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MSCT semiotics of muscles in chronic osteomyelitis of the femur and lower leg

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Abstract

Introduction It is known that the function and structure of the muscles of the thigh and lower leg are closely related to the function of the lower limb, which is impaired to one degree or another in all patients with chronic osteomyelitis. However, the nature of structural changes in the muscles, which, in turn, affect the condition of the bones, has not been well studied. **Purpose of the work** To study the features of changes in the muscles of the thigh and lower leg in patients with chronic osteomyelitis according to MSCT data. **Material and methods** The study is retrospective conducted at a single centre of Evidence level IV. Multislice computed tomography (MSCT) was used in 112 patients with chronic osteomyelitis of long bones of the lower extremities to study the radiological morphology of the muscles of the thigh and lower leg, including density, muscle belly area, and anatomical features. Twenty patients had chronic osteomyelitis in the area of transosseous elements (pins). The mean age of the patients was 48.5 ± 9.8 years. Males prevailed among the patients (87.5 %). The cause of osteomyelitis in 107 cases was trauma or surgery, five patients had consequences of hematogenous osteomyelitis. **Results** The results of the study showed that the muscles of the thigh and lower leg in patients with chronic osteomyelitis have pronounced dystrophic changes. In 89.4 % of patients, they were manifested by an increase in the density of the anterior tibial muscle, long extensor of the toes (84.7 %), peroneal muscles (78.5 %) and a decrease in the density of the head of the gastrocnemius muscle (91.3 %). In 10.6 % of the patients, there was a decrease in the density of the anterior tibial muscle, the long extensor of the fingers. In all patients with chronic osteomyelitis of the femur, the density of the muscles of the anterior and posterior groups was reduced, except for the musculus vastus intermedius of the thigh that was characterized by fibrotic changes with an increase in density. **Conclusion** The data obtained indicate that radiological morphological changes in muscles occur in all patients with chronic osteomyelitis of the femur and lower leg. The most pronounced alterations in the architectonics were in the anterior tibial and gastrocnemius muscles, and the intermediate broad muscle of the thigh.

Keywords: chronic osteomyelitis, long bones, MSCT, thigh and leg muscles

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Osteomyelitis has challenged orthopedic surgeons for many decades and, most likely, the problems of chronic osteomyelitis will remain relevant and difficult for specialists of various profiles in the near future [1–5]. An increase in the number of injuries, surgical interventions in orthopedic pathology, the emergence of resistant and multiresistant bacteria create new problems in post-traumatic and postoperative chronic osteomyelitis, which remains a stumbling block for current orthopedics [6–8]. However, improved imaging techniques, especially radiodiagnosis, are able to solve many diagnostic problems, while future developments in immunology, microbiology, and pharmacotherapy will undoubtedly help in treatment [9]. The role of radiological diagnostics in improving the results of the prevention and treatment of chronic osteomyelitis has been shown in a relatively small number of works [10, 11]. There are practically no specific indications about the role of radiological diagnostics in relation to chronic osteomyelitis, namely, the influence of its competent and practical use to improve treatment results. Undoubtedly, the maximum attention of orthopedists and radiologists in the study of the clinical picture and the data of radiological methods in patients with chronic osteomyelitis is riveted to bone changes, since in many cases it is the condition of the bone that determines the tactics and methods of treating this complex pathology [11]. According to the classification of Cierny et al. (2003), the second, third and fourth stages can develop both after hematogenous and secondary osteomyelitis [12]. This is a known fact, but the point, in this case, is that in both conditions, the bone is damaged and soft tissues change, including the muscles, only in a different sequence [13]. The nature and extent of bone changes in chronic osteomyelitis have been studied for many decades, and the data obtained are used to resolve the issue of treatment methods [2, 12]. As for changes in muscles or soft tissues in chronic osteomyelitis, single studies have studied anatomical, histological and immunological changes in them without analyzing how these changes affect the structure of the bone, since they are anatomically and biomechanically closely related [14]. Our studies have shown that in any location of the osteomyelitic process, the structure of the bone changes throughout its entire length [10]. There are several reasons for this: the influence of inflammation, limitation of load on the limb or lack of its function, muscle dysfunction, as evidenced by the data of Zhan Shi et al. (2018) [15]. Pronounced bone changes in chronic recurrent osteomyelitis, repeated surgical interventions, limitation of limb function lead to alterations in the muscle, the nature of which (atrophy, dystrophic changes), in turn, affects the state of the bone, especially the subchondral bone, apophyses, leading to secondary bone changes. [16]. Studies conducted by Zhan Shi et al. (2018) showed that when the magnitude of muscle atrophy after Botax injection into masticatory muscles exceeded the metabolic balance, degraded remodeling was not limited to cartilage but also led to subchondral bone involvement [15]. This is an extremely important conclusion, which can partly be used to explain changes in the bone throughout its extension in patients with chronic osteomyelitis, provided that the focus of inflammation is localized in a limited area of the bone. Moreover, there are a large number of works that indicate a decrease in muscle function and their hypotrophy in various bone diseases, including osteoarthritis [17, 19]. The changes in the gluteal muscles in patients with aseptic necrosis of the femoral head and Legg-Calve-Perthes disease, which are manifested by anatomical (area, thickness, length) and radiological morphological disorders, depend on the stage of the disease, the age of the patients and the duration of the disease, and show a close relationship with anatomy and function of the joint (its bone component) and muscles [19]. Many other works have shown a close relationship between bone and muscle function and, despite the insufficient understanding of the pathways that regulate these homeostatic mechanisms, a bidirectional cross-talk between osteocytes and muscles is evident [20–24]. The relationship between muscle and bone was considered self-evident for many years, but only in recent decades has this been confirmed by direct measurement of muscle and bone mass. A number of studies have shown that appendicular skeletal muscle mass and muscle CSA are positively correlated with BMD in some areas of the body [25–31]. Bone adapts its morphology and strength to long-term stress caused by muscle contraction as a result of physical stress and gravity [32]. There is a close relationship between bone and muscle from embryogenesis, growth and development to aging. Throughout life, bones and muscles integrate with each other and work physically and biochemically as one entity. Muscle-related diseases usually affect the bones and vice versa. Understanding the mechanical, cellular, and molecular mechanisms responsible for the biochemical bond between bone and muscle is important as a means to identify potential novel therapies that can simultaneously have a positive effect on bone and muscle [23, 24, 33]. Due to the fact that muscles play a vital role in developing bone strength, providing mechanical protection, and maintaining or repairing skeletal tissue, it is important to study muscles and bones simultaneously by screening, monitoring, or studying skeletal health or potential fracture risk, and for developing preventive or therapeutic intervention programs. [22, 34–37].

Purpose To study the condition of the muscles of the thigh and lower leg with the method of MSCT in patients with osteomyelitis.

Study design The state of the muscles of the thigh and lower leg was studied with the use of MSCT in 112 patients with chronic osteomyelitis of the femur and tibia, who were admitted for treatment at the departments of the Ilizarov Centre in 2018-2020. The study is a retrospective at a single center, level of evidence - IV (according to UK Oxford, version 2009). The inclusion criteria were chronic osteomyelitis of long bones of the lower extremities in patients aged 18 to 65 years, a complete MSCT archive available for studying muscles with post-processing data. Exclusion criteria were age over 65 years, total bone involvement, unavailable complete MSCT archive with the presence of a special reconstruction algorithm "Soft Tissue". Materials for the study were obtained in compliance with the ethical standards of the Declaration of Helsinki of the World Medical Association, as amended by the Ministry of Health of the Russian Federation. All patients participating in the study gave informed consent to the publication of the obtained data without identification.

MATERIAL AND METHODS

The group of the study consisted of 112 patients. Twenty patients had chronic osteomyelitis in the area of transosseous elements (wires or half-pins). The mean age of the patients was 48.5 ± 9.8 years. Among the patients, males prevailed (87.5 %). The cause of osteomyelitis in 107 cases was trauma or surgery, and five patients had consequences of hematogenous osteomyelitis.

Polypositional radiography and multislice computed tomography (MSCT) were used in 112 patients. The study used computed tomography systems "Toshiba Aquilion-64", "GE Light Speed VCT". MSCT was performed using a special reconstruction algorithm "Sft Tissue". Axial sections were processed in the multiplanar reconstruction (MPR) mode in the coronal and sagittal planes. To study the muscles before treatment on axial sections, the area, total and local density (Hounsfield units (HU)) of the tibial and gastrocnemius muscles, the long extensor of the toes in the upper and middle third of the thigh or lower leg were measured with the construction of histograms. When measuring the total area, the muscle under study was contoured on the axial section with automatic determination of the area and density. If possible, similar parameters were determined for the contralateral limb (Fig. 1).

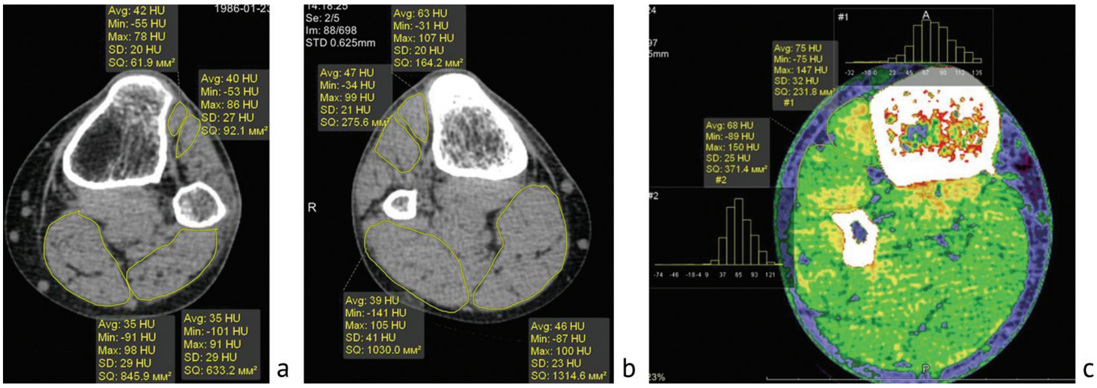

Fig. 1 MSCT of the lower legs of patients with chronic osteomyelitis. Axial sections. Measurement of the density and area of the muscles of the involved and contralateral limb (a, b). Measurement of muscle density and area with the construction of histograms (c)

RESULTS

Based on anatomical studies, it is known that normally the transverse section of the bellies of the tibial and gastrocnemius muscles, the long extensor of the toes, the rectus and intermedius, sartorius, glacialis muscles, the biceps femoris in the upper and middle third of the thigh or lower leg has a certain shape [38], that can change due to muscle hypo- or atrophy. It is accompanied by an increase or decrease in density, a decrease in the area, and a change in the structure (Fig. 2).

The main differential diagnostic criterion for the severity of muscle morphological changes in patients with various pathologies is their average density [39–41]. According to various authors, muscle density ranges from 35 to 50 HU with various deviations for separate muscles of the limbs and trunk in normal and pathological conditions of the musculoskeletal system [39–43].

An analysis of the density of the muscles of the lower leg showed that in 89.4 % of patients the density of the anterior tibial muscle, the long extensor of the toes (84.7 %), the peroneal muscles (78.5 %) increased, and the density of the heads of the gastrocnemius muscle decreased (91.3 %). In 10.6 % of the examined, the density of the anterior tibial muscle, long extensor of the toes reduced to varying degrees (Fig. 3).

Not only density indicators but also muscle architectonics and their shape (Fig. 4) changed in patients with a long course of chronic osteomyelitis.

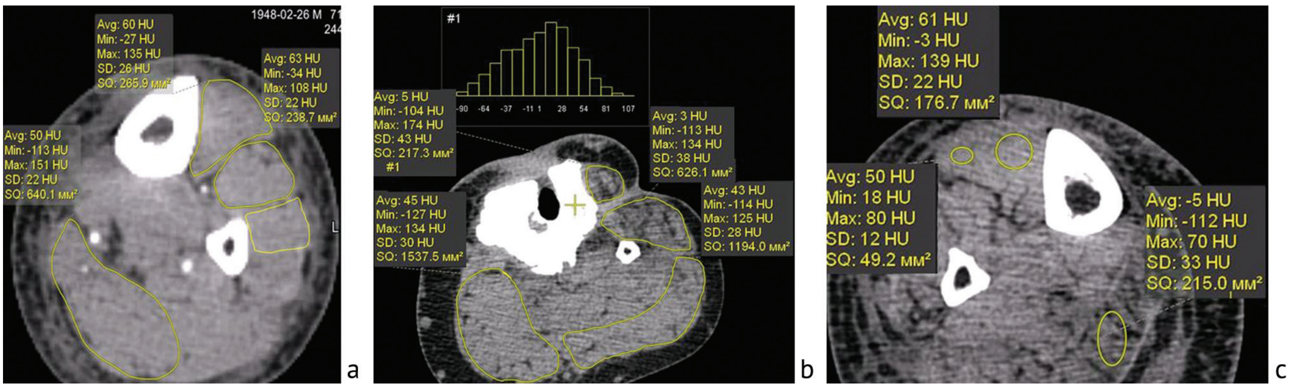

Fig. 2 MSCT of the lower legs of patients with chronic osteomyelitis. Axial sections: (a) contralateral limb of patient M., 56 years old, measurement of total muscle density and area; measurement of total density and area of muscles (b) and local density of calf muscles (c) in patients with chronic osteomyelitis of the tibia

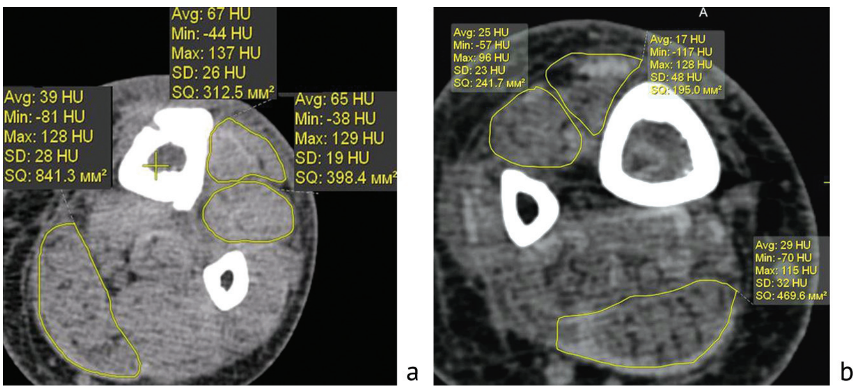

Fig. 3 MSCT of the lower legs in patients with chronic osteomyelitis. Axial sections. Increased density of the anterior tibial muscle, extensor digitorum longus, decreased density of the medial head of the gastrocnemius muscle (a); a decrease in the density of the anterior tibial muscle, long extensor of the toes, pronounced decrease in the density of the medial head of the gastrocnemius muscle (b)

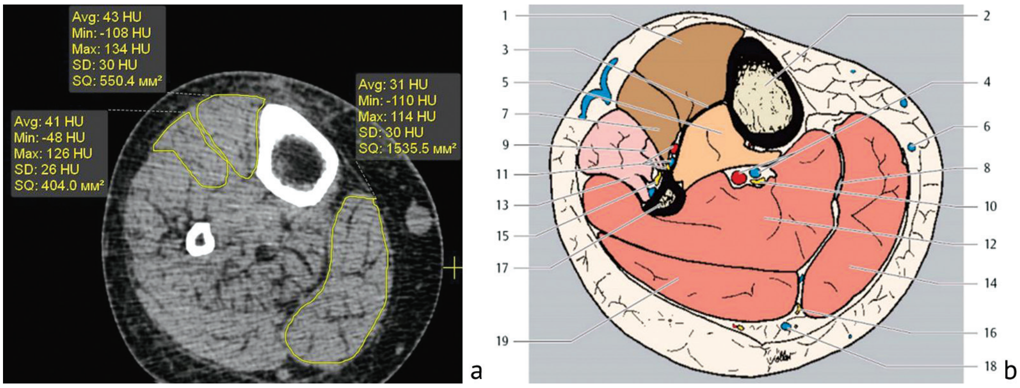

Fig. 4 MSCT of the lower leg of a patient with chronic osteomyelitis. Axial section (a). The shape of the tibial muscle (1), the long extensor of the toes (7) has been changed; wide connective-tissue gaps are visualized between the groups of muscle bundles, especially the gastrocnemius muscle (14, 19). Diagram of the anatomical section of the lower leg in the middle third (b) [46]

Table 1 presents data on the total density of the lower leg muscles in patients with chronic osteomyelitis (Table 1).

Table 1

Total density of lower leg muscles in patients with chronic osteomyelitis

Muscle	Density (HU), n = 50
Musculus tibialis	57.5 ± 8.811
Gastrocnemius	43.24 ± 8.74
Extensor digitorum longus	51.68 ± 6.542

[1,2] – $p < 0.001$ – difference between the density of the tibial muscle and extensor digitorum longus from the density of the medial head of the gastrocnemius muscle

The study of the local density of these muscles did not reveal any definite pattern, and the density of separate sections of the tibial muscle or the long extensor of the toes could reach 65-80 HU, and the medial head of the gastrocnemius muscle could be in the negative spectrum of the Hounsfield scale, what is due to pronounced changes in the muscle structure (Fig. 5).

The muscles of the thigh, especially the posterior group, had a lower density than the muscles of the lower leg, due to anatomical features. This pattern persisted for patients with chronic osteomyelitis. As a rule, only the interstitial muscle of the thigh had an increased density (Fig. 4).

Table 2 presents data on the density of the thigh muscles in patients with chronic osteomyelitis.

In addition to moderate dystrophic alterations, there were pronounced fatty and fibrotic changes in the muscles and subcutaneous fat (Fig. 7).

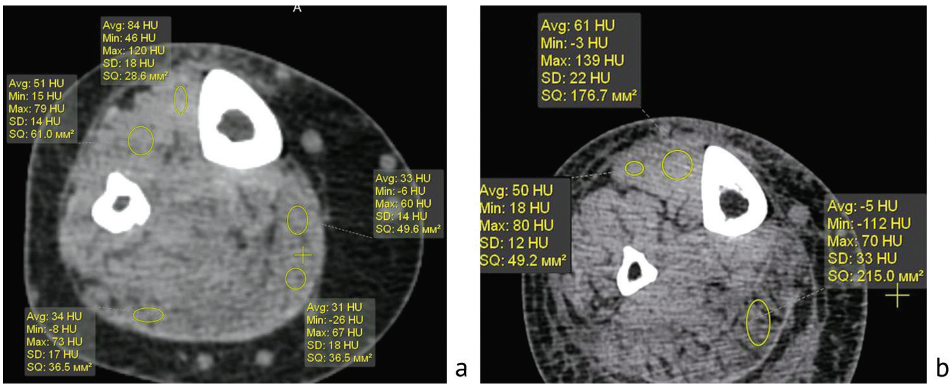

Fig. 5 MSCT of the lower leg in patients with chronic osteomyelitis. Axial sections. The local density of the tibial muscle is 84 ± 18 HU (a). and of medial head of the gastrocnemius muscle - 5 HU (b)

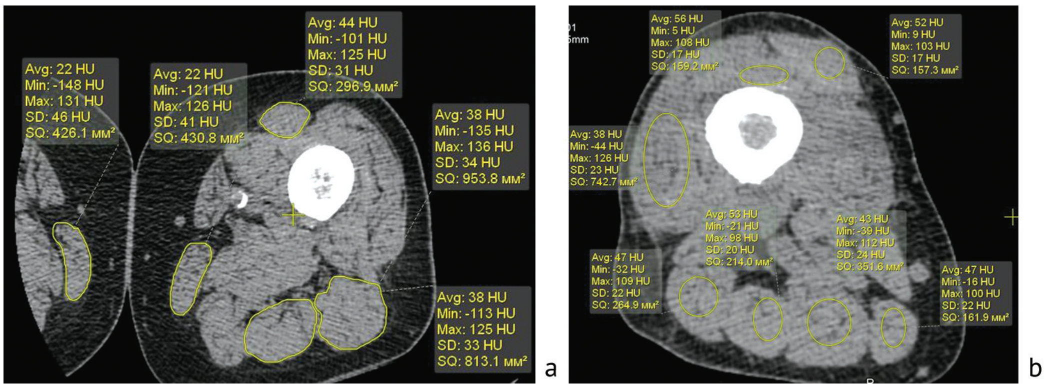

Fig. 6 MSCT of the femurs of patients with chronic osteomyelitis. Axial sections. Local density of the musculus intermedius 56 ± 17 HU (a, b)

Table 2

Femoral muscles density in patients with chronic osteomyelitus

Muscle	Density (HU). n = 20
Musculus rectus femoris	44.72 ± 7.34
Intermedius	56.41 ± 11.32
Sartorius	16.32 ± 9.561
Gracilis	39.14 ± 4.212
Biceps femoris (long head)	47.12 ± 5.34

[1,2] – $p < 0.01$ – difference in the density of the sartorius and glacialis muscles from the density of the rest of the muscles

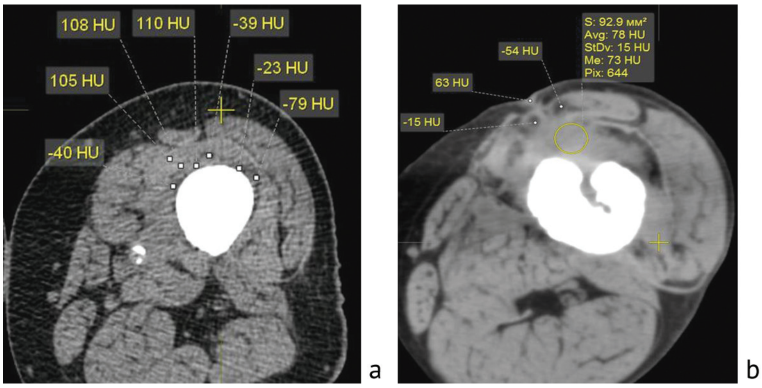

Fig. 7 MSCT of the thigh of a patient with chronic osteomyelitis. Axial section. Fatty and fibrous changes in the msculus intermedialis of the thigh (areas of density from -79 HU to +110 HU) (a); diffuse and local fibrotic changes in subcutaneous adipose tissue and quadriceps femoris. Retracted scar on the medial surface of the thigh (b)

The results of the study showed that the muscles of the thigh and lower leg in patients with chronic osteomyelitis have pronounced dystrophic alterations which in 89.4 % of patients were manifested by an increase in the density of the anterior tibial muscle, the long extensor of the toes (84.7 %), peroneal muscles (78.5 %) and a decrease in the density of the heads of the gastrocnemius muscle (91.3 %). In 10.6 % of the examined, there was a decrease in the density of the anterior tibial muscle and long extensor of the toes of varying grades. In all patients with chronic osteomyelitis of the thigh, the density of the muscles of the anterior and posterior groups was reduced, except for the intermediate group, which was characterized by diffuse and pronounced local fibrotic changes with an increase in density.

DISCUSSION

The rationale behind an imaging technique for studying skeletal muscle depends on availability, technical capability, experience of specialists, anatomical area of interest, and level of structural detail. The possible risks to the patient, the reproducibility of imaging protocols and analysis, and the value of measurements in diagnosing diseases must be considered. The radiodiagnostic methods as a standard for muscle study cannot be used due to economic problems and radiation exposure. However, there is the possibility of "opportunistic" screening, the use of the data from the studies conducted in conventional medical activities (not for studying muscles. for example. studying joints or the spine), to determine the area and density of muscles, which allow obtaining objective data and a more efficient use of the results of MSCT or MRI [44].

To study the muscles of the thigh and lower leg in patients with chronic osteomyelitis, the cross-sectional area and muscle density in the upper and middle thirds of the limb segment were studied. A number of works recommend studying the muscles in the middle third. However, given that it was necessary to assess the state of the gastrocnemius muscle, which most quickly responds to functional limitation, we also studied cross sections at the border of the upper and middle thirds, since the most massive part of the lateral and medial bellies is located at this level [44–46]. As shown by MSCT data, which was performed before treatment to identify the level and bone damage severity, the muscle changes depended on many factors: the duration of the disease, the number of surgical interventions, the nature and extent of destructive changes in the femur or tibia. The analysis of the revealed changes showed that the muscles of the thigh and lower leg in patients with chronic osteomyelitis have pronounced dystrophic alterations, which in 89.4 % of patients were manifested by an increase in the density of the anterior tibial muscle, the long extensor of the toes (84.7 %), the peroneal muscle (78.5 %) and a decrease in the density of the heads of the gastrocnemius muscle (91.3 %). In 10.6 % of the examined, there was a decrease in the density of the anterior tibial muscle and long extensor of the toes of varying grades. In all patients with chronic osteomyelitis of the thigh, the density of the muscles of the anterior and posterior groups was reduced, except for the intermediate group, which was characterized by diffuse and pronounced local fibrotic changes with an increase in density up to 56.41 ± 11.32 HU, and in some areas up to 100–110 HU.

CONCLUSION

The data obtained indicate that radiological morphological changes in muscles occur in all patients with chronic osteomyelitis of the femur and lower leg. The most pronounced alterations in the architectonics are found in the anterior tibial and gastrocnemius muscles, and the intermediate broad muscle of the thigh.

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