ULTRASTRUCTURAL ASPECTS OF ANGIOGENESIS IN FASCIAE OF SKELETAL MUSCLES IN LENGTHENING WITH THE ILIZAROV TECHNIQUE

By. G.A.ILIZAROV, S.N.ASONOVA

Tension stress, which appears in limb tissue during gradual lengthening and / or thickening, has a marked angiogenic effect on limb lengthening on limb vessel pathologies, regardless of the tension stress vector (1). The connection between the osteogenesis in newly formed distractional regenerates, and the process of angiogenesis on one side, and the formation of new vessels in the paraosseal tissue as well as in the fasciae of the skeletal muscles of the limb under lengthening stress have been described in the literature (2). Studies of the ultrastructural angiogenesic process in the skeletal fascia make the purpose of this study.

MATERIAL AND METHODS OF INVESTIGATION

The fasciae of the tibial anterior of adult dogs was studiedafter a bilateral flexion osteoclasy was performed and gradual lengthening with the ilizarov apparatus was started after 5 days after the operation. The material for the electronic microscope investigation was taken and prepared according to the standard technique. The ultrastructural aspects ofthe angiogenesis at the end of the first and second week, and at the end of the first and second month of distraction were studied using the JEM-100B electronic microscope. The half thin section of fascia were prepared with the diamond knife of an LKB 8800 ultraatom. The sections were studied under OPTOM photomicroscope after being colored with metilen blue.

RESULTS AND DISCUSSION

The neoangiogenesis of microvessels in the fasciae during the first week of distraction exists of the formation of gemmae. They are formed due to protruding of endotheliocytes basal parts of preexisted capillaries and their following migration to the direction of gemmae growth. Capillary gemmae became numerous at the 7th day of distraction and are formed, as a rule, by two endotheliocytes, pulled in the direction of the growing gemmae. Their nucleous and the cytoplasmatic structures are relatively oriented. The boundary between the endotheliocytes of the growing double cellular gemmae has a complicated profile. The lumen of the endothelial space in these gemmae is not clear. The ultrastructural pecularities of the endotheliocytes forming the growth gemmae are as follows:

1. A cytoskeletal hypertrophy.

2. A wrong profile of its basal plasmolemma forming finger-shaped protrudings within the gemmae growth vector.

3. A high density of microvesicles in the basal parts of the cytoplasma.

It is known that one of the function, of the endotheliocyte's mocrovesicle apparatus, is a deposition of the membrane's bulk (3). It is also known that the process of fusion of the microvesicles with the endotheliocyte's plasmolemma, its surface is increasing at the expense of the microvesicle's membrane insertion. This membranoplastical function of the endotheliocyte's microvesicular apparatus, is actively realised during the first week of the distraction and stimulates the increase of the endothelial basal plasmolemma surface, which leads to the formation of finger-shaped protrudings, and the migration of endotheliocytes in the growth direction. It is typical, that the numerical density of the microvescular structures at the growing capillary gemmae 's ends, is the highest in endotheliocytes's basal parts, at the 7th day of distraction, and is almost disappearing by its luminal surface and in the areas of interendothelial contacts. It alsoconfirms strangely the membranoplastical function of the microvesicular apparatus in the growing gemmae, but not the metabolic one.

Cytoskeletal hypertrophy, uneven nucleous and plasmolemmacontours, finger-shaped protrudings of basal parts indicate the high migrational activity of the endotheliocytes. The cytoskeleton of the endotheliocytes in the growing gemmae is represented by the tightly packed bundles of microfilaments, of approximately 7 nm thick. They pierce the cytoplasma from the zone of perikaryon to the peripheral parts of the endotheliocytes, and are especially pronounced· by the zone of maximal mobility of their basal plasmolemma.

It is known that endothelial migrational activity, during the process of gemmae growth, anticipates its profilerative activity (3). During the first week of distraction, the heterogeneity of endotheliocytes is observed in the areas of growing gemmae. Along withthe cells of electronically dense and dark cytoplasma, there are so called "light" endotheliocytes (4). It is known that the displacement of the endotheliocytes, in the process of their migration, during gemmae's growth, causes the seperation of interendothelial contacts, and removes the block of their proliferation contact inhibition (3). The transition of zone endotheliocytes of growing gemmae to the other phase of the life cycle is indicated by the appearance of endotheliocytes with light cytoplasma, which are more active in proliferative and biosynthetic aspects, during the first week of distraction. Those "light" endotheliocytes are characterized by high activity of basal plasmolemmae and a density of near-membrane, near the finger-shaped protrudings. This confirms the high migrational activity, exactly of the "light" zones of endothelial layer.

The indication, of the intensive angiogenesis by the end of the 2nd week of distraction, is a large number of intrafascial microvessels of the hemomicrocircular bed, distributed, by the groups between the fascial layers in central, non-vescular parts of fasciae in intact adults dogs. The growing of the intrafascial microvessels takes place with the formation of interstitial canal in a dense collagenous frame of fasciae by means of its destruction and remodelling.

The stereoultrastructural studies has shown that by 14th day of distraction,the zones of its local remodelling are revealed in the archytectonicaly intact collagenous frame through the formation of lacunae. The lacunae have a round or oval profile, 7x10 - 10x25 mcm in size, and indefinite depth. The lacunae distribution density is high, and they they are revealed within the length of collagenous fibers with an interval of 10-20 mcm, and no definition in the order of their definition. The collagenous matrix, forming the wall of some lacunae, is slightly loosened, and does not have a regular packing of collagenous fibrils. The walls of the other lacunae are flat, with smooth surfaces. These formations in the intracellular matrix, by the 14th day od distraction, represents the stereoultrastructural equivalent of interstitial canals, revealed in half-thin and ultrthin sections of fasciae, which have similar contours and size. They are the zones of ingrowth microvessels.

The formation of those interstitial canals takes place by means of macrophagal destruction, followed by the remodelling of the intracellular matrix in these fascial zones. In the ultrathin sections, fragmentation of collagenous fibers is observed, the exfoliation of the collagenous fibril bundle, and the loss of fibrill regularity in the bundles. The subsequent formation of the intracellular matrix in the interstitial canal formation zones, where the microvessels grow in, is performed by differentiated fibroblasts. They are often revealed, nearby the active macrophages, and form the macrophagal - fibroblasteal contacts. Remodelling of intracellular matrix is going on intensively. This is clearly confirmed by the synthesis products being discharged from fibroblastic cytoplasma - their secretion coming directly from the cisterns of the granular endoplasmatic reticulum, through clasmatosis.

By the end of the first month of distraction, the intensity of the angiogenesis processes was very high. This is confirmed by the large number and the maximal structural polymorphism of newly formed microvessels, reflecting all the consecutive stages of the genesis, growth and special differentiation, throughout the investigated period of distraction.

As, at the previous stage of distraction, on the 28th day , the hemocapillaries are growing at the expense of the mobility. They increasethe basal parts of the endotheliocytesplasmolemma, and the formation of cytoplasmic processes. They subsequently migrate in the direction of growth with the formation of capillary gemmae of two types, reflecting the two phase of their growth - the fast one and the slow one (5). and subsequent differentiation of newly formed microvessels endotheliocytes.

The initial stages of growth gemmae formation, are accompanied by protrution of endothelial basal parts. They have a shape of 2-3 mm obtuse finger-like protrudings with non-differentiated cytoplasma, mostly presented by ribosomes, polysomal complexes and seperated vesicles. Basal membrane in the zone of finger-shaped processes of endotheliocytes is absent.

The subsequent endotheliocytic migration in the direction of the growth, leads to the formation of two types of capillary gemmae:

1. Formed by two endotheliocytes with non-defined intraendothelial space

2. With an obtuse end and pronounced intraendothelial space.

The capillary gemmae of the 1st type, with closed intraendothelial gap, present a fast phase of gemmae growth (5). In crossed ultrathin sections, they have a shape of double-cellular hemangioblast island, of 5-7 mcm in diameter. Sometimes these islands are formed by 3-4 endotheliocytes of a wrong shape, likely rectangular, with tight intraendothelial contacts and myelinic figures in the intraendothelial gaps.

Endotheliocytes in double-cellular capillary gemmae have a crescent profile in cross sections. Their cytoplasma is mostly represented by hypertrophical golgi complexes with a pronounced vesicular apparatus, respnsible for the membranoplastic function in the process of gemmae growing. There are numerous mitochondrias, short, narrow cisterns of endoplasmeal reticulum, ribosomes, and poliosomal complexes. They indicate the high level of endogenic biosynthesis, ensuring the process of endotheliocyte growth. Cytoskeletal structure are represented by the thin layer of subplasmelemma microfilaments, in the basal parts of the endotheliocytes. Intraendothelial contacts of two endotheliocytes have an ultrastructure of simple connection of 7 mcm length with local widening of the intraendothelial space, upto 0,2-0,3 mcm. The concentration of cytoplasmeal vesicles reaches its maximum in a subplasmalemma zone of intraendothelial space of double-cellular gemmae. This was indicated by the telescopic way of its growth ends (5). Double-cellular gemmae are surrounded by pericyte processes, performing the directional function in the gemmae growth process, and forming pericyteal endothelial contacts.

Capillary gemmae of the 2nd type with intraendothelial lumen, manifesting the stage of the slower growth (5), have a leading obtuse end, which often, forms two or more finger-shaped, 2-3 mcm V-like protrudings. These protrudings are formed with two endotheliocytes with the closed intraendothelial lumen and represent end zones of capillary gemmae's fast growth.

Endothelium of the 2nd type gemmae , growing more slowly, is thin. In the peripheral parts of the endotheliocytes, its thickness reaches 0,2-0,3 mcm.

In its nucleous, parts widen upto 2 mcm. Endotheliocyte nuclei have a protruding, elongated in the direction of the growth, form. The structure of their karyoplasm indicates the high level of nucleous synthesis. It is represented by disperse euchromatin, and a thin strap of subacryolemmal heterochromatin. Vacoulized nucleoli, of nucleolonemic type, are situated in submembranous nucleous zones. The density of the nucleous pores is very high. At the same time cytoplasma, of the 2nd type endotheliocytes, has a limit of organoids. There are, mainly, a lot of ribosomes and polysomal complexes, mitochondrias, short, narrow cisterns of endoplasmatic reticulum, cytoflaments, but it does not have markers of special differentiation of endotheliocytes - microvessels. Intraendothelial contacts are also marked by insignificant length, upto a point, ensuring a high permeability of these capillar walls. The picture of contact profile is rather simple. the contacts of complicated contours, which are characteristic for the differentiated endothelial layer, are absent. The ultrastructural features of capillar gemmae's endothelium of the 2nd type, indicate its primary specialization in the growth and the migration processes, but do not perform special metabolic function.

In the process, of the subsequent differentiation, newly formed vessels of the hemomicrocirculatory bed, by the end of the 1st month of distraction, the formation of the endothelial layer with the ultrastructural features, characteristc for differentiated endothelium, takes place. They have a considerably high endothelial layer upto several mcm, hypertrophy of the biosynthetic apparatus of cytoplasma, high activity of the nucleous structures, and development of a microvesicular system. During this period happens the complication of the profile and the specialization of the intraendothelial contact zones, with the formation of the obliteration areas in luminal and abluminal parts. This ensures the regulation of the endothelial wall permeability. The availabilityof some microvessels, can be confirmed by the excess of their plasmolemmas, forming the cytoplasmayic protrudings in the vessel lumen, near the luminal parts of the intraendothelial contacts. The progressive differentaition is observed in the adventitial layer of the newly formed vessels. It has continuous pronounced basal membrane and formation of pericytial membrane.

The angiogenesis in the fasciae, during the studied period of distraction, has a prolonged character. It is indicated by the availability of numerous vessels and capillary gemmae in the intrafascial areas, not only in the first month of distraction, as it was shown above, but also in the second month of distraction. The morphology and the ultrastructure of probed microvessels at the 58th day of distraction. The endothelial layer is extremely thin. They have short incompleted intraendothelial contacts, and a siple profile. In the endothelial cytoplasma, of checked microvessels, one findsnumerous ribosomes and polysomal complexes, small mitochondrias, with electronically dense matrix, short narrow cisterns of rough endoplasmatic reticulum, and golgi structures. This confirms a high level of endogenic biosynthesis, ensuring microvessels growth processes. The feature of their ultrastructure is a hypertrophy of filaments, and a very low density of microvesicular structures, markers of specific differentaition of metabolic microvessels, which also confirm the provisional character of these vessels and the high migrational activity in them.

As in the previous periods of distraction, angiogenesis was performed by seperation of endotheliocytes from preexisted capillaries, with the formation of capillary gemmae of the 1st type. In cross section, they have a shape of a double-cellular hemangioblastic islands, with non-pronounced lumen. Their subsequent intensive growth, is ensured by polyploidization (6) of nucleous material of endotheliocytes, which is indicated by the availability of double-cellular endotheliocytes and opposite invagination of karyolemma, with a formation of nucleous strangulation in the endothelial coat of the capillary gemmae of the 2nd type, with pronounced intraendothelial lumen. Occuring karyokinesis without subsequent cytotomy, leads to reducing of cellular cycle and guarantess multiple set of nucleous structure, which is a factor of accelerated microvessels growth (7).

In comparison with the previous period of distraction, by the end of the 2nd month of elongation, most of intrafascial microvessels is protruded on the way of specific differentiation. It is characteristic of the endothelial coat, to have a considerable height, long complicated profile of intraendothelial contacts with obliteration zones in the luminal and basal parts, and development of a microvesicular apparatus. The basal membrane, and the pericytial elements, of these microvessels have a differentiated ultrastructure.

Thus, the angiogenesis, during the studied period of distraction, has a prolonged character, and is performed by capillary gemmae formation. Its intensitivity increases in the 1st month of distraction, by the end of which the number and polymorphism of the provision vessels, reach their maximum. By the end of the 2nd month, most of the newly formed tissue was protruded on the way of specific differentiation. Along with the provision capillaries, the newly formed vessels of a metabolic type are observed.

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GUIDED TRANSOSSEOUS OSTEOSYNTHESIS IN TREATMENT OF FRACTURE COMPLICATIONS ON LONG BONES

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The problem of rehabilitation treatment of the patients with posttraumatic consequences in long bones inspite of its many years studying stays the same till today. A large percentage of unfavourable results after using traditional surgery was a reason for research resulting in the introduction of more effecient method of treatment. From this a growing interest of theorists and clinicist is seen for the new trend of restorative surgery being developed by the ILIZAROV School.

Various laboratory experiments performed in this research center, investigated the problems of tissue genesis under different conditions of guided transosseous osteosynthesis. The study of and the application of the new techniques on more than 3000 patients with post traumatic orthopeadics pathology, led to the finding of unknown biological processes of restoration of bone as well as of soft tissues. These regulation of the restorative formation process became the basis for the revision of the conventional surgical principle and were elaborated into new original biologically based decision for these treatments.

The essence of the developed treatment techniques now consists in the guided modelling of tissue structures under conditions of transosseous osteosynthesis by external fixation. On this basis, the clinic of our scientific center uses a new system to preserve and restore organs. The treatment now represents a new trend in the rehabilitation of patients with posttraumatic complications of long bones, usinig biomechanical and clinico-experimental aspects of investigation.

The stimulating influence of tention stress has allowed for the first time to :

a) substitute without grafting large bone and soft tissue defects
b) To elongate extremities to desirable limits
c) To model simultaneously their shape
d) To eliminate severe deformities.

Stable fixation of bones by the apparatus enables the patient to walk with gradually increasing load on the extremity, to serve one self and to do physical exercises for bone regeneration. This prevents especially, in middle-aged and old patients, serious complications connected with a prolonged bed rest.

By performing preserving surgeries the following principles should be observed as a fundamental unity:

1. Free, auto- and allotransplants and endoprosthetic appliances are not used.

Bloodless techniques of treatment are now used. To minimise maximally, the volume of surgical intervention in the pathological situation when adapting the fragments to the complex form of their ends. Biomechanically expedient adaptable changes formed during the disease, are not violated. Biomechanically based switching to statico-dynamic loading is widely used through transformation or transposition of bones and articular surfaces. Stabilization of the articulation is realized only in extreme causes, when all the possiblities of the preserving treatment are exhausted.

2. Blood supply and tissues are maximally spared during reconstruction, preserving the developed mechanism of their adaptation. This is the essence of the principle of preserving and assisting the

favourable condition for reparative tissue regeneration.

3. Biologically admitted values of mechanical traction or compression of tissues are used taking into account their neological posttraumatic properties.

Reconstructive - restoration surgery forsees restoration of the biomechanical functioning of the extremity by means of its segments reconstruction. The elongation of the extremity length with its simultaneous shape modelling, improves the firmness of the thin bone segments by the influence of different loading, creates a neoarthrosis for function preservation of the peripheric extermity segments.

Discovered by G. Ilizarov, the tension stress effect of biological tissue, stimulating the genesis, is widely used for formation of bone regenerations in the direction planned in advance and diversed in configuration and length. This discovery led to find out new decisions of treatment of bone defects and pseudarthrosis of different localization and origins. On the basis of plastic potentialities of bone tissues, the methods of its closed transformation were developed. It became possible to treat bloodlessly stable joint contractures.

The application of these treatment techniques has raised the number of bloodless variants of transosseous osteosynthesis to 35%.

The investgation of the biomechanical aims of transosseous osteosynthesis has shown the importance of the following demands:

1. Optimal mechanical conditions for tissue regeneration should be created by the rational choice of the apparatus modules providing regulated statico-dinamic extremity function.

2. Osteosynthesis should be realised taking into consideration the possibilities of switching over in time to the biomechanically based regimes of loading created by the system "apparatus-extremity", i.e., their guidance in exposure and magnitude preserving the necessary rigid fixation.

It should be stressed that the problem of optimal conditions for tissue regeneration nowadays is successfully being solved with the universal Ilizarov apparatuses, which standard pairs could be assembled into practically unlimited quantity of different configurations, depending on the pathology and treatment aims.

Thanks to the obtained progress in developing sparing treatment techniques of posttraumatic complications of locomotive system, it became possible to treat efficeiently not only stationary patients but out-patients as well which led to an organizing a new form of medical assistance.

Using the Ilizarov method for treatment of different bone non-unions omits the application of electromagnetic and electric tissue stimulators as well as the anastomosis of vessels by micro surgery.

CONCLUSION

The restorative surgery based on the modern techniques of transosseous osteosynthesis in treatment of trauma complications and diseases of bone is a dynamic system of rehabilitation measures, founded on the complex optimal mechanico-biological conditions for reconstruction of damaged tissue structures and funcions. Different application of these techniques obtained good results in treatment of 98% of patients at the Kurgan Institute.

THE INFLUENCE OF KNEE JOINT IMMOBILIZATION, WITH THE ILIZAROV APPARATUS, ON TIBIAL SKELETAL MUSCLE STRUCTURE IN VITRO

By N. K. Chikorina

In the treatment of the locomotor system, immobilization of limb, is a constant concomitant factor. The changes in the skeletal muscles, as described by several authors (2,3,5), can make a complex of soft tissue atrophy due to hypodynamics. In particular, plastic casts can cause acute vascular reaction of muscle fiber atrophy in 2-3 days time.

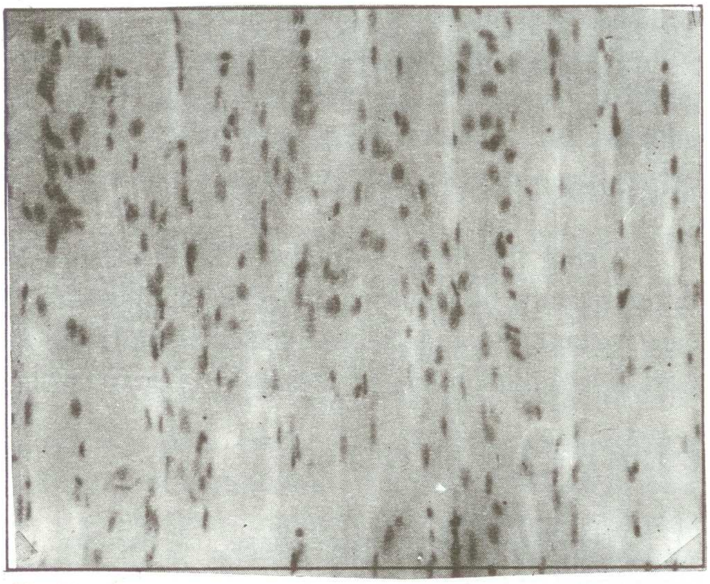

Fig No. 1

Some authors (4,6) state that the period of reconstruction of the soft tissue, independent of immobilization period, can take 3-4 times as much time. An immobilization of 5-12 days, after tenotomy or spontaneous rupture, can cause vivid changes in the skeletal and the muscle ultrastructure, upto myofibrillous fragmentation. Together with a decrease of the diameter of the muscle fibers, glycogen granules and fat sacroplasm disappear almost completely. Muscle immobilization , without distraction, leads to decrease of sacromeres because of low protein synthesis and enforcement of a catabolic process in the tissue.(6).

Animal experiment on mongrel dogs were undertaken in order to study the changes in skeletal muscles with lack of motor activity due to Ilizarov transosseous osteosynthesis. The knee joints of the dogs were fixed with the ilizarov apparatus in a close to physiological angle (110-120 degrees). X-ray control presented an even articular space.

Material and methods of investigation

Using VAN GIZON technique, morphological investigation were made on the material, taken from the upper third of anterior tibial and gastrochnemius muscles of experimental contralateral mongrel dogs limbs. Paraphin celluloid section with thickness 5-10 mkm were dyed by hematoxylin eogin. Ultrastructural investigation were made on samples, taken after histological experiments and were oriented on half thin sections. Ultra thin sections, thickness upto 400-500 angstrom were achieved by ultramicrotom and studied in electronic microscope. For pictures, a photomicroscope OPTON was used.

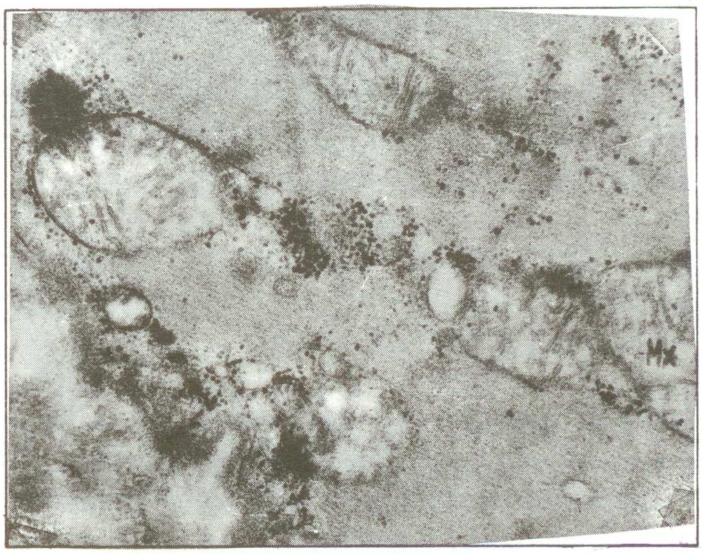

Fig No. 2

Results of Investigation

Histological investigations demonstrated that efore the 28th day of knee joint fixation with the izarov apparatus, there were no major changes in nvestigated muscles. (Fig. 1). At the same time, ilation of tubes and cisterns of the sacroplasmatic vas noticed under electronic microscope. Also, an ncrease of the area, taken by interfibrillar mitochondria vith electronic transparent matrix was noticed (fig.). In clear space of some capillars and arteriols rythrocytes with electronic thick multilayer exter- al membranes were found (fig.3). On the contralateral ide, no structural changes in the muscles were ound.

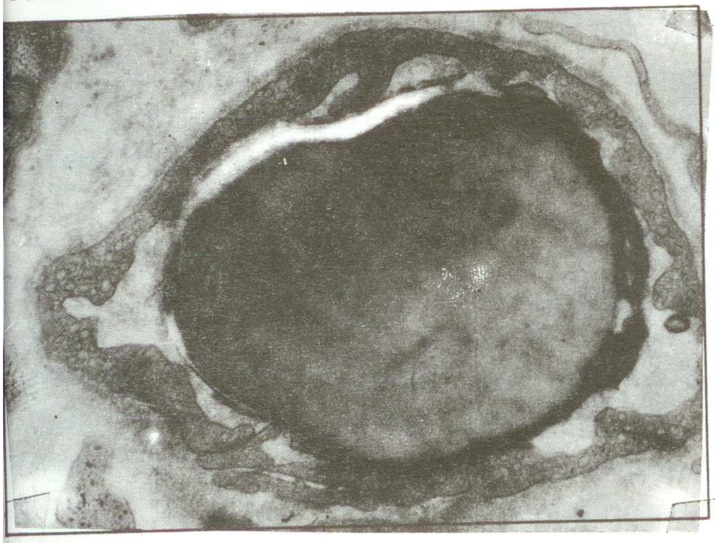

Fig No. 3

In 28 days of knee joint fixation in anterior tibial muscle of mongrel dogs, several muscle bundles with partly atrophied muscle fibers, decrease of the total number of muscle nuclei, focal thickening of perimysium in anterior external muscle layers, were found histologically. Electronic microscopical investigation showed that ultrastructural changes of muscle fibers had focal character and resulted in myofibrilles reduction in the peripheral area of some muscle fibers, increasing of the sacroplasm net triads pictures and the accumulation of the glycogen granules in interfibrillar spaces, mainly in I-discs area. The majority of interfibrillar mitochondria had dense matrix with single electronic transparent lacunes (fig.4). The same picture was determined on periphery of muscle fibers. The changes in capillar vascular net were vivid, cytoplasm of endoteliocytes had a lot of vacuoli and pinocytes bubbles, and in clear space precipitation of protein substance and mieloid bodies were determined.

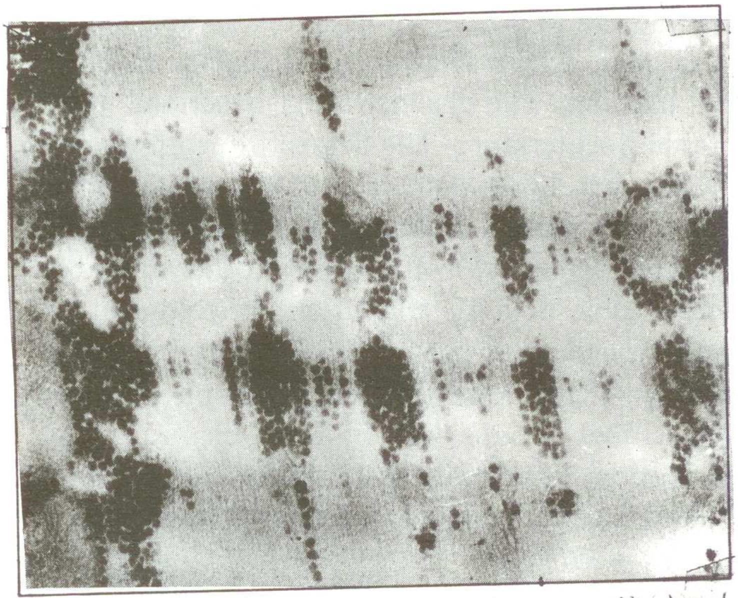

Fig No 4

In the gastrochnemius, minimal changes were found. On the contralateral muscle side, moderate hypertrophy of muscle fibers was determined.

14 days after knee joint fixation and 30 days after apparatus removal, histological changes in tibial muscles were not determined. Ultrastructural changes of myofibrilles apparatus were not vivid. They were identical to description of knee joint fixation after 14 days.

In the next 2 groups of investigated muscles, the changes of one and the same type were determined. They had focal dispersion character which lead to atrophy of muscle fibers groups, mainly in peripheric area of muscle bundles. Contraction of several arteriols, clear gaps and thickening of vessels adventition were vividly seen.

In 3 months of observation in histologically investigated muscles, no structural changes were observed. In majority of muscle fibers, normal regular sacromeres ultrastructure and plenty of interfibrillar glycogen granules were determined.

CONCLUSION

Investigation showed that in 30 days after knee joint fixation with the Ilizarov apparatus in tibial muscle of grown up mongrel, some changes did appear, which characterized mainly immobilized muscles. The changes were described many times in the literature. The degree of expression of the latter was lower compared to muscle immobilization , e.g plaster bandage application (1), long term confinement to bed (2,3) and other means of some muscle activity restriction. Histological investigation showed that in the majority of muscle fibers, no changes were observed,atrophy of some muscle fiber groups was of focal character and distribution was accidentally dispersed. Decrease of tissue capillarization and pronounced scclerotic changes were vivid.

Ultrastructural changes of mitochondrial apparatus of muscle fibers witnessed its temporal functional inferiority, and , energetic hunger of microfibrillar apparatus. This deduced of the focal reduction and absence of active biosynthetical processes. Enforced precipitation of protein substances in some erythrocytes in clear spaces of capillars and arteriols, and enforced vesiculation of endoteliocytes cytoplasm witnessed temporal reducing of regional bloodstream speed.

After apparatus removal focal changes described in muscles were eliminated, and potential possibilities of skeletal muscle tissue led to muscle structure restoration. Accumulation of interfibrillar glycogen witnesses this fact.

The knee joint immobilization with the ilizarov apparatus in grown up mongrels never caused severe structural changes in tibial muscles with functional abilities breaking.
This is due to :

* preservation of blood circulation in limb.

* preservation of relative contraction ability of tibial muscles in case of free neighbour joint function.

Description of pictures.

Picture 1. The part from the anterior tibial muscle upper third in 14 days after knee joint fixation with the Ilizarov apparatus. Dyed by gimatoxilin- eozin x 30.

Picture 2. Ultrastructure of muscle fibers from the upper third of gastrochnemius in 21 days after knee joint fixation. Focus of myofibrilles reduction (arrow). Large interfibrillar mitochondria (Mx) with electronic transparent x 20600.

Picture 3. Ultrastructure of anterior tibial muscle capillar in 21 days after knee joint fixation. In capillar's clear spaces, erythrocytes, closely connected with endoteleocytes surface x 12600 can be seen.

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SURGICAL LENGTHENING OF LOWER LIMBS IN ADULTS USING THE ILIZAROV TECHNIQUE.

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Covering a long path from first attempt of lengthening bone through skeletal traction, to the automatic distraction with modern apparatus for transosseous osteosynthesis, the surgical lengthening of the lower limb has been actively developed over a period of more than 70 years.

At present, surgical lengthening uses two different principles:

A). UNILATERAL EXTERNAL FIXATION PRINCIPLE

1. Wagner method - Three surgical interventions are necessary: diaphyseal osteotomy, distraction using the Wagner apparatus on 1,5 - 2,0 mm/day; bone plastics using bone grafts on the newly formed bone defect with fixation by metal plate and screws; removal of plate and screws after consolidation of bone fragments.

2. Ilizarov method - In this method, progressive distraction of the bone after partial corticotomy, stimulates regeneration of bone tissues.

This surgical technique is less traumatising and practically does not damage the osteogenic tissues. Bone grafts are not used, and there is no necessity for additional fixation. Optimal distraction rate preserves full volume of blood supply in fragments under lengthening and does not disturb innervation of the limb. Rigid fixation of bone fragments at any part of the limb gives an opportunity for functional loading during the treatment.

In this article, the treatment of 631 patients, 357 females and 274 males, aged average 28,6 ± 10 (from 18 to 56 years of age), operated between 1972 and 1990, are subdivided according to etiology of shortening. (Table 1).

TABLE 1

PERCENTAGE OF SHORTENING	ETIOLOGY OF SHORTENING
29,3 %	Congenital Shortening
15,8 %	Hematogenic Osteomyelit
9,9 %	Tuberculosis of bones and joints.
35,4 %	Residual Polio
9,6 %	Trauma

Subdivision of 631 patients

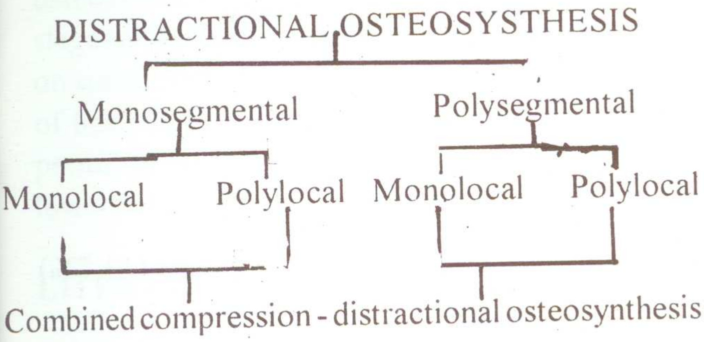
Majority of patient had a total limb shortenin of more than 6 cms. 44.6 % had a shortening of on segment (femur or tibia), 55.4 % had shortening c both segments. The average shortening of the femu was 8,5 cms ± 3,0 cms and the average shortenin of the tibia was 6,2 cms. A majority of cases showe an accompanying pathology of the adjacent joints o foot. (Table 2).

TABLE 2

ASSOCIATED PATHOLOGY	PERCENTAGE	NO. OF PATIENTS
Ankylosis of hip joint in malposition	6.8 %	43
Flexion contracture of hip joint	6.5 %	41
Valgus, varus or recurvation of ankle joint	20 %	126
Foot Deformities	21.2 %	134
	54.52	344

The remaining 287 patient (45.48 %) did not present any aassociated pathology or foot deformity. Diaphyseal deformities of long bones were found in 80 cases (57 - femur, 23 - tibia).

In the Ilizarov technique, following classification of transosseous osteosynthesis is used.



The whole period of treatment after the surgery includes the period of distraction, fixation with Ilizarov frame and functional rehabilitation. The duration of distraction depends on the amount of lengthening, the rate of distraction, the selected technique for distractional osteosynthesis, the dynamics of reparative process, the neuromuscular system in the lengthening limb and the functional position of the adjacent joints. The amount of anatomic femoral lengthening varied between 2 and 11 cm (5 - 50%) of total lengthening. The amount of anatomic tibial lengthening varied between 2 and 13 cm (5 - 50%) of total lengthening.

Monosegmental lengthening was performed in 346 cases (147 - femoral lengthening, 199 - tibial lengthening),. In 123 cases the lengthening was done with bilocal distractional osteosynthesis. In 36 cases femoral and tibial lengthening was performed simultaneously, (average 22,9+1,4% of initial level). Simultaneously with femoral lengthening malposition of hip joint was corrected, and the axis of limb became even.

In 134 cases together with tibial lengthening surgery on the foot was done. (arthrodesis of foot joints, foot lengthening, corrective osteotomies).

The average rate of distraction in monolocal distractional osteosynthesis was 0,9 mm per day in femural lengthening and 0,8 mm per day in tibial lengthening. The average increase of distractional osteosynthesis was 1,5 times in tibia and 1,9 times in the femur. In both tibial and femoral lengthening the rate of distraction was not more then 1,5 mm daily. The consolidation of the bone fragment is obtained during the fixation period with the ilizarov apparatus. Giving functional load on the operated limb, without additional fixation, helps to obtain good bone regeneration. The period of fixation depends on: the etiology, the amount of lengthening, the level of segmental osteotomy and or complications during lengthening. The period of distraction using bilocal osteosynthesis in femur or tibia can be reduced by 1,5-2 times period of distraction, and period of fixation reduces in 1,3-1,4 times.

In table 3 and 4,the percentage of lengthening of femur with ilizarov apparatus in monolocal distractional osteosynthesis depending on the level of osteotomy and the etiology of the shortening is shown.

TABLE 3

Level of osteotomy	% of lengthening Congenital shortening	Acquired shortening
Proximal metaphyses	14.1±1.8	14.3±1.5
Diaphyses	17.5±2.3	12.1±1.5
Distal metaphyses	17.7±2.5	13.3±2.4

TABLE 4

Level of osteotomy	Period of fixation Contenital shortening	Acquired shortening
Proximal metaphyses	14.8±0.7	12.0±2.8
Diaphyses	14.7±2.7	24.2±5.1
Distal metaphyses	17.6±2.3	17.6±1.7

Tibial lengthening was performed, as a rule, in proximal metaphyseal zone of the tibia and the average period of fixation in congenital shortening was 22,07±1,4 days and in acquired shortening 25,07 ± 1,4 days.

In the next two tables (5 and 6), the influence of the character of the osteotomy of femur on the percentage of lengthening and period of of fixation respectively is analysed.

TABLE 5

Character of osteotomy	% of lengthening	
	Congenital shortening	Acquired shortening
Partial Corticotomy	15.4±2.3	16.7±1.8
Osteotomy	16.5±1.7	15.8±2.3
Fragmental Osteotomy	16.8±2.2	16.4±2.1

TABLE 6

Character of osteotomy	Period of fixation (days)	
	Contenital shortening	Acquired shortening
Partial Corticotomy	12.0±0.9	8.9±2.3
Osteotomy	18,9±3.0	18.7±2.4
Fragmental Osteotomy	28.3±5.3	27.8±5.02

As seen from Table 6, the period of fixation in femoral lengthening increases in more traumatic surgical intervention. The patients, 2-3 months after the removal of apparatus walked with full load on operated limb.

During the treatment, complications appeared in 143 cases (22,7%). Only in 48 cases, complications influenced the results of treatment. In all the other cases, complications were diagnosed but did not influence the results of treatment, but the period of osteosynthesis was increased in these cases.(6-12 days per 1 cm of lengthening).

In complications being observed during lengthening, following observations were made:

1. purulent inflamations (5%)
2. sublaxation of femur (0,1%)
3. tibia (1,1%)
4. paresis of personeal (0,75%)
5. angulation deformity of segments (13,7%)
6. flexion contracture of knee joint (2,6%)
7. Contracture of the ankle joint (2,6%), Delayed consolidation of bone fragments (3,7%).

In some cases combined complications were observed. Stable extension contracture of knee joint (average amplitude of movements - 55,3±12,(degrees) was formed in 18 cases: (14 patients - after lengthening of lower third. The average lengthening was 17,6 cm. The etiology of shortening in 50% was congenital. Amplitude of movements in ankle joint was restored in 2-3 months and in long-terms period of observations reached the inital stage in all cases.

Comparative analysis of gained data with the data of literature showed that it became possible not only to reduce the number of complications, but even to eliminate such complications as infected hematoma, sepsis, thrombosis and thromboembolism, injuries of main vesels and nerve trunks with the help of the technique of osteotomy, elaborating the stability of osteosynthesis and using the method of quantitative control for the lengthening.

The analysis the results of treatment allow the conclusion that the complex of techniques of distractional osteosynthesis after Ilizarov (mono and bilocal, mono- and polysegmental) gives th opportunity for individual and differential treatment of the patients, depending on the degree of shortening and accompanying deformities.

CONCLUSION

Methodical principles of controlled distractional osteosynthesis which makes possible to unite the stages of treatment of orthopaedic cases, to incfluence on speed of distraction and terms of reconstraction of bone regenerate, is a real way for reducing of period of treatment in patients with shortening of lower limbs.

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MANAGEMENT OF HUMERAL FRACTURES IN CHILDREN WITH ILIZAROV TRANAOSSEOUS OSTEOSYNTHESIS

By: Sysenko Y.M. Znamenskly G.B., Novichkov S. I.

Among pediatric problems in CIS, trauma and accididents occupy one of the leading places, and lately do not have a tendency to drop (Kulakova T.V., Andrianov V.L., Zatekin A.I. 1983). Of all children's injuries, humeral fractures make quite a high percentage (27,9%). (Machavariani M.S., Amirbegova E.D., Cholokava A. R., 1978; Luzianin A.V., Vasilevisky D.R., 1988).

Treatment of such fractures in children with conservative methods has the only advantage of small trauma, but they lack the precise repositioning and stable fixation, while surgical methods allow precise fragment repositioning causing additional trauma to soft and bone tissue. That is why the method of transosseous osteosynthesis has been gaining wider recognition for pedriatic trauma management.

In our country and abroad, the ilizarov apparatus is used most often for pedriatic injuries differing from other designs by simplicity of construction, versatility and possibility to control fragment position throughout the treatment period. (Znamensky G.B., 1980, Ilizarov G.A., Konstantinov B.K., Karagodin G.E., Shevd S.I., 1981, Golikov V.D., Sysenko Y.M., 1982; Karagodin G.E., 1982 etc)

From 1968 to 1989, the ilizarov transosseous osteosynthesis has been applied at Kurgan Center for 244 patients, aged 5 to 15 with humeral fractures. 183 cases (75 %) of all were boys, 61 cases (25%) were girls.

The study of the trauma character revealed a majority of routine trauma (180 cases - 73,8%). Less frequent were road accidents (41 case - 16,8%) and sports injuries (23 cases - 9,4%).

Direct impact caused humeral fracture in 168 patient (68,9%) while in 76 cases (31,1) an indirect trauma was the reason of injury.

The overwhelming majority (201 cases - 82,4%) repetitive unsuccessful attempts of closed manual repositioning of the humeral fractures elsewhere in Kurgan or the region, which somehow delayed their admission to our center.

Very important for making up a frame with a minimum number of parts, allowing precise reposition and stable fragment fixation, was a clear differentiation of not only of humeral fracture, but also the type of fracture line, and the amount and type of fragment displacement.

On a total of 244 patients 39 cases (16,4%), had proximal humeras fracture, 70 cases (28,6%) shaft fractures and 135 cases (55%) had distal humeras fractures.

Of the proximal injuries, most frequent were the surgical neck fractures (18 cases) of which 7 transverse fractures, 6 oblique and 5 multifragmental fracture and the osteoepiphyseolyses (15 patients). Less frequent were epiphyseolyses and dislocation fractures (4 and 2 cases respectively).

Of the shaft fractures, 35 cases were of transverse type, 15 oblique fractures, 10 spiral fractures, 9 multifrgamental and 1 double fracture. Among distal injuries, most frequently were supracondular (63 cases) and transcondular (41 cases) fractures. Less frequent were T- and Y-shaped (17 cases) and L-shaped (14 cases) fractures.

Examination and pre-op preparation started at the admission department. After evaluating objective status, roentgenological data and clinical analysis, the thime and amount of the surgery was decieded.

The type of anaesthesia was chosen with the anaesthesiologist according to individual pecularities and the age of the children. In 157 cases, we used a mask (64,3%), in 83 (34%) cases - theKulenkampf conduction anaesthesia of the brachial plexus and in 4 (1,7%) cases, a local infiltration anaesthesia was applied.

Ilizarov transosseuos osteosynthesis was performed of the orthopaedic table. To correct the fragment displacement, skeletal traction was applied to humerus with a special device made of ilizarov parts.

At the initial stage of mastering the ilizarov transosseuos osteosynthesis, children with humeral fractures were treated the same way as adults. The techniques are described in detail manuals (Ilizarov et al., 1979,1982).

Later under the guidance of Prof. G.A. Ilizarov, transosseuos osteosynthesis in children was improved, making use of minimum number of parts. Least possible number of wires (4-5) was used driven away from the off growth plates and , as a rule, at different levels (distant crossing). The ilizarov apparatus was assembled with a minimum number of rings (2-3) thinner (3mm) and with a greater number of holes, than the regular ones. Wire fixator bolts were used instead of special wire fixators, posts were extensively applied, the rings were joined using a minimum number of rods.

In 203 patients (83,2%), precise bone fragment repositioning was reached on the operation table, while in the rest (41 cases - 16,8%), it was achieved in 1-2 days after osteosynthesis.

In the post operative treatment complex for the children with humeral fractures, a great deal of attention was paid to early function, patient's mobility and the prophylaxis of complication. The decision to end humeral fixation with the ilizarov apparatus was taken on the basis of clinical and roentgenological data. The average period of fragment fixation was: 20,4±1,8 days in proximal fractures, 33,2 ± 1,4 in shaft fractures and 14,8 ± 1,1 days in distal femur fractures.

The average period of in-clinic treatment of children with humeral fractures was 3,5 ± 2,5 days which corresponded to the average period of the complete functional restoration of an injured limb.

21 (8,6%) patients had complications during treatment. 18 patients had soft tissue pin tract infection. In 15 cases, this complication was managed with conservative treatment (dressings with antiseptic soloutions, antibiotic injections at the sit of inflammation, UV treatment). In 3 cases, these procedures failed to help, and the inflammation subsided only after the removal of affected wire. 2 patients had a secondary fragment displacement in the post operative period, due to slack of the repositional wires. After wire tightening, the humeral fragment displacements was corrected. In one case, fragment fixation eas terminated untimely, and inadequate loading resulted in an angular displacement of the humerus. To correct the appeared deformity, an ilizarov fixator was once again applied.

Late follow-ups (1 to 14 years) were traced in 197 patients making 80,7% of all patients treated. Studying late follow-ups, the following was taken into consideration:

1. Absence or presence of pain at fracture site and in the adjacent joints during active and passive motion.

2. Roentgenological characteristic of fragment consolidation and restorationa of anatomical shape.

3. Restoration of shoulder and elbow range of motion

4. Restoration of muscle power.

treatment results were evaluated with a four-mark system: excellent, good, fair and poor. (Table 1).

Table 1

Fracture level /Mark	Proximal Humerus	Humeral Shaft	Distal Humerus	Total	%
Excellent	38	39	97	174	87,8
Good	1	3	18	22	11,2
Fair	-	1	-	1	1,0
Total	40	43	115	197	100,0

As seen from table 1, the majority of the studied patients (196 -99%) had excellent and good results and only one case) 1%) was considered since the patient had angular (varus-antecurvatum) hemeral deformity.

Three clinical example are given below to illustrate the application of the ilizarov transosseuos osteosynthesis in children with humeral fractures.

CASE 1 :

A 12 year old boy, fell 2,5 m and hit the ground with his left shoulder. A regional hospital used mask anaesthesia for double fragment reposition and posterior cast splint. Roentgenological check-up demonstrated unsatisfactory position.

Nine hours after trauma, the patient was admitted to Kurgan Center. Diagnosis on admission - closed adduction multifragmental fracture of the surgical neck of the left humerus. After corresponding preoperative preparation, mask anaesthesia was used for closed transosseuos osteosynthesis of the left humerus with ilizarov fixator. Fragment reposition was achieved in operation theater. The fixator was removed 15 days after fixation since fragment consolidation was achieved.

The late follow-up was studied 2 years after treatment and stated complete anatomical and functional restoration of the affected limb.

CASE 2 :

7 year old boy fell in a 3 meter pit and hit the ground with his right shoulder. Two hours after the trauma, the patient was admitted to the Kurgan Center. diagnosis on admission: closed transverse fracture in the midshaft of the right humurus. After the corresponding preoperative preparation, mask anaesthesia was used for the closed transosseuos osteosynthesis of the right humerus. The fracture was reduced on the operation table. fixator was removed from humerus after 35 days of fixation - fragment consolidation was achieved.

The follow-up was studied 3 years after the traetment - complete anatomic and functional recovery of the affected limb was reached.

CASE 3 :

Twelve year old boy had fallen on a straightened left arm in the gymnasium. Threee hours after the trauma, the papatient was admitted to Kurgan center. Diagnosis on admission: closed intraarticular transcondular fracture of the left distal humerus. After corresponding preoperative preparation, a Kulenkampf conduction anaesthesia of the brachial plexus was used for the closed transosseuos osteosynthesis of the left humerus. The fracture was reduced on the operation table. The fixator was removed from the humerus after 20 days of fixation - fragment consolidated. The late follow-up was studied 2,5 years after the treatment - complete anatomic and functional restoration of the affected limb was achieved.

The study of extensive clinical material demonstrated that:

1. The ilizarov method of transosseuos osteosynthesis applied for humeral fractures in children causes little trauma, and is well tolerated by the patients.

2. The versatality of the ilizarov fixator design, allows, depending on fracture site and type, to make various assemblies, using a minimum number of parts for the children.

3. Closed, precise repositioning, with a stable fixation, and an early full-value functional treatment, creates optimum conditions for complete anatomic and fuctional recovery within short periods, by combining the periods of consolidation and functional recovery.

4. Mistakes and complications occuring during the period of the mastering of the transosseuos osteosynthesis technique for humeral fractures in children, being revealed and corrected in time, did not have any serious negative effect on the positive treatment results.

5. A large percentage of excellent and good results, in the managemnt of pediatric humeral fractures, proves the high efficacy of the ilizarov transosseuos osteosynthesis, and allows to recommend its introduction for the treatment of the said injuries.

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MORPHOFUNCTIONAL PECULIARITIES AND SPACE POSITION OF HEMOMICIRCULATORY VESSELS OF SUPERFICIAL FASCIA OF THE LENGTHENING LIMB

V. I. Shevtsov, Y.M. Iryanov, N.V. Petrovskaya

The hemomicrocirulatory bed of the superficial fascia of canine tibia, after flexion osteoclasia of the tibial bones was studied with electronic microscopy in corrosion injection vascular replicas and compared with that of intact adult animals and 6-8 month old puppies, at three different moments i.e at 5 days, 28 days and 42 days after the operation.

Angioarchitectonics of the superficial fasicia in intact adult dogs is characterized by the presence of triadae, comprising terminal artery and two accompanying parallel veins, which go in different directions, like singular capillares, while in puppies they have mainly longitudinal orientation.

By the time of experiment (33 and 47 days after surgery) a a vascular complex of a typical zig-zag shape (fig. 1) is formed in the superficial fascia of the bone regenerate of the lengthening limb. This vascular complex is comprised of:

1) a circular placed terminal artery 60-75 mcm in diameter,

2) parallel to the above. Portions of the longitudinal terminal vein 150-200 mcm in diameter

3) two circular venules branching off it, 70-110 mcm in diameter

4) two paraarterial vascular plexi positioned proximally and distally from it.

The latter is surrounded by multiple venous tracts, 6-10 in munber. which is characteristic of tissues under long term tension stress in natural conditions.

Straight arterioles 25-30 mcm in diamete with even contours were branching from the termi nal artery every 700-1000 mcm i distal and proxima direction at an angle close to 80 degree whicl provided good supply to the exchange vessels o microcirculatory bed. Arterioles were placed alon the tension stress vector strictly in vertical directio and were accompanied by several parallel venulae Multiple arteriol-venular, arteriol-arteriolar an venulo-venular arcade anastomoses from a certai structure of direct and inverse blood flow, tha reminded a rope ladder at certain areas.

Precapillar arterioles, both parallel and per pendicular to each other, were branching off fro either vertical arterioles or directly from circula terminal artery (fig. 2). Vertical precapillar arteriole were 900-1100 mcm in length and were almos twice as long as circular arterioles that were 450 600 mcm with almost equal initial diameter of 15-2 mcm. The angle between precapillary arterioles an arterioles was 60-80 degrees and was open from th side of the blood flow, while the angulation wa oriented along the hemodynamic gradient, that be ing an important morphofunctional feature, al lowed to obtain objective information on directio of blood flow in different parts of arteriolar tract Examination of our preparations demonstrated tha in vertical arterioles blood moves, not in singl direction (from terminal artery to vertical arterioles) but, due to multiple arteriol-arterioloar anastomose there was a back blood flow (from aberant arteriole to the circular artery). There occured a heterogeni distribution of blood flow, when in the neighbourin arterioles blood flowed in opposite directions whicl improved the usage of arterial blood, providin intensive metabolism in the lengthening fascia.

The orientation of the microcirculatory bed of the superficial fascia of the lenfthening limb was characterised by recurrent zonal structure-functional complexes of microvessels - microcirculatory units (microcirculatory modules), oriented in vertical and circulatory directions. They were rectangular, romboid or polygonal shaped of identical structure, limited by venular and arteriolar trunks (fig.2,

They comprise arterioles, precapillary arterioles, precapillares, capillares, postcapillares, postcapillar venules and venules. Vertical microcirculatory complexes had a most complex structure and length equal to precapillar arterioles (up to 1100 mcm) which proved vector direction of fascial growth of the lengthening tibia under stimulating influence of tension stress, arised under gradual distraction of bone fragments.

Fig: 1

The forming microcirculatory modules were of different maturity. In those developing directly near acircular vascular complex close to the longitudinal vein and trunks, coming off it in vertical and circular directions, the microcirculatory bed was almost completely formed which had a complex 3D structure. In other modules this process was far from end and they looked like almost half-empty cells limited by venous trunks with an initial stage of microcirculatory bed formation in the corners of the cells (fig. 2).

Precapillar arterioles are the main sourse of microcirculatory modules blood supply. Here they placed along their longitudinal axis parallel to one of peripheric venulea or diagonally between two venules. Precapillary arterioules stert 5-6 precapillares which were formed by side or end V-shaped dichotomic branches. This created a dense capillary network with polymorphous loops and were placed mostly longitudinally. Short postcapillary trunks were formed by two capillares and entered into postcapillar venules, bringing blood into venules at the edge of the modules. The lenght of longitudinal microcirulatory modules measured 900-1100 * 500-600 mcm, while circular modules were 450-600 * 200 -300 mcm long.

Analysing pecularities of incoming blood vessels, that were presented with precapillary arterioles, precapillares and outgoing vessles, formed with a complex of postcapillares, postcapillar and collective venulae, a peculiar structure of microvessels in the modules could be noted. Two separte poles were formed: arteriolar and venular with concentration of the same type of vessels. The arteriolar pole was closer to the circular terminal artery, while the venular pole was situated at the oppsite side. This proved that connection of the modular microvessels was made in accordance with the hemodynamic gradient direction which has mostly a centrifugal direction.

Precapillar arterioles, giving 5 - 6 precapllares, provided 2- 3 neighboring microcirculatory modules, with blood, giving them in this way additional bloodsupply, alongside with their main source, their own precapillar arterioles.

Precapillares had an initial diameter of about 8-10 mcm and they dichotomically separated into two trunks. Each of them made 3-4 capillares by side branching and a couple more by terminal branching. Therefore, One precapillar makes 10-12 caplliares. Since several precapillares took part in blood supply, the total number of capillares in microcirculatory module shaped along the tension stress vector was 20-22.

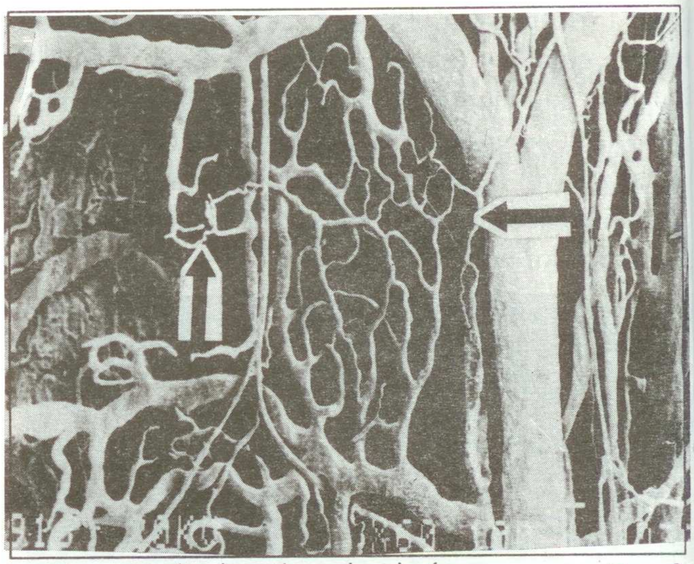
Each precapillary branched together with its capillares joining into a postcapillary. One postcapillary venula formed an elementary working subunit of microcirculatory module. It was possible to reveal 5-6 such subunits 500-600 * 300 mcm long in a mature microcirculatory module that had mostly a vertical orientation as the module itself. Despite a certain structural and functional independence, microvascular networks of the elementry sub units were gathered into common vascular system of the module functioning as one unit.

In non-mature microcirculatory modules 600-700 mcm laterally and medially of the central longitudinal vein (fig. 2) local working subunits had rather simple structure and were not connected with each other. Blood came to them from thin precapillares, oriented at 40-60 degrees, or at a right angle to the tension stress vector, formed after side or terminal branching of an arteriole. One forming working subunit containedbeside precapillare, 1-2 parallel postcapillar venules 100-250 mcm of the length, which had the shape of a bush or a chandellier, oriented along the tension stress vector, 2-3 postcapillares entered them and short growing capillar terminales, had no ties with each other, nor a strict orientation.

It is to be noted that newly forming capillar terminales started mainly from venular vessels of the microcirculatory bed of the developing local subunits, while the growing arteriolar terminals spreaded over considerable distance without branching into capillares; only after 3-4 generations of dichotonic branching they became thinner, forming a long straight arteriolar-venular passage where a capillar can be distinguished only by its rather thick venular end.

Microcirculatory modules, formed by precapillar arterioles and venulae with circular orientation, and perpendicular to the tension stress vector, were characterized by concentrated vascular elements with considerably greater number of venules compared to the number of arterioles, a large number of venulo-venular and arterio-venular anestomoses which demonstrated a sideways circulation.

A part of precapillares coming directly into postcapillar and collective venulae provide rapid circulation. The cells of the formed vascular network had an almost rectangular shape and were perpendicular to the tension stress vector. Major capillaries in the modules are mostly vertical as the venulo-venular anastomoses were, while nutrient ones formed rectangular cells around vertical arteriolar and venular



trunks, enveloping them in circles.

Fig. 2

In the part of the circular vascular complex between the terminal artery and large longitudinal venous trunks, the microcirculatory modules were formed mainly from two working subunits, supplied with blood by one precapillary arteriole (fig. 1)). The latter was separated into two branches each of them started 2-3 nutrient capillares 160-200 mcm long forming longitudnal and perpendicular closed ellypsoid cells, neighboring local subunits of which were connected through long communication capillares 400-500 mcm long. The capillares enter short postcapillar venules, or directly, collective venules, frequently forming closed round circular structures gathering into two parallel veins, accompanying the artery.

Proximally and distally from the circular terminal artery there was a dense vascular network of paraateriolar junctions with multiple venous vessels (fig.1). They were represented by large T-shape branching venulae, anastomosing with vertical and circular trunks, and also, by multiple collective and postcapillar venulae placed along the circular arterial surface. Bloodsupply of paraarterial vascular junctions was provided through precapillar arterioles, which branched off vertical terminal arterioles and dichotonically separated into capillares, while modular structure of the micricirculatory bed of paraarterial junction was not clearly marked. Each branch of precapillar arteriol started 6-8 capillares that were mostly of the major group, and formed circular arterio-venular passages that acted as additional collaterales.

Therefore, the studies conducted have demonstrated a number of peculiarities of angioarchitectonics of the superficial fascia of the lengthening tibia, which to our opinion, proves active vasculogenesis, especially marked in the venular part of microcirculatory bed which acquires greater volume and length compared to the arterial one. Largest in numbers are venous vessels in paraaterial vascular junctions, shaped around the terminal circular artery. Such vascular complexes are described by a number of authors in different tissue types, e.g. in the tail offlipper of dolphin (A. G. Tomilin, 1951; V. V. Kuprianov, 1993), in abdomen (J. L Karaganov, V. V. Banin, 1973), in mesentery (V. P. Tutatchikov, 1983), in serous cover of rectum (R. J. Krasnay, 1884), in pericardium (I. U Yuldashev, 1986) and in tissue under long term natural tension stress. Angiogenesis in the superficial fascia of the lengthening tibia is accompained with formation of new structural and functional microvascular complexes. Microcirculatory modules of longitudinal and circular orientation. Modules that proivide vector type growth of fascia under stimulating influence of tension stress have the greatest length.

Lengends for figures

Fig.1. Circular vascular complex forming at the level of distractional bone regenerate in the superficial fascia of the lengthening tibia. Straigth vertical arterioles accompained by venulae (arrow). A paraaterial vascular junction formed by multiple venous trunks is situated at both sides of the terminal artery. 42nd day of distraction. magnification 45.

Fig.2. Longitudinal structural functional microvascular complexes (microcirculatory modules); a mature (horizontal arrow) and a forming (vertical arrow) ones. 42nd day of distration. Magnification 45.

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