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ANATOMIC AND PHYSIOLOGICAL FEATURES OF DISTAL LOWER LEG AND THEIR INFLUENCE ON THE PROCESS OF OSTEOGENESIS

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Osteogenesis is the process of bone tissue forming, i.e. bone or callus regeneration. This process is influenced by many factors, and the degree of bone fragments' stability and vascularization in the fracture area are the basic local factors which determine the nature of reparative process. Regenerative process of all bone structures increases with increasing of blood supply.

The distal lower leg has its specific biomechanical features, and plays an important role in the transfer of body weight to foot. The distal part of tibia has a small diameter, which as a consequence has reduced diameter in medullar cave. Through this anatomic feature, the medullar network in the lower tibia part is also reduced.

As for anatomic aspect, vascularization in the lower end of tibia is poor. It primarily depends on periosteal vascularization, because medullar vascularization is reduced. Fasciae, tendons and skin cover the lower part of the leg, and there is no muscle mass. These tissues have poor vascular network and that is why the extraosseous blood circulation in tibia is poor, and does not participate in the osteogenesis process. For these reasons, distal lower leg represents a predelection site for delayed osteogenesis and pseudoarthrosys development.

Osteosynthesis causes secondary damage to bone and soft tissue circulation. The screw plate damages the periosteal circulation – in the lower part of tibia it is the main source of vascularization, and for this reason, this method of osteosynthesis should not be applied. The external fixator has a sparing role regarding vascularization, and that is the reason why this method is recommended for fracture stabilization at the level of distal lower leg. *Acta Medica Medianae 2010;49(2):51-55.*

***Key words**: distal lower leg, bone vascularization, osteogenesis*

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Introduction

Final structural aim in fracture healing is the reconstruction of original cortical bone. The bone tissue is regenerated "ad integrum", by generating the same tissue in a regenerate, and not by making a scar in some other tissues. The post-traumatic reaction in circulation is characterised by compromised local metabolic-circulation status, tissue hypoxia, accumulation of metabolites, capilarry dilatation and increased propulsion in blood vessels – tissue disorganization and increased blood circulation occurs at the bone fracture spot (1).

Within 8-16 hours after trauma the cell proliferation begins, i.e. osteogenesis process (2-5). This process is influenced by many factors: type of injured bone, localization and type of fracture, degree of development and damage in bone vascularization at the fracture level, degree of trauma, loss of bone tissue, degree of fragments' dislocation, degree of fracture reduction, fracture stability, surgical operation, type of osteosynthesis, etc.

Each segment in extremities has particular anatomic features and biomechanical characteristics, which grants its specificity and various approaches in healing the trauma. The distal part of the lower leg has specific biomechanic and anatomic features, that is the reason why there are so many cases of unhealed fractures and exogenous osteomyelitis. These are quite serious and grave complications, which require long-term and expensive treatment, and which are very often followed by disability.

The aim of the paper was to indicate the specificities of the lower leg segment from the anatomic – physiologic aspect and to explain frequent cases of unhealed fractures in the distal lower leg, and also the occurrence of osteitis.

Biomechanic features of distal lower leg

Tibia in its leg segment has an eccentric position - its front internal side is covered only by skin, while its rear external side is covered by muscle mass.

Its strength is 23±0,27 kg/mm^2, and elasticity module is 1673±80,2 kg/mm^2 (6). High degree of strength and elasticity is the result of specific structure where a small number of cells are immersed in a large quantity of intercelullar substance which is composed of mineralized colagen fibres and cement. The above mentioned features are equal to the features of cast iron, with only difference that tibia is three times lighter and ten times more flexible (7,8). This provides a possibility to receive and transfer body weight from knee to foot. To perform this function, a considerable reduction in bone diameter develops in the lower half of tibia. Thereby, there is no loss of stroma, yet bone density is even increased. The relation of medullar cave diameter and cortex is 1:2,5-3, which indicates a disproportion between small space taken by medullar core and large compact mass of bone substance. This relation causes a considerable reduction in medullar circulation and a local bone vascularization, and therefore, the degree of osteogenesis process and resistance to infection is reduced.

Vascular features of distal lower leg

Adequate supply of blood is the basis for vitality and bone growth, infection resistance and ability of fracture healing. Extraosseous blood network of tibia is made of a.nutriens, metaphysic-epiphysic arteries and periosteal arteries.

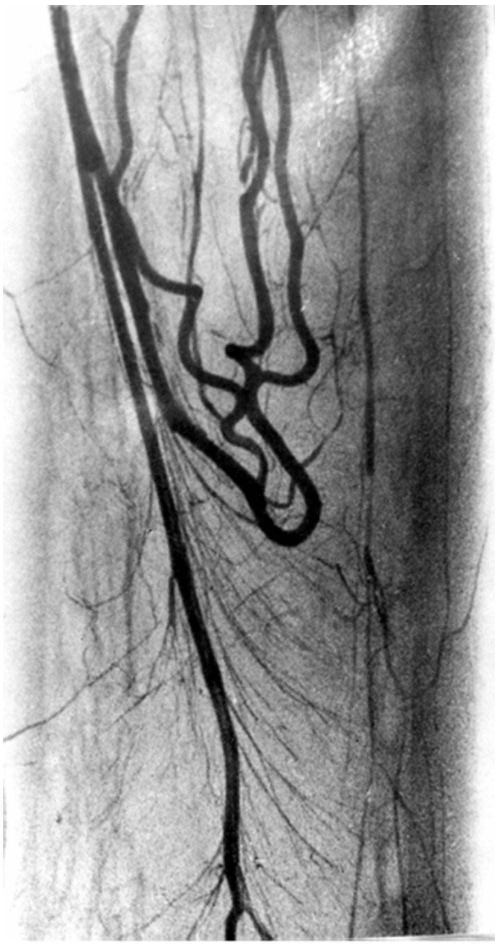

Figure 1. Vascular knot a.nutriens

A. nutriens tibialis is the front branch of a.tibialis posterior. It enters the nutritive groove in the rear tibia side, which is long from 1 to 3,7 cm, and then the foramen nutriens which is located at the juncture of the middle and proximal third of diaphysis. When entering the medullar channel, a.nutriens is branching in ascendent and descendent branch. The ascendent branch is lowering down and soon changes direction, mounts up by building the so- called vascular knot. It is devided in three and more branches which mount up rectangularly to the proximal metaphysis. The descending branch lowers down, lies near the rear side of the medullar cave and ends in a vascular bundle, which anastomoses with epi-metaphysic dense net of arterioles (Figure 1). The branches of a.nutriens in medulla do not anastomose (5,9-12).

Usually, medullar circulation network feeds internal ⅔ of the cortex, while vascularisation for the external third is provided by periosteal arteries. Cortical circulation in the distal part of tibia is weak. In this part it does not depend on medullar circulation, which is usual for other bones since medullar circulation is poorly developed. Circulation in the distal part of tibia cortex depends on the network of blood vessels of periosteal origin – which is the reason why this part of tibia is the poorest area in vascularization, when compared to vascularization in other bones.

Periosteal arteries are numerous, short and of small calibre. Periosteum gets blood vessels from three systems: musculoperiosteal system, fascioperiosteal system and directly from segment arteries (13). Musculoperiosteal system is evident in places where muscle is attached to the periosteum by Sharpey's fibres. Fascioperiosteal system consists of the limb branch arteries. It enters intermuscular septum and builds this system.

The source of vascular network of tibia periosteum is a.tibialis anterior (14). It lowers down the front surface of membranae interosseae and on its surface emerge the side branches (Figure 2). They are horizontal and at the juncture where membrane attaches to tibia there emerge two branches – one of them goes toward the rear surface of tibia, and another toward the external surface. These transversal vessels are connected by small longitudinal vessels. Tibia capilarry network is an entity which makes connection among capilarry networks of periosteum, medullar cave and metaphysis. In the proximal part of tibia cortex, the capilars, in larger part, emerge from medullar cave and go transversally down and toward external part. The periosteal supply is weak. In the middle bone part, there is an equal participation of periosteal and medullar capillaries. In the distal part, the supply of medullar origin disappears. Cortical capillaries and vascularization of this part depend on periosteal network.

The soft tissues that surround the bone are sources of large number of periosteal branches, they build additional vascular system between periosteum and soft tissue, and before all, muscles. The distal lower leg is deprived of muscle junctures, over it there are tendons and fascia, and it is covered by skin. The mentioned anatomic elements do not provide side periosteal branches. Peribone soft tissue of lower leg distal part can not form additional extrabone vascular system – usually it is the first one to be involved in osteogenetic process and fight against infection.

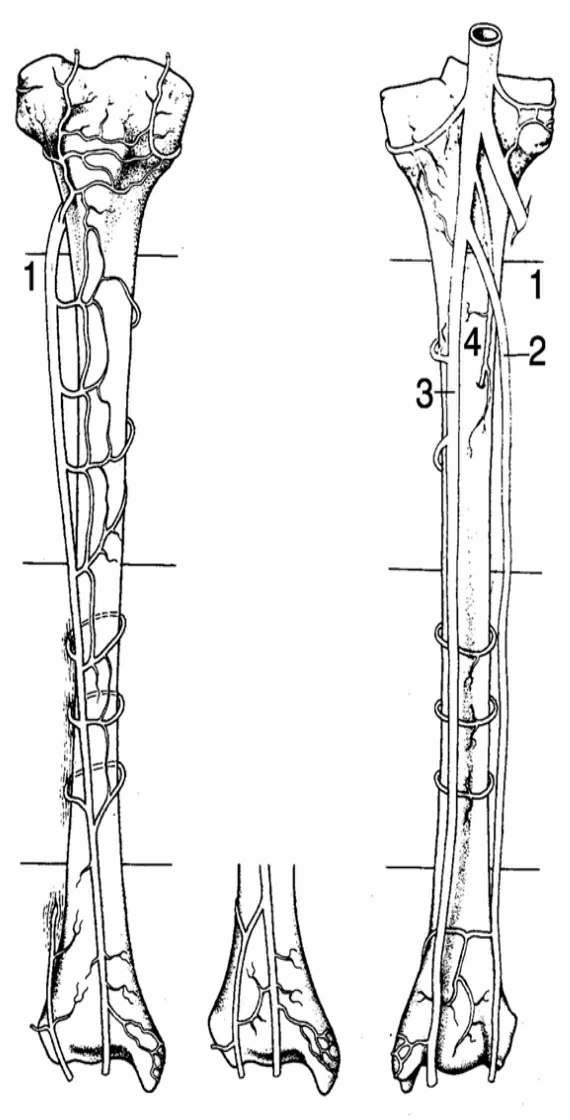

Figure 2. Arteries in tibia periosteum

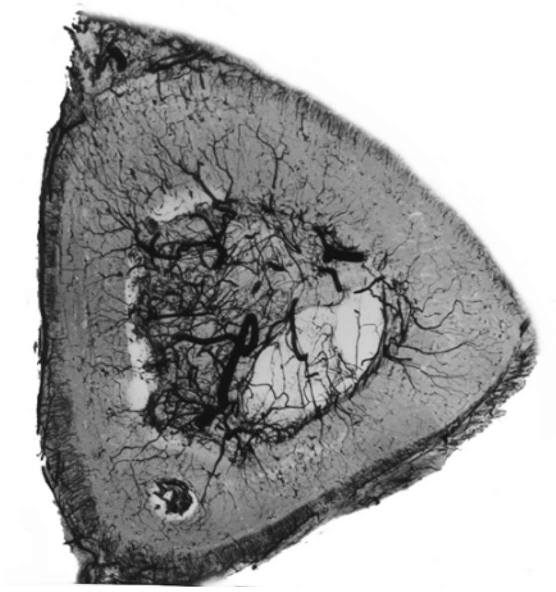

Figure 3. Angiogram of deperiosted bone. Unequally filled blood vessels by contrast mass at the place of deperiosted bone (Zone A)

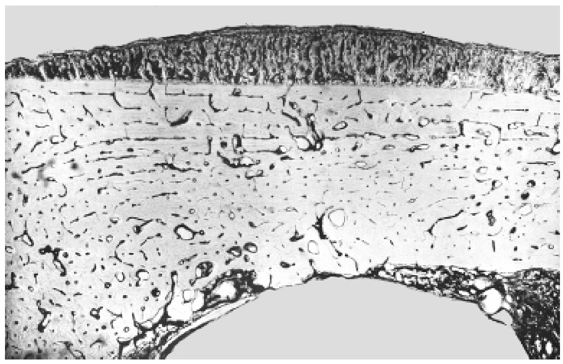

Figure 4. Non-vascularity of cortex and medulla after placement of medullary nail

Having in mind all these distal lower leg vascular features, one must conclude that it is necessary to be cautious with distal tibia osteosyntesis, i.e. secondary damage in bone circulation which occurs during osteosyntesis must be at its minimum (15). In order to meet this requirement, it is necessary to respect the relationship between the type of osteosyntesis and bone vascularization. During plate application there is always a possibility of damage to periosteal vascularization (due to bone deperiosteumation) and extraosseous source of vascularization (smaller or larger damages in soft tissues during surgery). The cortex at the spot where screwed plate is located has reduced vascularization (Figure 3). Intramedullar nail destroys the whole medullar vascular network. In this way, a.nutriens branches are devastated which further compromises vascularization of internal ⅔ of cortex (Figure 4). Wires or nails, which are constituent parts of external fixator do not disturb bone tissue vascularization. They pass through the periosteum, cortex and medulla in one spot, and their penetration causes only minimum damages to circulation network (1,16-23).

Distal leg skin cover

The skin within leg area is the only cover of bone so that it is exposed to direct influence of trauma, especially at the front internal side where it directly lies on tibia – and that is the reason why it is so often exposed to internal traumas with indirect fractures.

Feeding of the leg skin, i.e. vascular network, is relatively poor, especially in the front part which is the most exposed to trauma. Tibia fracture is followed by bleeding and swelling, the skin becomes ischemic, regional capillary paralysis develops, followed by the appearance of hemorrhagic bullas. They most often appear in the lower third of the leg. They present a relative danger for infection in soft and bone tissues, and that delays or stops the osteogenesis process. The period of hemorrhagic bullas' occurrence with the closed type of leg fracture is: first half an hour 1%, after one hour 2%, after three hours 12%, and after six hours 28%, after 24 hours 43%, and then the occurrence of bullas is reduced, so that after 48 hours hemorrhagic bullas occur in 13% of cases.

Discussion and Conclusion

The distal part of the lower leg has its specificities from anatomic-physiological aspect, which gives it higher vulnerability with respect to osteogenesis process and possibility of secondary bone tissue infection after osteosynthesis.

The distal tibia part is oval, it narrows its medullar channel and enlarges cortex thickness, whereby it deprives itself of medullar circulation. The bone vascular network depends on periosteal circulation, but it is also weak, it is better developed in the rear-external part – and this is the reason why callus is first formed in this place.

The osteosynthesis in distal tibia provides stability in bone fragments, but it also causes secondary damages in osteogenic elements and undermines conditions in local circulation. Various methods of osteosynthesis cause different damages to bone vascularization: plate with screws disturbs periosteal circulation, intramedullar nail destroys medullar vascularization, while nails and needles of external fixator cause minimum damages to bone vascularization (1,5,12,16-19).

The distal lower leg skin is poorly supplied by blood and it adheres to tibia at the front side, and this is where it is most often exposed to injuries. Its protective role is high, especially when we know that distal tibia, fascie and tendons are relatively avascular tissues (7,8).

After fracture reduction, there are two factors which are important for the osteogenesis process and which guarantee that there would be no bone infection – and in addition provide fracture stabilility, osteosynthesis and blood supply in the fracture area.

The distal lower leg is the part which has the poorest vascular network, and therefore it represents the place of delayed osteogenesis with the possibility of secondary infection. Thus, one should save bone circulation in distal tibia, avoid osteosynthesis with screwed plate, and often apply the method of external fixation for fracture stabilization – which spares bone and soft tissue vascularization (12,18,21-23).

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ANATOMSKE I FIZIOLOŠKE ODLIKE DISTALNOG DELA POTKOLENICE I NJIHOV UTICAJ NA PROCES OSTEOGENEZE

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Proces osteogeneze je proces formiranja koštanog tkiva, tj. regenerata kosti ili kalusa. Na proces osteogeneze utiču mnogi faktori, a stepen stabilnosti koštanih fragmenata i vaskularizacija u zoni preloma su osnovni mesni faktori koji opredeljuju karakter reparativnog procesa. Regenerativni proces svih koštanih struktura povećava se sa povećanjem protoka krvi.

Distalna potkolenica ima specifične biomehaničke karakteristike zato što ima važnu ulogu u prenosu težine tela na stopalo. Distalni deo tibije ima mali prečnik, i to na račun smanjenja dijametra medularne šupljine. Ovim anatomskim obeležjem redukovana je medularna mreža donjeg dela tibije.

Sa anatomskog aspekta, vaskularizacija donjeg okrajka tibije je siromašna. Ona zavisi pre svega od periostalne vaskularizacije jer je medularna redukovana. Fascije, tetive i koža pokrivaju donji deo potkolenice, a nema mišićne mase. Ova tkiva su siromašna vaskularnom mrežom pa je zbog toga i ekstraosalni krvotok tibije slab i ne učestvuje u procesu osteogeneze. Iz ovih razloga distalna potkolenica predstavlja predilekciono mesto usporene osteogeneze i stvaranja pseudoartroza.

Osteosinteza izaziva sekundarno oštećenje cirkulacije kosti i mekih tkiva. Ploča sa šrafovima oštećuje periostalnu cirkulaciju-ona je u donjem delu tibije glavni izvor vaskularizacije, i zbog toga ovu metodu osteosinteze ne treba primenjivati. Poštedna je uloga spoljnog fiksatora u odnosu na vaskularizaciju, pa zbog toga se ova metoda i preporučuje za stabilizaciju preloma u nivou distalne potkolenice. *Acta Medica Medianae 2010;49(2):51-55.*

Ključne reči: *distalna potkolenica, vaskularizacija kostiju, osteogeneza*