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A multifaceted osteomyelitis: radiological diagnosis

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Introduction Analysis of the literature and our own data confirm that changes in bone structure in chronic osteomyelitis vary in extension and severity, the boundaries of which are very difficult to determine. **Purpose** To analyze the extension of the lesion and the depth of bone structure destruction with the method of MSCT in various types of osteomyelitis and variants of its location. **Materials and methods** The study is retrospective and single-center. The method of polypositional radiography and multislice computed tomography (MSCT) was used to study the features of the X-ray morphology of the femur and tibia with a quantitative assessment of the density of various bone areas in 235 patients with chronic osteomyelitis. **Results** Chronic osteomyelitis was mostly located in the diaphysis of the femur (33) and tibia (52). Osteomyelitis in all cases was post-traumatic or post-surgical. Fourteen patients had pseudarthrosis or bone defect as a result of a long duration of the disease. Analysis of MSCT data showed that anatomical changes in the femur and tibia in chronic osteomyelitis were individual in all patients. Radiographic morphological manifestations consisted of general symptoms (osteoporosis, osteosclerosis, disorders in architectonics). However, the severity, extension and nature of the structural changes were extremely diverse. The change in bone density featured large deviations. **Conclusion** The data obtained indicate that the "imaging reality" in the diagnosis of chronic osteomyelitis is computed tomography as it enables to determine the extension and nature of bone changes, to detail various changes in anatomy and architectonics, indicating the "multifaceted character" of chronic osteomyelitis.

Keywords: chronic osteomyelitis, diagnosis, long bones, MSCT

INTRODUCTION

The XXI century, having behind it a centuries-old history of the treatment of chronic osteomyelitis, has not yet solved this medical problem. Analysis of literature has revealed a constant increase in the incidence of osteomyelitis after trauma, orthopedic surgery and significant economic costs of its treatment [1–7]. Despite the fact that chronic osteomyelitis as one of the "ancient" and still severe and difficult to treat diseases can be diagnosed with effective methods such as radiography, ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), PET / CT, PET / CT with 18 F-fluorodeoxyglucose, the result largely depends on various structural manifestations of osteomyelitis, extension of the process, location, and duration of the disease [8–11].

Moreover, the specificity and sensitivity of diagnostic methods for different locations and stages of the disease are far from being equivalent [12–14]. According to M.F. Termaat et al. and other authors, the positron emission tomography with 18 F-fluorodeoxyglucose is the most accurate for detecting or excluding the diagnosis of chronic osteomyelitis of the spine, whereas scintigraphy with leukocytes labeled with 99mTc-HMPAO has a greater diagnostic accuracy in the peripheral skeleton [12, 13]. It is difficult not to agree with this, but the identification of an inflammation focus in the spine or long bone is far from a final conclusion, since planning a method of treatment, especially a surgical one, requires more accurate data on the extension of the process, structural disorders of bone tissue, changes in the adjacent areas of the cortical plate and epiphyses.

The imaging methods with the use of radiopharmaceuticals, according to S.S. Daset al., are not specific, and the ideal method has yet to be developed [14]. From the point of view of W.J. Metsemakers, there are four criteria to confirm osteomyelitis: 1) fistula, cavity, or wound; 2) purulent drainage from the wound or the presence of pus during surgery; 3) phenotypically indistinguishable pathogens identified by culture from at least two separate deep tissue / implant samples; 4) presence of microorganisms in deep tissues taken during surgery is confirmed by histopathological examination [15]. However, a positive answer to all four points of the criteria for osteomyelitis will not allow clinicians to develop a treatment plan, since it does not provide information on the exact location of the process and its extension. Currently, an accurate diagnosis (of osteomyelitis) requires a combination of various techniques, which have their own advantages and disadvantages [11, 12]. However, taking into account the possibilities of MSCT in the examination of patients

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with chronic osteomyelitis, the role of which has long been proven in preoperative planning, it is possible to solve many diagnostic problems, taking into account modern methods of postprocessor data processing, especially for the detection of sequesters, osteomyelitic cavities, damage to the cortical plate, adjacent bone areas [9, 12, 16].

Various structural changes in bone in osteomyelitis which may extend from a single small focus to total damage to the entire bone with the spread of inflammation to the adjacent joints with multiple intermediate variants do not always fit into the classification proposed by Cierny G. et al., which singles out 4 anatomical types of osteomyelitis (medullary osteomyelitis, superficial osteomyelitis, localized osteomyelitis, diffuse osteomyelitis) [17]. It is difficult to imagine that in medullary osteomyelitis, the inner layer of the cortical plate will not be changed, and with the local type – the adjacent areas of the bone, which has been proven by various studies, including the ones performed at our Centre [9, 17]. The unpredictability and the varieties of bone changes even in superficial or local osteomyelitis suggest that examination of patients should study not only the inflammation zone revealed by X-rays or positron emission tomography with 18 F-fluorodeoxyglucose, but also the state of the bone along its entire length, which provides MSCT [9, 18, 19, 20].

The **aim** of the study was to analyze the extension of the lesion and the depth of bone structure destruction with the use of MSCT in different types of osteomyelitis and variants of its location.

Study design The study included data from 235 patients with chronic osteomyelitis of the long bones of the lower extremities, who underwent treatment at the Clinic for purulent osteology of the Ilizarov Centre in the period from 2016 to 2018. The study is retrospective, single-centre, with level IV of evidence. Inclusion criteria were chronic osteomyelitis of the femur or tibia, the age of patients from 18 to 60 years, and available complete set of X-rays and MSCT archive with the possibility of postprocessor data processing. Exclusion criteria were patients over 60 years old, lack of complete X-ray and MSCT archives.

MATERIAL AND METHODS

We examined 235 patients. Their average age was 45.7 ± 13.9 years. Among the patients, men prevailed (83.3 %). The cause of osteomyelitis was trauma or surgical intervention in 204 cases and 31 patients had consequences of hematogenous osteomyelitis (Table 1).

All patients were treated for 5 to 25 years at their residence hospitals (opening and drainage of purulent wounds, osteonecrectomy, various types of bone grafting and osteosynthesis) (Table 2).

Table 1

Distribution of patients by localization and etiology of osteomyelitis

Segment	Location	Hematogenous osteomyelitis	Post-traumatic or postsurgical osteomyelitis
Femur (n = 117)	Femoral head and neck	9	15
	Proximal metaphysis	5	10
	Diaphysis	–	33
	Distal metaphysis	2	16
	Distal metaepiphysis	6	13
	Total involvement	–	8
Tibia (n = 118)	Metadiaphysis (proximal)	4	18
	Diaphysis	–	52
	Metadiaphysis (distal)	3	15
	Distal metadiaphysis	2	9
	Total involvement	–	8
Total		31	204

Table 2

Distribution of patients by disease duration

Location	Disease duration, years				
	Up to 5	6–10	11–20	21–25	More than 25
Femur (n = 117)	85	14	6	5	7
Tibia (n = 118)	101	11	3	2	1
Total – 235	186	25	9	7	8

Polypositional radiography and multislice computed tomography (MSCT) were used in 235 patients. The examination was carried out with Toshiba Aquilion-64 and GE Lihgt Speed VCT computed tomography systems. The MSCT axial slices were studied by multiplanar reconstruction (MPR) in various planes. The morphological features were analyzed, and bone density in Hounsfield units (HU) was determined, in particular, in the area of the osteomyelitis cavity and sequesters. We studied bone changes characteristic for a specific location of inflammation (shape and length of osteosclerosis areas, zones of resorption, osteonecrosis, number and size of sequesters, length of cavities), and qualitative bone characteristics. All patients underwent interventions at the Centre using various techniques, based on the nature of bone changes determined with MSCT, as well as data from clinical, biochemical, microbiological, and immunological studies.

Statistical data processing was performed using the Microsoft EXCEL-2010 data analysis package and the Attestat-2001 software. The normality of distribution of the sample was determined using the Shapiro – Wilk test. In cases with normal distribution, Student's t-test was used. Nonparametric methods were also used (Mann – Whitney test, Wilcoxon test). The accepted level of significance was $p < 0.05$.

RESULTS

The most frequent location of chronic osteomyelitis was the diaphyses of the femur (33) and tibia (52). Osteomyelitis in all cases was caused by trauma or surgery. Pseudarthrosis or bone defect was formed in 14 patients due to a long-term course of the disease. In addition, changes of varying severity were characteristic throughout the entire femur. In the area of the head and the entire proximal femur, the architectonics was deficient and bone density decreased; no less pronounced were changes in the distal femur, where the average density value was in the negative spectrum of the Hounsfield scale (-39 HU) (Fig. 1).

Osteomyelitis was localized in the proximal femur in 39 patients, and was a consequence of its hematogenous type in 14 of them. When the focus of inflammation or a cavity was localized in the metaphyseal part of the femur, the maximum changes were visualized throughout the upper third, also extending over the entire length of the bone. There was a cavity in the proximal femur in 7 patients. The length of the cavity ranged from 2.5 to 18 cm (10.7 ± 2.5 cm). So, patient A., 59 years old, had a 16-cm long cavity that occupied the entire proximal part of the bone. The cortical plate in the cavity was multilayered, thickened, with areas of density from 740 to (-50) HU. In the histogram, the density of different areas ranged from 29 to 1245 HU. The density of the condyles was reduced in some areas to 50 HU; areas with a density from 163 to 205 HU dominated in the histogram of the lateral condyle (Fig. 2).

Total involvement of the femur took place in eight patients. Destruction spread to its entire volume, the structure and density of the head and condyles were changed. Mean density of the condyles was 24.8 ± 9.6 HU; the density was in the negative spectrum of the Hounsfield scale in the trochanter area. The cortical plate was unevenly thickened throughout the bone, multi-layered, and had defects of varying length. Density was reduced throughout with isolated areas of osteosclerosis. The case presented is an example of almost all bone changes characteristic of osteomyelitis: presence of a cavity, defects in the cortical plate, its thickening and multi-layering, osteoporosis and osteosclerosis (Fig. 3).

In patients with a partial defect of the cortical plate, the plate was unevenly thickened throughout the diaphysis, had a multilayer structure with a density of 665 to 1388 HU. The density of sequesters in the medullary canal was higher than the density of the cortical plate. The bone marrow canal in some areas had zones of eburnation; layers and defects on the side of the endosteum caused its uneven contours and irregular shape.

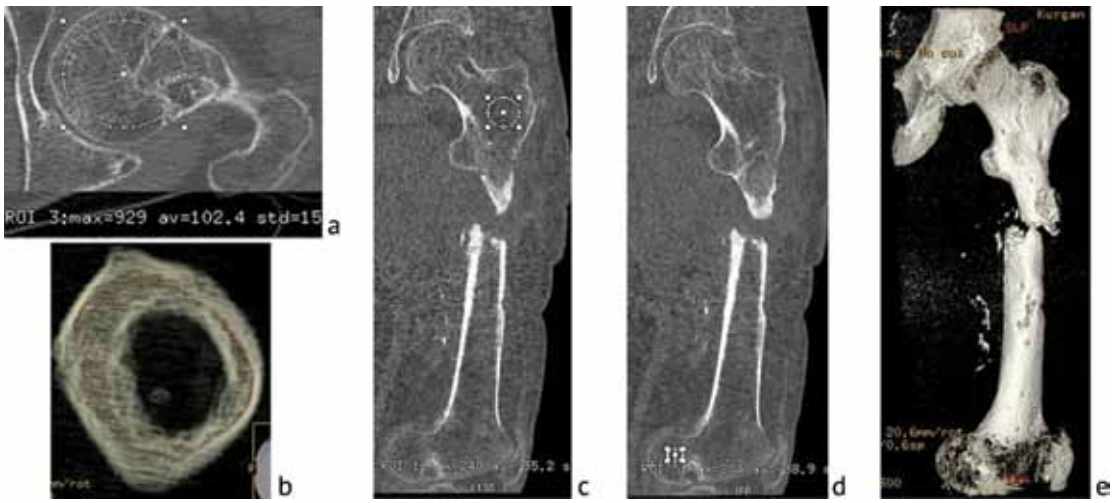

Fig. 1 MSCT of the femur, patient Ch., 47 years old. CPO of the left femur. Fistulous type. Nonunion of the femur in the middle third. 11-cm shortening of the left femur. Axial slices (*a, b*); MPR (*c, d*); VRT (*d*)

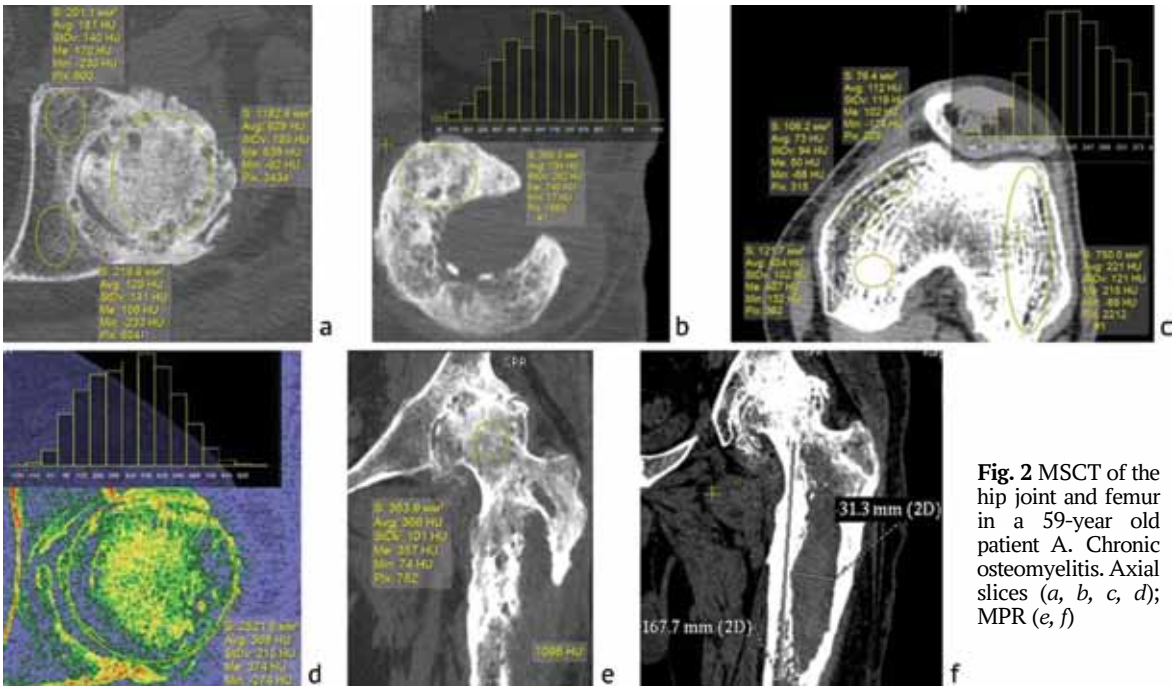

Fig. 2 MSCT of the hip joint and femur in a 59-year old patient A. Chronic osteomyelitis. Axial slices (*a, b, c, d*); MPR (*e, f*)

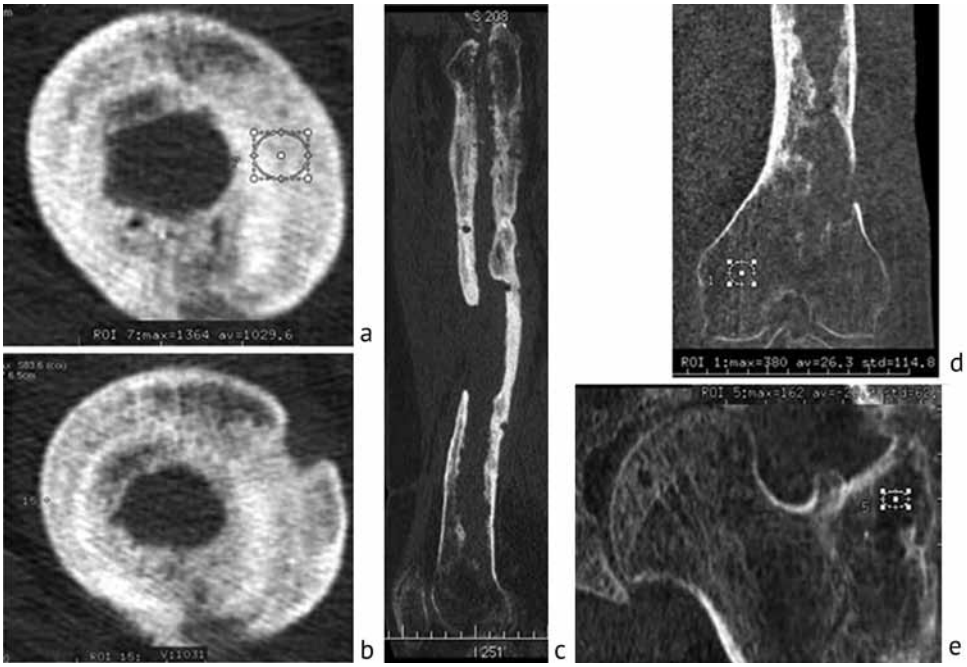

Fig. 3 MSCT of the femur, patient B., 25 years old. CPO of the left femur, 7-cm shortening of the left lower limb. Axial slices (*a, b*); MPR (*c, d, e*)

If the focus of inflammation was localized in the distal femur, especially in the presence of a cavity, the maximum changes concerned the metadiaphyseal bone. Depending on the size of the cavity and its location, disorders of the anatomy and structure were more pronounced in the area of the transition zone to the diaphysis or in the area of the condyles. In some cases, as in patient G., 27 years old, the structure of the entire distal end of the femur with a defect in the condyles was changed. Changes were noted along the diaphysis (decreased density of the cortical plate, its thickening, multilayers in the proximal part) (Fig. 4).

The study of the density of various parts of the femur in osteomyelitis in the proximal and distal parts showed that they significantly differed from the normal condition, which was predictable. But more importantly, if the inflammation was localized in the proximal part, the density in the distal metaphysis was significantly reduced, and if the area of inflammation was in the distal third of the femur, decreased density was observed at the proximal end (Table 3).

Changes in the tibia in patients with chronic osteomyelitis of a prolonged course and recurrence also differed in a variety of manifestations and prevalence of radiographic morphological changes. In the inflammatory process localized in the distal tibia, structural changes were observed throughout the diaphysis and in the bones of the foot, especially in the talus and calcaneus. Their anatomy changed (defects, uneven contours), density decreased, zones of sclerosis or resorption were detected (Fig. 5).

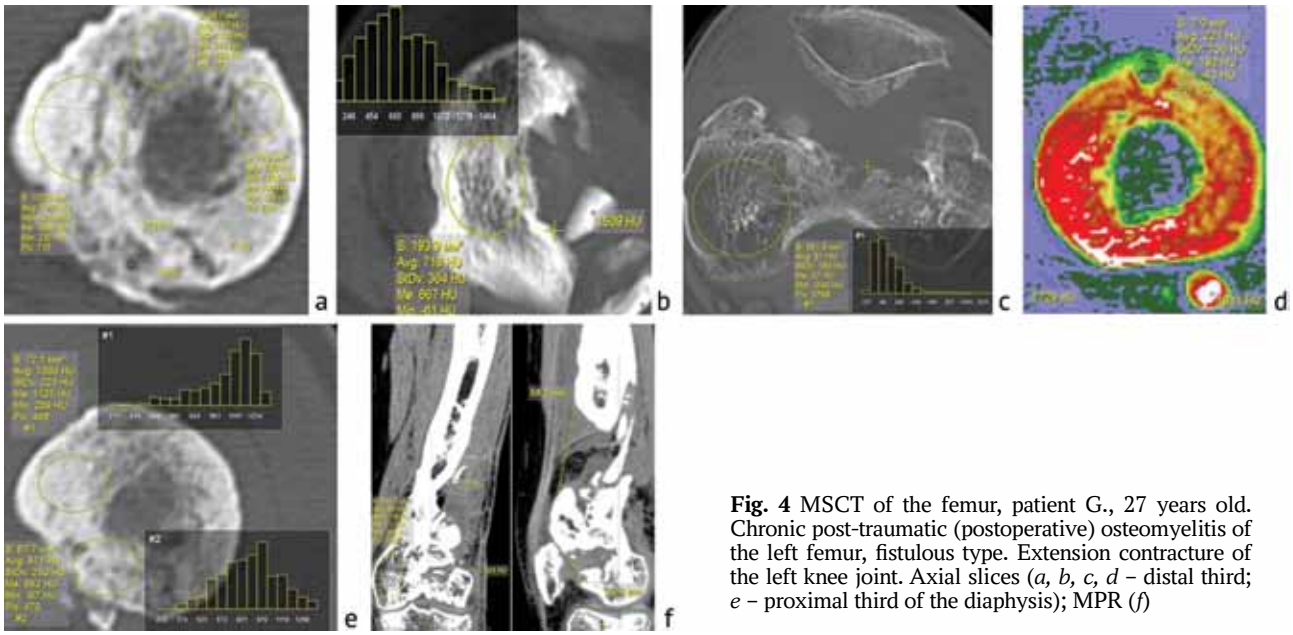

Fig. 4 MSCT of the femur, patient G., 27 years old. Chronic post-traumatic (postoperative) osteomyelitis of the left femur, fistulous type. Extension contracture of the left knee joint. Axial slices (*a, b, c, d* – distal third; *e* – proximal third of the diaphysis); MPR (*f*)

Table 3

Bone density in the femur in osteomyelitis located in its proximal and distal parts

Proximal femur		Distal femur	
Involved zone	HU value	Involved zone	HU value
Cortical plate density outside the focus	1117.30 ± 254.61[1]	Cortical plate density outside the focus	1070.10 ± 65.24[2]
Cortical plate density in the focus of inflammation	1498.71 ± 302.45	Cortical plate density in the zone of inflammation	791.11 ± 18.10
Density in the intertrochanteric area outside the focus	75.21 ± 17.57	Density of distal metaphysis inside the focus	170.36 ± 16.14
Density in the intertrochanteric area adjacent to the inflammation focus	45.18 ± 21.45 (five patients – in negative spectrum of Hounsfield scale)	Density of distal metaphysis outside the focus	199.89 ± 56.17
Density of distal metaphysis outside the focus	201.11 ± 14.72	Density in the intertrochanteric area	79.43 ± 18.34

[1,2] – significant differences in the density of the cortical plate outside the focus and in the area of inflammation ($p < 0.05$)

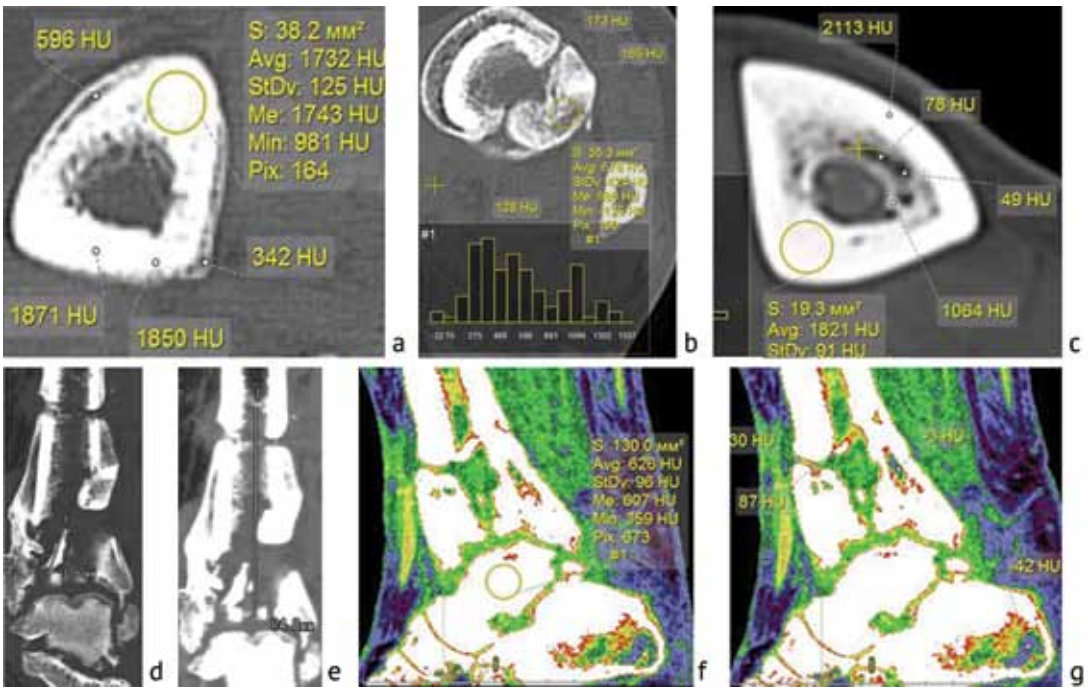

Fig. 5 MSCT of the tibia of patient D., 53 years old. Chronic post-traumatic osteomyelitis of the left lower leg, fistulous type. Axial slices (*a, b, c* – bone site proximal to the inflammation zone); MPR (*d, e, f, g*)

The study of the density in the tibia if osteomyelitis focus was located in its proximal metaphysis showed that the maximum changes occurred in the presence of a cavity in this zone. In such cases, especially in a long-term disease, the "diversity" of osteomyelitis manifests itself much. Every patient has a radiographic morphological picture so individual that a quantitative assessment of the density in the proximal region with statistical processing is almost impossible, since the fluctuations are in the range from (-40) to (+500) HU. In the distal region, bone density also varied significantly. But in 9 patients without large osteomyelitic cavity and gross destructive changes, its average values were found near the focus of inflammation (Table 4).

A detailed analysis of MSCT data in 235 patients with chronic osteomyelitis of the femur and tibia showed that the anatomical changes were individual in all patients. As for the radiographic morphological manifestations, they consisted of general symptoms (osteoporosis, osteosclerosis, violation of architectonics). However, the severity, extent and nature of the structural change were extremely various as well as the changes in density with large deviations. Thus, it was not always possible to obtain average values with reliable differences.

Table 4

Tibial density in osteomyelitis located in its proximal and distal parts

Proximal tibia (n = 24)		Distal tibia (n = 24)	
Involved zone	HU value	Involved zone	HU value
Cortical plate density outside the focus	1401.74 ± 243.84	Cortical plate density outside the focus	1138.25 ± 34.181
Cortical plate density in the area of the osteomyelitic focus	1498.71 ± 302.45	Cortical plate density in the area of inflammation	876.35 ± 78.14
Density in the zone of Ward's triangle	От (-30) до 45 HU	Density of distal metaphysis near the focus (n = 9)	165.28 ± 51.63
Bone density in the intercondylar area adjacent to the focus	Density fluctuations (-40) – (+500) HU	–	–

[1] – significant differences in the density of the cortical plate outside the focus and in the zone of inflammation ($p < 0.001$)

DISCUSSION

The extremely variable patterns revealed by us in chronic osteomyelitis, even in a similar location, coincides with the data of J. Desimpel et al., 2017, according to which it could be explained by various pathogenetic mechanisms involved in the spread of infection and age-related vascularization of the bone [21].

We found multilayer and thickened walls of osteomyelitic cavities with areas of sclerosis. It corresponds to the opinion of a number of researchers [9, 16, 22], who paid attention to the role of bone blood supply, disruption of bone structure and metabolism in osteomyelitis, since such walls are an impenetrable barrier to antibiotics.

We obtained data on changes in the structure of bones along their entire length at any location of the focus of inflammation. All patients had a change in the structure of the metaphysis with the formation of foci of resorption and zones of sclerosis, decrease in the total density, and appearance of zones of gross trabecular structure. Alongside, the thickness and structure of the cortical plate changed, which were most pronounced in the focus of inflammation, with signs of its multilayer structure and a violation of the typical three-zone structure throughout the diaphysis. This fact coincides with the data of several authors [23], that with a long and recurrent course of osteomyelitis after four, five or more surgical interventions, radiographic morphological changes in the bone are aggravated by repeated interventions, limb function limitation, osteoporosis, metabolic disorders.

Moreover, only a thorough analysis of the structure of the cortical plate in MPR enabled to detect micro-foci of reduced density, corresponding to the density of fluid (pus) or fat (-25) HU, located 1.5–2.5 cm distal or proximal to the main lesion, defect or cavity and indicating that the boundaries of healthy bone are at a certain distance from the focus, proximal or distal. Based on this, there is a reasonable possibility of planning the level, volume and nature of reconstructive and plastic interventions [9, 16, 24].

The limitation of this study is that a radiographic morphological picture is very individual in each patient and a quantitative assessment of the density of various bone areas with statistical processing is often not possible. However, it is always possible to determine the density of the cortical plate, sequesters, cavity walls, and microabscesses in the inflammation zone.

CONCLUSION

The results of the work confirm that computed tomography shows the "visual reality" in the diagnosis of chronic osteomyelitis. It enables to determine the extent and nature of bone changes, to detail various changes in anatomy and architectonics, revealing the "multifaceted" nature of chronic osteomyelitis.

The study was carried out within the framework of the research theme "Optimization of the treatment process in patients with orthopedic and traumatologic pathology, complicated and uncomplicated by purulent infection; development of new pathogenetically substantiated (expedient) methods of surgical treatment aimed at the comprehensive restoration of the anatomical and functional state of the limb, general homeostasis and persistent

suppression of purulent infection" as a state assignment for the implementation of scientific research and development at the Federal State Budgetary Institution Ilizarov NRC for Orthopaedics and Traumatology of the Ministry of Health of Russia.

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