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Osteomyelitic cavity as a form of chronic osteomyelitis termed by radiological morphology

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Introduction Osteomyelitic cavity is one of manifestations of chronic osteomyelitis (cOM) that requires continuous application of both non-operative and surgical interventions. The condition is often recurrent. The study of bone quality, techniques for identifying boundaries of pathological process should contribute to the development of advanced methods of treatment to avoid recurrence. **Material and methods** Radiomorphological assessment of the femur and tibia was performed for 48 patients with cOM characterized by osteomyelitic cavities using polypositional radiology and multislice computed tomography (MSCT) and quantification of bone density produced at the cavity and throughout the bone. **Results** Review of MSCT findings showed involvement through the cortical bone thickness of osteomyelitic cavity, structural changes in the entire bone with sinuses, sequestrae and alterations in the soft tissues (n = 40). Cortical bone was entirely involved in the cavity, with sinus observed and half-length of the bone featured with normal structure and low density in five patients. COM was diagnosed with present fixation metal constructs (n = 2) and recurrence noted after cavity repair with osteoinductive material (n = 1). **Conclusion** The findings showed that osteomyelitic cavity in patients with cOM resulted in extensive disorders of bone structure and density, evident changes in cortical bone, multiple layers, defects, considerable density fluctuations in intramedullary canal, in particular.

Keywords: chronic osteomyelitis, osteomyelitic cavity, long bone, MSCT

INTRODUCTION

Chronic osteomyelitis (COM) in long bones presents a variety of challenges with increasing incidence due to complications after different types of metal osteosynthesis and joint replacement [1–3]. The incidence of COM ranges from 3 % to 10 % among purulent surgical conditions and from 10 % to 25 % among musculoskeletal infection [4, 5]. The overall incidence of postoperative bone infection may continue to rise with the recurrence rate of 3-50 % and average hospitalization costs amounting to tens of thousands of dollars [6, 7]. Continuous purulent and necrotic process and disturbed limb function result in secondary changes in the bone and associated decrease in reparative tissues' capacity [2, 9, 10, 11]. Objective assessment of bone involvement in COM and grading of osteomyelitic process is one of the constituents of successful treatment. Modern multislice computed tomography (MSCT) allows evaluation of bone structure at almost histological level identifying changes in the cortical and trabecular bone with quantitative density characteristics and assessment of bone quality. In the last decade, spiral CT based applications were devised to evaluate bone density, macro- and microstructure, accurately determine boundaries of infection focus and treatment options [12–16]. Fluorodeoxyglucose positron emission tomography was found to be a useful imaging method in the investigation of patients with COM [17–20]. MSCT as the gold standard in detecting destructive bone changes provides the most detailed imaging of the bone anatomy and structure in COM enabling appropriate decision-making for treatment modalities [9, 21]. Osteomyelitic cavity is one of manifestations of chronic osteomyelitis (COM) that requires continuous application of both non-operative and surgical interventions. The condition is often recurrent. The study of bone quality, techniques for identifying boundaries of pathological process should contribute to the development of advanced methods of treatment to avoid recurrence.

STUDY DESIGN

Total 48 patients with long bone OM of lower limbs enrolled into the study received treatment at the osteology infection clinic (OIC) of the Russian Ilizarov Scientific Center "Restorative Traumatology and Orthopaedics" (RISC "RTO") between 2012 and 2018. Patients with osteomyelitic cavity in the

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femur or tibia were included in the study. The mean age of the patients was 40.3 ± 14.0 years (n = 3 (4.2 %) under 18 years, n = 43 (89.6 %) 18-59 years and n = 3 (6.2 %) years older than 60 years). Most of the patients were males (n = 40 (83.3 %)). OM was caused by an injury (n = 41) and hematogenous osteomyelitis (n = 7) (Table 1). Patients were earlier treated at different hospitals during 3 to 25 years prior to admission to OIC (Table 2).

Prior to admission to the OIC of the RISC "RTO" all patients underwent surgical treatment including incision and drainage of purulent pockets, osteonecrectomy, various types of bone grafting and osteosynthesis. Surgical procedures previously performed for the patients ranged from one to 10 and over. Among 48 patients, 17 had surgery for OM performed at the OIC for the first time (Table 3).

With regard to the size of osteomyelitic cavity, presence of sequesters and concurrent orthopaedic pathology surgical treatment consisted of debridement of osteomyelitic focus with excision of involved tissues, removal of foreign bodies, correcting osteotomies, Ilizarov external fixation in disturbed integrity of a segment after radical necrectomy, arthrodesis, repeat osteonecrectomy and wound plasty with local tissues.

Table 1

Distribution of patients by localization and etiology of OM

Segment	Localization	Hematogenous OM	Posttraumatic OM
Femur	proximal metadiaphysis	2	–
	shaft	3	8
	distal metadiaphysis	2	8
	distal metaphysis	–	1
Tibia	proximal metadiaphysis	–	2
	shaft	–	11
	distal metadiaphysis	–	3
	distal metaphysis	–	8

Table 2

Distribution of patients by duration of the disease

Localization	Duration of the disease, years				
	under 5	6–10	11–20	21–25	older than 25
Femur	14	3	0	2	6
Tibia	19	3	0	1	0
Total	33	6	9	3	6

Table 3

Surgeries performed earlier

Type of surgery	Number of surgeries		
	from 1 to 5	from 6 to 10	more than 10
Surgical intervention on limbs	35	6	4
Surgery performed for OM	24	5	2

METHODS OF EXAMINATION

Polypositional radiography and MSCT were performed for all patients. Toshiba Aquilion-64 and GE Light Speed VCT scanners were employed for imaging using specified algorithm of "Bone" reconstruction with enhanced spatial resolution and improved visualization of bone structures. Bone mineral density was measured in Hounsfield units (HU). Multiplanar reconstruction (MPR) was used for processing axial slices in coronal and sagittal planes. Roentgenomorphological findings were evaluated and quantitative measurements of bone mineral density produced. Topographic and anatomical changes were reviewed with 3-D reconstruction at the third stage. Bone mineral density was measured in the epiphysis and metaphysis, cortical bone (overall and local), osteomyelitic cavity and sequesters for identifying bone quality. Specific changes in the bone being characteristic for particular localization (shape and extent of osteosclerotic bone, areas of resorption, osteonecrosis, number and size of sequesters, cavity dimensions) and qualitative bone characteristics were assessed. All patients underwent surgical treatment at the OIC using different techniques based on radiological manifestations. Statistical analysis was performed using Microsoft Excel to calculate sample mean and standard deviation (M ± σ).

RESULTS

Femoral or tibial diaphysis (n = 22) and distal femur or tibia (n = 22) were most common localizations of osteomyelitic cavity. Osteomyelitic cavity was also detected in the proximal femoral metaphysis (n = 2) and proximal tibial metaphysis (n = 2). Evident changes in the trabecular bone were seen in the head and neck with the cavity localized in the proximal femur. Axial images showed different cavity dimensions measuring from 3 to 6.5 cm. The density of the cavity walls was 250 to 360 HU. Patients who underwent intramedullary nailing showed a cavity spreading through the femoral bone with clearly visualized sclerotic rim around the removed nail with the diameter measuring 11.6 mm to 12.7 mm. Density of femoral muscles was similar to that in the contralateral limb but was less than normal values. Cortical density measurements ranged from 510 to 630 HU in the shaft with areas of resorption noted. Signs of atherosclerosis were seen in the vessels on axial slices and with 3D-reconstruction (**Fig. 1**).

Osteomyelitic cavity localized in the bone diaphysis of 22 patients and measured 3.5 cm to 18.2 cm (Table 4).

The bone had different thickness in the shaft; cortical plate over the cavity was unevenly thickened up to 16 to 18 mm with many layers measuring 500 до 1750 HU. Internal layers of thickened cortical plate had lesser density than external layers (345.6 ± 61.1 and 1586.14 ± 118.3 HU, respectively). Cortical bone defect at the sinus tract measured 7.3 to 23.7 mm in axial plane and 1.3 to 10.4 cm in sagittal plane (MPR). Changes in metaphyseal bone structure and density were observed in all the cases regardless of the dimensions of diaphyseal cavity. Extensive changes were noted in the femoral condyles with cavity localized in the middle third of the femoral shaft or at the boundary of the middle and lower thirds of the femur. Overall density was not more than 65–90 HU, and extensive areas of resorption with density in the negative spectrum of the Hounsfield scale occupied half of the condyles. Muscles' density was considerably decreased (29.6 ± 4.5 HU) (**Fig. 2**).

Extensive cavernous defects, evident structural changes in condyles with the density decreased to 75.3 ± 15.4 HU were characteristic for osteomyelitic process and the cavity localized in the distal femur. Cortical defects measured 23.2 ± 5.1 mm in axial plane and 68.4 ± 13.7 mm in sagittal plane (**Fig. 3**).

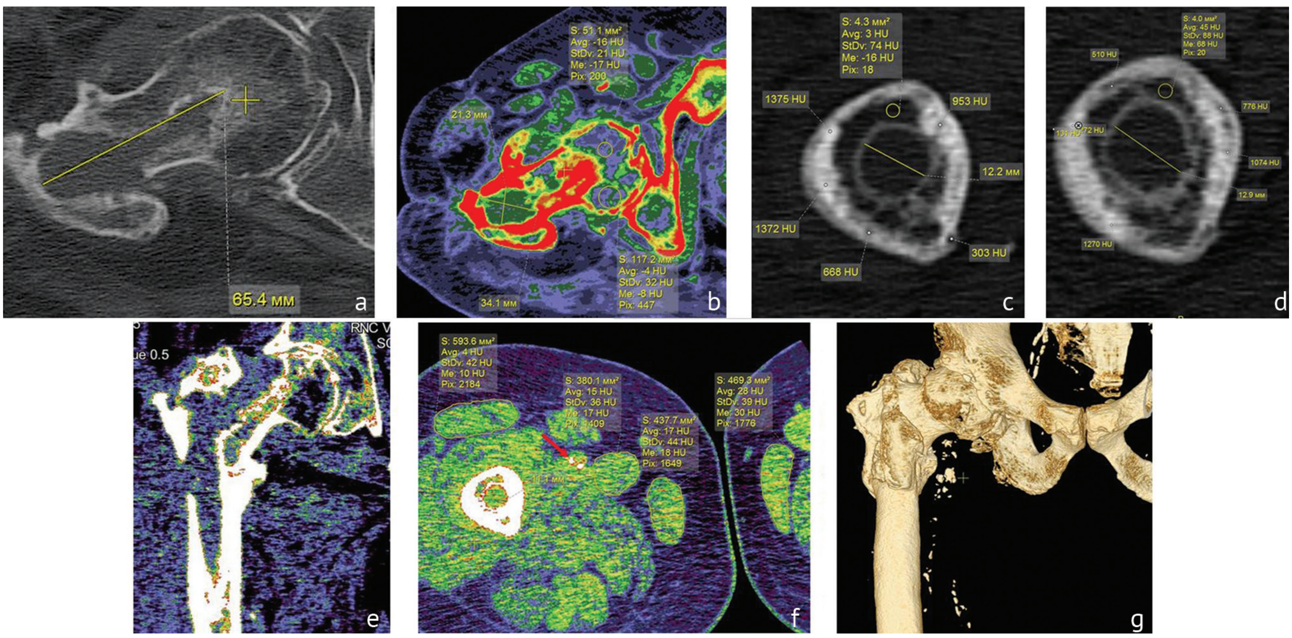


Fig. 1 MSCT of the hip joint and proximal femur of a 51-year-old patient Sch. with COM, osteomyelitic cavity in axial slices (***a, b, c, d, e***); MPR (***f***); VRT (***g***)

Table 4

Distribution of patients by cavity dimensions in the diaphysis

Localization	Cavity dimension			
	from 2 to 4 cm	from 5 to 8 cm	from 9 to 12 cm	more than 12 cm
Femur	–	4	2	5
Tibia	5	3	2	1

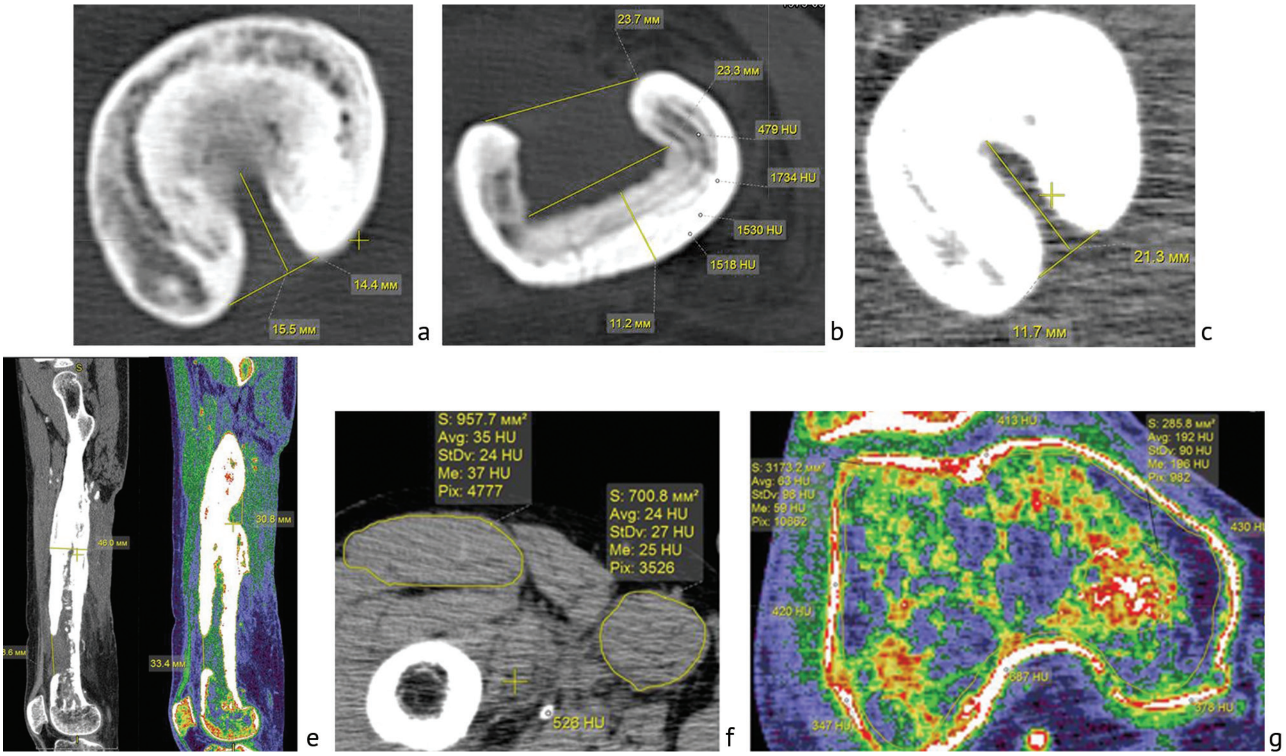


Fig. 2 MSCT of the femur in a 38-year-old patient Kh. with COM, osteomyelitic cavity measuring 18.5 cm in the shaft and 7.2 cm in the distal femur. Axial slices at the level of cortical defect over the cavity (***a, b, c)***; MPR in sagittal plane (***d***); axial slice (soft-tissue window), decreased density of femoral muscles; an axial slice at the level of femoral condyles. Overall density measuring 63 HU and local density being (-60) to (+192) HU.

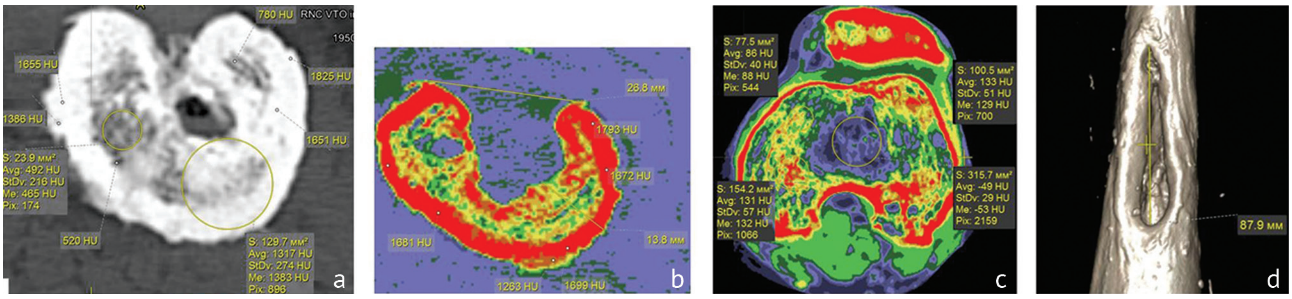
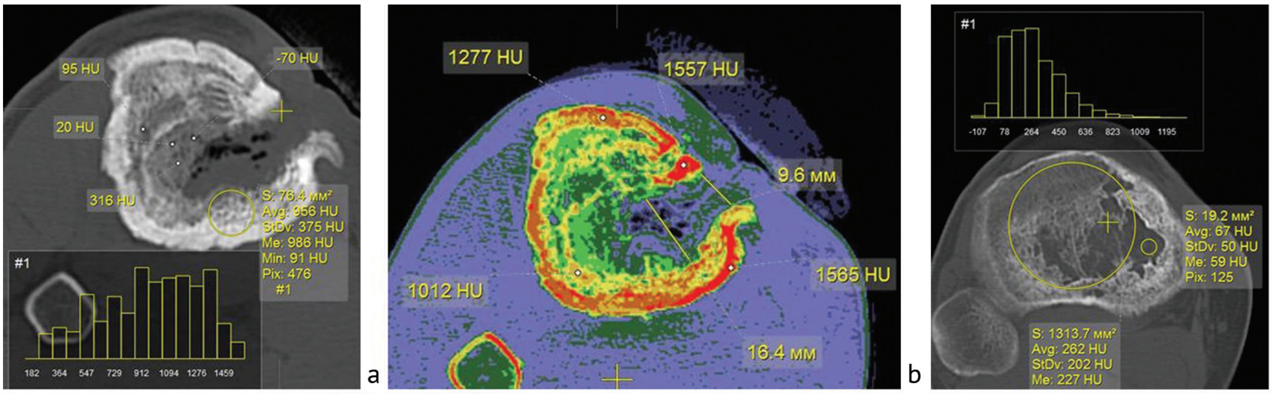


Fig. 3 MSCT of the femur in a 68-year-old patient Sh. with COM, osteomyelitic cavity in the distal femur. Axial slices (***a, b, c*** – color map); 3D-reconstruction (***d***)

Osteomyelitic cavity was localized in the proximal tibia in two cases. The cavity was located in the cancellous bone, and adjacent bone had heterogeneous structure of different density. The density of the cavity wall measured 182 to 1450 HU on histograms. Internal wall contained parts of the bone with the density of up to 320 HU and small areas with the density measuring 20–90 HU. Close location of the cavity and the epiphysis was accompanied by evident changes in epiphyseal structure. Coarse trabecular structure alternated with areas of resorption. Histotopogram contained areas of density from 1160HU to negative values on the Hounsfield scale (-107 HU) (**Fig. 4**).



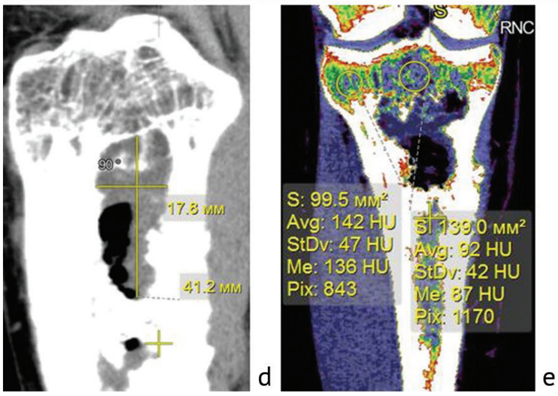


Fig. 4 MSCT of the proximal tibia in a 33-year-old patient Sh. with COM, osteomyelitic cavity. Axial slices (***a, b*** – color map, ***c*** – histogram); MPR in sagittal plane (***d***), coronal plane, color mapping (***e***)

A diversity of changes is observed with osteomyelitic cavity located in the distal tibia with sequestration, in particular. All the patients developed changes in the foot bones, primarily in the calcaneus, due to proximity to the ankle joint. Local decrease in density was revealed in the calcaneal tuberosity and inter-arc area showing negative values on the Hounsfield scale. Coarse trabecular structure of the heel was observed in three cases. Cancellous sequesters had the density of 520 to (-15) HU. Areas adjacent to the cavity and zones of resorption had decreased density. The cavity walls had different density and areas of 360-830 HU prevailed (**Fig. 5**).

MSCT findings of 40 patients with COM complicated by cavities showed bone involvement through the cortical thickness of the cavity, structural changes in the whole bone, sinuses so that the pathology was classified as diffuse osteomyelitis (type IV) according to the classification of Cierny G. et al. (2003). Five patients had a cavity with the cortical bone involved through the thickness, a sinus and a normally structured bone in half of the length with decreased density. Unusual clinical and radiological manifestations were observed in three cases. One patient presented a cavity of 18 cm filled with round implants in the distal femur, a sinus in the mid femur, and fistulography showed the contrast spreading from sinus to the cavity. Another patient presented the femur fixed with intramedullary nail and screws, nonunited fracture in the femoral mid shaft, sinus in the posterior aspect of the distal femur and cortical defect in the proximal femur. A bone perforating defect 7.0 cm long, 10–13 mm wide resulting from nail was visualized in a 33-year-old patient after femoral fracture repaired with nail and cerclage wire. Density in the walls of bone defect (a canal from nailing) measured 1200 to 1300 HU.

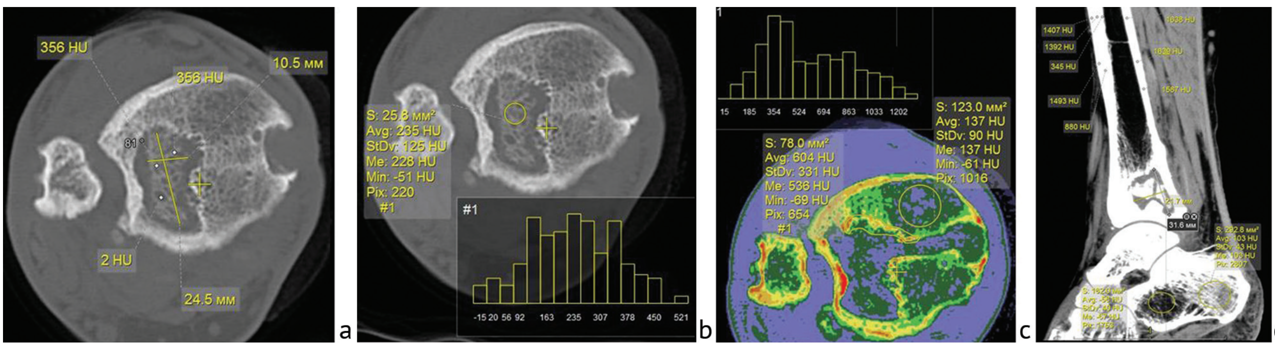


Fig. 5 MSCT of the ankle joint and distal tibia in a 48-year-old patient B. Axial slices (***a, b, c*** – histograms); MPR in sagittal plane, measuring density of cortical bone, sequester size and density of different parts of the calcaneus (***d***)

DISCUSSION

COM is characterized by a triad of major symptoms: a relapsing and remitting course, presence of sequestra (or osteomyelitic cavity) and a sinus [14]. Clinical scenario of osteomyelitic bone cavities, large-sized, in particular, circular destruction of bone structure is even more challenging [8, 22, 23]. According to Kaim AH et al., 2002, four main questions arise for diagnosis of COM:

1. Where is the main focus of the infection? Are there septic metastases?
2. Which tissues and neighboring organs and articulations are involved?
3. Local quality and vitality of bone and surrounding tissues?
4. Postoperative anatomy and stability including orthopaedic devices? [24].

Pineda C et al. (2006) suggests that OM frequently requires more than one imaging technique for an accurate diagnosis [14]. Some authors suggest that 18F-fluorodeoxyglucose (FDG) PET/CT is very sensitive in COM and 18F-sodium-fluoride PET/CT (NaF-PET) has a high specificity for identifying non-viable bone. The combined administration of F-NaF/F-FDG PET/CT scans with high sensitivity and specificity allows for accurate evaluation of bone infection [17, 18]. Based on the best available evidence of recent years, both WBC or (AGA) scintigraphy combined with SPECT/CT or FDG-PET combined with CT have the best diagnostic accuracy for diagnosing peripheral post-traumatic OM [15]. Taking into consideration certain difficulties in application of PET/CT for diagnosis of osteomyelitis including high costs and low availability of the modality in Russia MSCT is more common in clinical practice of the country due to its high sensitivity and specificity [10, 14, 25].

All clinical goals can addressed with MSCT incorporating benefits of modern workstations equipped with powerful application software. The main focus of infection was identified in all the cases and 45 patients diagnosed with osteomyelitic cavity of different size containing sequestra in 32 cases. MSCT findings of 40 patients showed bone involvement through the cortical thickness of the cavity, structural changes in the whole bone, sinuses (one to three) so that the pathology was classified as diffuse osteomyelitis (type IV) according to the classification of Cierny G. et al. (2002) [26]. Five patients had a cavity with the cortical bone involved through the thickness, a sinus and a normally structured bone in half of the length with decreased density in the metaphysis, in particular. Unusual clinical and radiological manifestations including nail in the intramedullary canal, implant in the cavity, bone defect from the nail and sequestrae. Ankle joint and foot bone (talus and calcaneus) were involved with the cavity localized in the distal tibia. Ankle joint was infected in totally involved tibia of two patients with extensive areas of resorption in the distal femur without destruction or infection. The hip joint was infected in one patient with the cavity located in the proximal femur. Changes in the adjacent soft tissues with present sinus included increased density of 70 HU at the skin and subcutaneous cell adhesion, homogeneous muscle structure without typical longitudinal striation in MPR and axial slices. Areas of negative density (-15; -60 HU) were observed at the sinus tract zone. Cortical plate of the cavity walls was changed through the whole thickness with stratified structure, thickening of 1.5-1.8 cm, resorption areas and foci of decreased density, defects extending from 0.5 cm to 2.0 cm, and intramedullary canal appeared to be eburnated proximally or distally of the cavity over 2.5–4.5 cm in some of the cases.

CONCLUSION

The findings showed that COM complicated with cavities led to evident changes in the bone at the site of the defect and throughout the length. Cortical bone appeared to be stratified with different density in internal and external layers, areas of resorption and small defects. The cavity located in the distal tibia was associated with changes in architectonics and density of talus, calcaneus and mid foot. Sinus tracts often developed with different cortical defects, fibrous changes in soft tissues, impaired muscle structure and decreased density.

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