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Comparative evaluation of modern coagulation methods in case of pulmonary parenchyma impermeability damage

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In case of the lung tissue damage, aerostasis recovery becomes the acute problem for thoracic surgery. It is especially important by video-thoroscopic surgical operation, in case when interrupted suture is technically difficult.

According to the Military Medical College of thoracic surgery clinic data, 12,3% of patients with partial lung resection, manifested air discharge through drains during several days after surgical operation due to ineffective aerostasis. It prolongs the period of medical treatment. It also requires invasive procedures (application of guided medical pneumoperitoneum, repeated pleural cavity drainage), special procedures of pleural cavity treatment and intensive antibacterial therapy.

In recent time the use of new methods of coagulation for lung tissue capsulation has been reported. Electric coagulation in ionized argon flow has now become popular. Its mode of functioning means transferring of high-frequency electric current from electrode to lung tissue in flow of rare gas (argon). During this process, local overheating and coagulation of surface tissue layers take place.

Cold-plasma coagulation is a new step in development of coagulation techniques. This method is based on ionization of helium gas flow, which leads to corona discharge at the tip of electrode nozzle. When corona discharge spike contacts with the tissue, corona discharge transforms to arc discharge. High current density and energy of ionized gas fulfil coagulation and vaporization of tissue in the point of contact. Advantage of this method is in absence of neutral electrode and full safety for patient and surgeon.

High effectiveness of mentioned coagulation methods is obvious. However, its potential for achievement of adequate aerostasis in course of lung surgical operations remains insufficiently explored.

We have investigated in our study principal possibilities for aerostasis achievement in course of experimental lung wound treatment and morphology of scabs, which are formed by the treatment of lung wound with various coagulators: traditional diathermocoagulator (DTC), coagulator for argon plasma coagulation (APC) and coagulator for cold plasma coagulation (CPC).

Materials and methods

Study has been performed on 15 out-bred rabbits weighing about 3 kgs.

Morphological structure of scab and underlying tissues has been investigated by means of light microscopy on paraffin microscopic sections stained by hematoxylin-eosin.

Animals have been subjected to lateral right-side thoracotomy under total anaesthetic (thiopental and calipsol) together with local anaesthesia (lydocaine). Wounds of lung tissue mantle zone (about 1cm long and 2mm deep) have been made by scalpel, whereupon wounds have been coagulated by various cautery.

In the first group (5 rabbits) lung wounds have been coagulated by DTC. Three of the animals have been taken out of the experiment 1 hour later and others have died during the first day because of respiratory failure.

In the second group (5 rabbits) lung wounds have been coagulated by electrocoagulation in ionized argon flow (ATC). Three of the animals have been taken out of the experiment within 1 hour and two others have been taken out of the experiment 2 weeks later.

In the third group (also 5 rabbits) lung wounds have been treated by cold plasma (CPC). Three of these animals have been taken out of the experiment within 1 hour and two others have been taken out of the experiment 2 weeks later.

Lung wound coagulation has been carried out with “Soring” company (Germany) instruments.

The period of wound treatment has been set from 3 to 6 seconds with similar power rates.

After treatment of lung tissue defect by cautery, thoracotomic wounds have been sewn. Lungs have been spread by vacuum-aspiration through drain tube, which has been then removed.

Animals have been taken out of the experiment by injection of lethal thiopental dose. The whole trachea-lungs complexes have been extracted from these animals. Scab impermeability has been examined. For this purpose cannula with tube has been inserted and fixed into trachea. The cannula has been connected with mercury manometer and syringe through T-joint. The trachea-lungs complex has been submerged in the vessel with isotonic solution of sodium chloride. Pressure in the trachea-lungs system has been raised up due syringe.

Results of the investigation.

Aerostasis check of scabs shows that, when pressure rises in tracheo-bronchial tree, air immediately passes through lung tissues coagulated by traditional diathermy. On the contrary, scab formed by treatment of lung tissue defects with APC and CPC is very durable under pressure up to 20-25 millimeter of mercury.

Investigation of scab morphological structures conducted on lung preparations, taken during the first hour after coagulation, displays the features mentioned below.

DTC does not form solid, monomeric scab. This fact is also confirmed by loss of impermeability of lung tissues. On lung histological preparations scab formed by DTC exists in the form of separate fragments and looks cracked. Thickness of the scab fluctuates from 1mm to 1,5mm. Underlying necrotizing tissues do not form well-defined zone. They are separated. Fragments of scab can be found in upper layers of necrosis zone. Thus, the border between scab and necrosis is broken and has ruptures. Necrosis zone is most extensive (in comparison with APC and CPC) and spreads for 0,6 – 2mm.

In case of CPC, lung tissue preparations are characterized by the least extensive zones of scab and necrosis: from 0,1mm to 0,3mm and from 0,4mm to 0,6mm correspondingly. Junction of the scab with underlying necrotizing tissues is tighter. Border between the scab and the necrosis zone is well defined (flat and uninterrupted). High consistency of scab (in comparison with APC and, especially, DTC), particularly in its lower part adjoining the necrosis zone, and high consistency of adjoining necrotizing tissues are noticed as well.

All considered characteristics of APC (scab consistency, border between scab and underlying tissues expression, tightness of scab with necrotizing tissues) mediate between corresponding characteristics of DTC and CPC. Scab consistency is fluctuating from 0,2 mm to 0,6 mm. Consistency of necrosis zone fluctuates from 0,5 mm to 1,2 mm.

In lung tissues underlying scab and necrosis zone (not further than 1 cm from scab because of histological preparation size) the following changes have been observed. (These changes are more expressed in materials after APC and CPC than in materials after DTC.)

For most middle and big size blood vessels plethora and stasis of blood cells are typical. Impregnation of some bronchioles, small bronchial tubes and teethridge by blood plasma and blood cells is observed. Conglomerations of desquamated epithelial cells are frequently observed in lumens of bronchi and bronchioles. Sometimes these conglomerates are observed in teethridge. In some cases these accumulations can close nearly whole lumen of bronchiole or block teethridge. It complicates respiratory function performance. Small parts of soot and flaky accumulations are also observed in teethridge. Some parts of teethridge are enlarged and others, on the contrary, look collapsed.

Special zone of haemorrhagic impregnation of tissues is located at some distance from necrosis zone (Fig. 2. ...). This zone always exists in lungs after APC and CPC, but not always after DTC. Separate sites of tissues with haemorrhagic impregnation can also be found relatively far from the place of impact.

Study of lung, taken two weeks later APC and CPC treatment, show that scar has been formed in place of lung tissue coagulation. This scar consists of conjunctive tissue with collagen fibers predominance over cellular elements (predominantly of fibrinoblastic type) (Fig. 3). Collagen fibers are presented by thick wisps, which extend in various directions. Scab is not fully resorbed within two weeks. Small fragments of coagulation scab can be found among newly developed conjunction tissue. Generally, scar is always larger in width and area than the initial defect. At the same time remains of the scab can be distributed in depth and width together with effused conjunction tissue. Sometimes they can be detected on some distance from the place of impact. Overgrowth of conjunction tissue more lateral than place of impact always leads to pleura thickening on the borders of zone subjected to coagulation. It is interesting that such thickened regions of visceral pleura can also be found relatively far from coagulation zone.

More solid scab is typical for CPC. Resorption of such scab is more difficult and also goes longer (Fig. 4). It is possible that some parts of such scab (with maximal consistency) remains in structure of the scar as encapsulated fragments.

Layer of conjunction tissue with predominance of cellular elements over fibers is observed under typical scar tissue (Fig. 3). Consistency of these cellular elements arrangement is higher than that in crumbly fibrous conjunction tissue. Location of this zone is most corresponding with former necrosis zone. Elements of conjunction tissue overgrow also on place of haemorrhagic impregnation (Fig. 3). Two different layers are formed as results of this overgrowth: in outer layer cellular elements are predominant and in inner layer collagen fibers predominates. Teethridge and airways are absent in this zone. Epithelial cells, which were organized in these structures, are presented in formless accumulations.

Reaction of lymphatic nodules is reinforced in lung tissues located behind the condensed zone, which has been formed on place of haemorrhagic impregnation zone (distance up to 1cm from lung border). These nodules are increased in size. They infiltrate epithelium of airways and surrounding tissues by lymphocytes, new nodules may be formed. Some vessels are overgrowing with conjunction tissues, fat cells and lymphocytes. Conglomerates of desquamated epithelial cells are still observed in empty spaces of airways (mostly in bronchioles). Sometimes they block bronchioles.

Thus, the performed study has shown that modern methods of coagulation (argon plasma coagulation and cold plasma coagulation) provide strong sealing of damaged lung tissue. On the other hand, aerostasis of lung tissue can not be achieved by traditional diathermocoagulation. Taking into account the changes observed in tissues under the necrosis zone, coagulator impact in course of lung parenchyma defect treatment must be strictly dosed and must not be extended to surrounding healthy lung tissue.

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