ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ

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ON THE ORIGIN OF OSTEOCHONDRAL EXOSTOSES AT THE END OF THE BONE STUMP

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To study the features of the formation of osteochondral exostoses on the lateral surface of the amputation stump of the bone. There were 8 series of experiments performed on 116 dogs, which had the amputation of the thigh with the subsequent plasty by myodesis, myodesis with different degrees of muscle tension, osteoplasty, fascio- and myoplasty, as well as myodesis, which in the postoperative period was accompanied by the electrical stimulation of the muscles.

The observation periods included – 1, 3, 8 months. In the postoperative period the muscle tone of all animals was daily measured. The method of investigation was histological with filling of the vessels with ink-gelatin mixture. Totally 36 exostoses were studied. The vast majority of them arose after fascio- and myoplastic amputation and myodesis with the excessive muscle tension. The causes of the appearance of exostoses were the excessive tension of the muscles created during the plastic surgery, and their contracture contractions in the postoperative period. There was a resorption of the cortical diaphyseal plate along the inner and outer surfaces, intraosseous circulation and reparative osteogenesis were disrupted.

Key words: amputation, muscle tension, osteochondral exostoses.

Introduction. Osteochondral exostoses are the manifestation of the diverse dysplastic disease – exostotic chondrodysplasia of bones. Despite the longtime studying of the exostoses – one of the most "ancient" of the bone diseases, mentioned in the literature, until now there is no sufficiently valid and generally accepted theory of their origin. A few attempts of the experimental reproduction of exostoses on animals cannot be considered as successful. In the clinical practice some authors [3, 5, 7] notice the nature of the appearance of exostoses in infection of the stump and excessive activity of the periosteum, others [4, 6] – in the postoperative hematoma. According to [1, 2, 5], periosteal deposits after amputation occurred in 40 %, osteophytes – in 60.3 % of the examined people.

Without claiming to creating of the new theory of the origin of exostoses, we consider that the data, obtained during the implementation of the experimental study on the character of reparative regeneration in the amputation stumps of the femur shaft depending on the method of their plasty, are worthy of attention.

Objective. To study the features of formation of osteochondral exostoses on the lateral surface of the amputation stump of the bone.

Material and Methods. There were 8 series of experiments on 116 adult outbred dogs. In I main series, the clinically proven technique of myodesis was used: insertion of the intersected muscles to the end of the saw-line through the drilled holes and tight suturing of their ends without taking into account the tension of the muscles. In II series, the muscles were fixed in the tension of 916–962 μN (optimal). In III series, the muscles were fixed in the tension of 980–1100 μN, and in IV – in the tension of 650–800 μN, in the V series – the saw-line was closed with the autotransplant from the removed part of the limb, in VI – the fascioplastic closure of the saw-line was performed, in VII – there was the muscle plasty with suturing of the antagonist muscles under the saw-line performed, in the VIII series, in addition to the myoplasty in the postoperative period, there was the electric stimulation of one of the muscles by the current of 3–12 mA amplitude, impulse duration 5–10 ms, modulation frequency 24–36 imp./min, impulse frequency 30–100 Hz daily for 10–15 min within 19–21 days. The observation periods consisted of 1, 3, 8 months, in separate series – 1 and 3 months. In the postoperative period the muscle tone of all animals was daily measured by applying the device to the muscle. The method of investigation is histological, with filling of the vessels with ink-gelatin mixture. Before removing from the experiment, the dog was intraarterially administered 10000 units of heparin in physiological solution. After 15 minutes the animal was killed by rapid intravenous injection of 1 ml of thiopental sodium and then the abdominal aorta was tied. Below the suture the canula from the system for intra-arterial injection was put, then fixed in the lumen and pouring of the vessels with 10 % ink-gelatin mixture was performed. The limb was disjointed, and the muscles were removed. A thin layer of the tissue surrounding the bone was left. The longitudinal frontal section of the thigh bone was made. After decalcination in the 15 % solution of nitric acid, it was poured into celloidine. The sections of 15–20 μm thick were painted with hematoxylin and eosin and according to van Gieson. At the same time the enlightened preparations were made. The thickness of the sections made up 90–100 μm.

The experiment was carried out in accordance with the principles of humane treatment of animals set out in the directives of the European Community (86 (609) EEC) and the Helsinki Declaration on Humane Treatment of Animals.

The Results. Totally, there were 36 exostoses detected and studied, 28 of them in different series, and 8 – in the series, where electric muscle stimulation was performed in the postoperative period. The greatest number of them was noted in VI and especially in VII series, respectively 6 and 15, less in I, III, IV – respectively 2, 4, 1. In two series – II and V – osteochondral exostoses were not detected.

The exostoses presented formations, significantly deforming the lateral surface of the bone stump, with dimensions from 0,6 × 0,9 to 1,5 × 2 cm with the rounded contours and the peak directed to the side or upwards, corresponding to the traction of the muscle bone attached to the stump.

The histological structure of the exostoses was of the same type: they consisted of the structures of the newly formed bone in the form of the irregular network of trabecula of bones elongated under the influence of the muscle traction, containing cartilaginous fibers. From the surface the bone structures were covered with a layer of the fibrous connective tissue or fibrous cartilage, in some places – with the osteoblastic tissue. The cartilage component was found in all studied exostoses, but it did not have the character of the fringing cartilaginous coating with the oriented arrangement of cells characteristic of the majority of osteochondral exostoses, removed from the patients.

In all observations the diameter of the end of the bone stump was enlarged by the periosteal regenerates. The shape of the stump was different. In three cases it resembled the epiphysis of the femur, in two more it acquired the irregular shape due to the asymmetric arrangement of the periosteal and endosteal-periosteal regenerates, which merged, and in two more the lumen of the medullary canal was enlarged due to the significant edema. In the remaining experiments it had a clavate shape. In all observations, the contours of the cortical diaphyseal plate were almost not detected as a result of its resorption and replacement by the regenerate; it merged on a large extent with the periosteal regenerate. Its spongization was noted above the regenerates. A closed osseous plate was not formed in any observation. The medullary canal is for a long extent filled with bone regenerate from immature trabecula of bones. There was a loose fibrous and fibre- reticular tissue observed in the inter-trabecula spaces of intraosteally formed bone tissue with the presence of the sinusoidal vessels and tissue cysts. The edematous fat bone marrow of the proximal part of the stump had areas of the loose fibrous connective tissue impregnated with ink, which indicated the porosity of the vessel wall. The sharply enlarged lumens of the feeding artery were detected, filled with ink. The same lumens appeared in the distal part of the bone stump. In most observations, the feeding artery and its branches have emerged into the connective tissue border of the stump end.

In contrast to the results of these experiments, in two series (II and V), where the optimal muscle tension was admittedly formed with the tight closure of the medullary canal by the ends of the strained muscles or its closure with a thin bone autotransplant, the formation of osteochondral exostoses was not observed. In the early periods, the intraosseous circulation was normalized; the reparative process resulted in the formation of a bone closure plate out from the compact tissue, that was adjacent to the saw-line of the fully preserved cortical layer of the bone.

Discussion. Thus, osteochondral exostoses were detected in the stumps, where the special plastic measures did not ensure even muscle tension and thorough overlapping of the open medullary cavity. The unevenness of the muscles tension or their contracture contraction caused the state of the "tensile stress" of the tissues. The absence of the tight closure of the medullary cavity led to the fact that the normalization of the intraosseous circulation did not occur even in the long term, the reparative process was not completed, which led to the pathological reconstruction of the bone tissue. On the preparations painted with the ink there were a variety of problems revealed both in the microcirculation system and in the state of the intraosteal great vessels. The great vessels were not reduced, their network expanded sharply and emerged into the connective tissue rim of the end face of the stump. In this connection, the possibility of formation of the perfect closure plate was absent because of the imperfection of the overlap of the medullary canal. In the intraosseous microcirculatory network, there were the unusual

sinusoidal bones and juxtapapillary circulation pathways appeared in the form of the tissue cysts. In these cases, the resorption of the cortical diaphyseal plate occurred along its inner surface, and in response to this bone formation processes proceeded in the bone marrow. Its resorption was due to the uneven muscle tension on the periosteal surface of the cortical diaphyseal plate. It was also accompanied by the significant disturbances in the intraosseous circulation, which led to the massive dissolution of the cortical diaphyseal plate and sharp deformation of the stump. The reparative process was not completed in none of the observations with the presence of the osteochondral exostoses even in the remote terms, up to 8 months.

It is interesting that in the series with the creation of the optimal muscle tension and osteoplastic closure of the canal by a thin cortical plate the development of the osteochondral exostoses was not observed in any case. Apparently this can be explained by the rapid normalization of the intraosseous circulation and by the significant prevalence of the bone formation process at the end of the stump by the specially created conditions.

In the series with the electrical muscle stimulation, where osteochondral exostoses were obtained in all 8 cases, the role of the excessive muscle tension in the origin of exostoses was confirmed.

The reason for the formation of exostoses was the uneven traction of the muscles attached to the bone surrounding the stump, which caused the increased periosteal bone formation. In fact, the exostoses were a distraction bone regenerate, which arose in the conditions of mobility. The mechanism of its formation seems to be possible to explain by the tension of the stretching of tissues, which excites active proliferative processes in them.

The importance of the biomechanical factors in the origin of osteochondral exostoses is undoubted, but the influence of the muscle traction cannot be regarded simplistically and unambiguously. The contractility of the muscles in this experiment is due to the unevenness of their tension during plasty. In the clinical manifestations it can be associated with the impact of some common factors.

It is permissible to assume that the muscle traction plays the role of a kind of "resolving factor", causing the growth of exostoses from the eliminated buds of the epiphyseal growth plate or periosteal cartilaginous islands. The best proof of the legitimacy of this assumption is the coincidence of the most frequent localizations of osteochondral exostoses at the articular ends of the bones of the skeleton with the sites of attachment of the most powerful muscle groups – in the area of the shoulder, elbow and knee joints. The role of the biomechanical factors is also maintained in the morphogenesis of already formed osteochondral exostoses.

We see the significance of the facts and assumptions that we have established not only in the opening possibilities of creating a "model" of osteochondral exostoses, which is close to the adequate, but also in the long term explanation of certain phenomena and patterns in the field of the bone pathology.

Conclusions. 1. Osteochondral exostoses at the end of the bone stump appear under the influence of the uneven traction of the muscles adjacent to the bone, which causes the increased periosteal bone formation. 2. Formation of bone-cartilaginous osteochondral exostoses disrupts the course of the reparative processes with the formation of organotypic stump of the bone. 3. Myoplasty with the defined muscle tension and its complementation with osteoplasty with a thin cortical bone plate, leading to the favorable healing of the end of the saw-line with the rapid formation of the osseous end plate, reduces the possibility of the appearance of exostoses.

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ДО ПИТАННЯ ПРО ПОХОДЖЕННЯ КІСТКОВО-ХРЯЩОВИХ ЕКЗОСТОЗІВ НА КІНЦІ КУКСИ КІСТКИ

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Вивчали особливості формування кістково-хрящових екзостозів на бічній поверхні ампутаційної кукси кістки. Проведено 8 серій дослідів на 116 собаках, яким виконували ампутацію стегна з наступною пластикою шляхом міодезу, міодезу з різним ступенем натягу м'язів, кістковою пластикою, фасціо- і міопластикою, а також міодезом, який в післяопераційному періоді доповнювали електростимуляцією м'язів. Терміни спостереження – 1, 3, 8 міс. В післяопераційному періоді всім тваринам щодня вимірювали тонус м'язів. Метод дослідження – гістологічний, з наливанням судин туш-желатинової сумішшю. Всього вивчено 36 екзостозів. Абсолютна їх більшість виникла після фасціо- і міопластичної ампутації та міодезу з надмірним натягом м'язів. Причинами виникнення екзостозів є надмірний натяг м'язів, що розвивається внаслідок пластики, і контрактурне їх скорочення в післяопераційному періоді. Відбувалася резорбція кортикальної діафізарної пластинки по внутрішній та зовнішній поверхнях, порушувались внутрішньокісткова циркуляція і репаративний остеогенез.

Ключові слова: ампутація, м'язовий натяг, кістково-хрящовий екзостоз.

К ВОПРОСУ О ПРОИСХОЖДЕНИИ КОСТНО-ХРЯЩЕВЫХ ЭКЗОСТОЗОВ НА КОНЦЕ КУЛЬТИ КОСТИ

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Изучали особенности формирования костно-хрящевых экзостозов на боковой поверхности ампутационной культи кости. Проведено 8 серий опытов на 116 собаках, которым выполнено ампутацию бедра с последующей пластикой путём миодеза, миодеза с различной степенью натяжения мышц, костной пластикой, фасцио- и миопластикой, а также миодезом, который в послеоперационном периоде дополняли электростимуляцией мышц. Сроки наблюдения – 1, 3, 8 мес. В послеоперационном периоде всем животным ежедневно измеряли тонус мышц. Метод исследования – гистологический, с наливанием сосудов тушь-желатиновой смесью. Всего изучено 36 экзостозов. Абсолютное их большинство возникло после фасцио- и миопластической ампутации и миодеза с избыточным натяжением мышц. Причинами возникновения экзостозов было избыточное натяжение мышц, создаваемое при пластике, и контрактурные их сокращения в послеоперационном периоде. Происходила резорбция кортикальной диафизарной пластинки по внутренней и наружной поверхностям, нарушались внутрикостная циркуляция и репаративный остеогенез.

Ключевые слова: ампутация, мышечное натяжение, костно-хрящевой экзостоз.