Merging proceeds by sealing of coagulated smooth muscles strings and collagen fibres bands. At the remainder of welding line, up to this moment, collagen fibres and smooth muscles raised coagulation changes and squeezing into the thin dense linear structure, included preserved contours of the nuclei (Fig. 3).

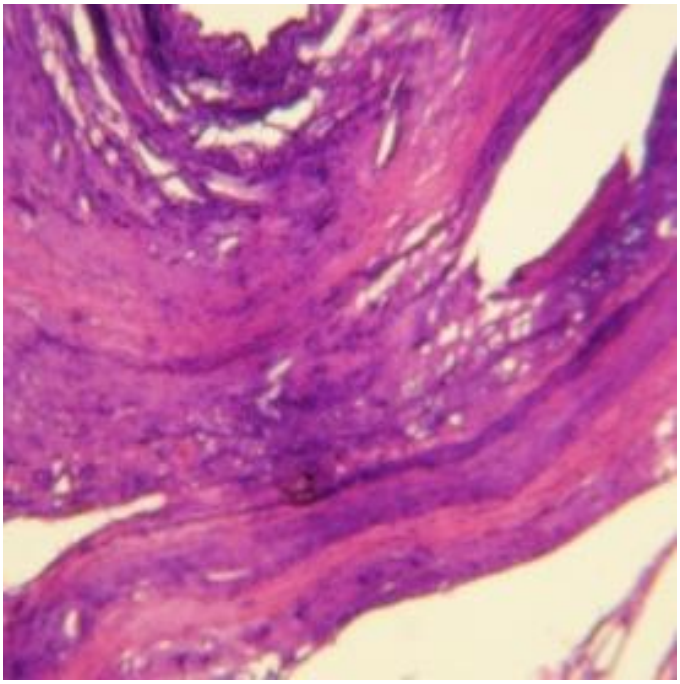

Fig. 3. Initial local merging of dense organ walls, including coagulated collagen fibres and smooth muscles, preserving contours of nuclei. Hematoxylin and eosin. X 100

Upon the welding continuation, the merging process spreads along the organ walls that were in contact. Simultaneously, the formed tissues common substrate becomes solid structure.

As a result of sufficient welding impact, consisting of 35-40 impulse's portion supply, the organ walls have achieved connected merges, for the whole electrodes' lengths. The formed welded tissue substrate was solid, had homogeneous density and coagulation depth, and several small fissures (Fig. 4). The preserved part of nuclei has oval contours. Muscles lost the string structure, and sealed with separated or banded collagen fibres in multiple points.

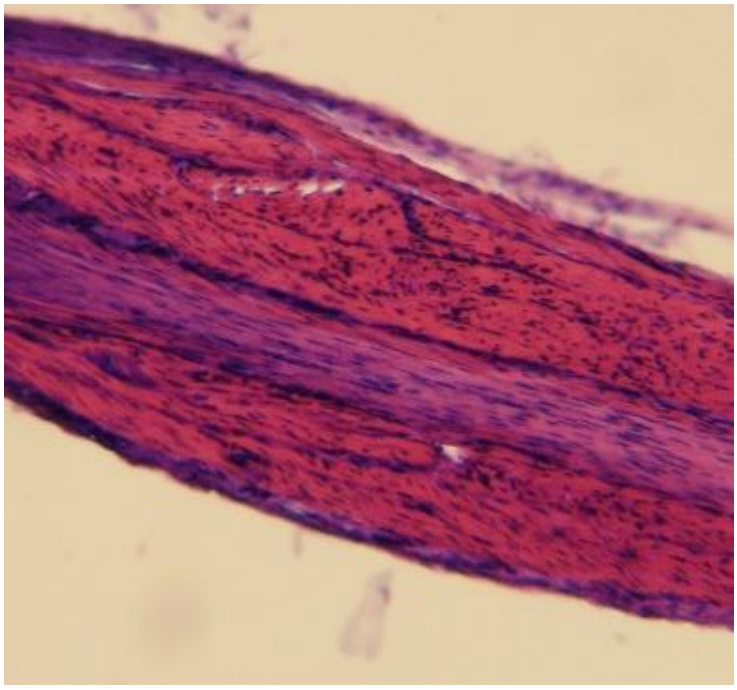

Fig. 4. Solid electric weld substrate consisting of coagulated collagen and smooth muscle fibres. Hematoxylin and eosin. X 100

Conclusions.

The structural phases of gut organs' tissues welding merging into homogeneous anastomosis substrate are: i) initial mucous epithelium destruction; ii) tissues loosening, partial fragmentation and orientation; iii) sealing of collagen fibres to smooth muscle cells; iv) derivation of walls merging points; v) forming continuous solid but structured tissue substrate, is dense and armoured by multi-point collagen fibres to smooth muscle cells sealing.

The fibrous and solidity of tissue structure in final welded gut anastomosis' substrate depends on radiofrequency impulses supply duration.

Discussion.

The tissues restructuration during the welding-fused gut anastomosis creation, is observed inside intestinal wall as well as in stomach one, proceeds in result of properly delivered radio-frequency electric welding impulses series, was supplied to organ walls in combination with appropriate previous compression. Such tissue impact provides the unique features of new type of gut organs' anastomosis: slight and vital coagulation changing, fibrotic armouring and partial membranes preserving inside solid anastomotic line. As for similarity of welding-provided restructuration phases, inside investigated gut organs, having so different walls, the welding anastomotic process could be uniform for surgical needs.

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