

Research Paper

Comparison of Bone Preserving and Radical Surgical Treatment in 32 Cases of Calcaneal Osteomyelitis

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Abstract

Introduction. Radical procedures like calcaneotomy and amputation performed for calcaneal osteomyelitis are regarded as effective in eradication of infection even though potentially functionally disabling. Bone sparing procedures offer better functional result at the expense of potentially worse infection control. The aim of the study has been to assess the influence of the surgical radicalism as much as the extent of bone infection on the final outcome in the surgical therapy of chronic calcaneal osteomyelitis (CO). **Material and method.** 32 patients with chronic CO have comprised the group under study: 8 with superficial type, 12 localised type and 12 with diffuse type according to Cierny-Mader classification. The aim of the treatment was to heal infection, preserve the heel shape and achieve good skin coverage over the calcaneus. The therapy consisted of 9 debridement surgeries with or without flaps, 8 drilling-operations of the calcaneus with application of collagen-gentamicin-sponge in bore holes, 15 partial and 2 total calcaneotomies, and 4 below-the knee amputations. **Results.** The healing of infection and wound has been achieved after 7 of 9 debridements, 6 of 8 drilling-operations, 13 of 15 partial and all total calcaneotomies. **Conclusion.** Bone preserving operations in chronic calcaneal osteomyelitis provided inferior infection control (76,47% vs 88,24%) and worse patient satisfaction (88,24% vs 100%) and almost comparable ambulation (100% vs 93,33%). Drilling of the calcaneus with application of collagen sponge containing gentamicin performed in chronic diffuse calcaneal osteomyelitis seems to offer a viable alternative to partial or radical calcaneotomy. Level of evidence: V.

Key words: chronic calcaneal osteomyelitis; calcaneotomy, collagen-gentamicin sponge; local antibiotic application.

Introduction

Chronic calcaneal osteomyelitis (CO) is a rare form of bacterial osteomyelitis [1]. It develops either as sequelae of penetrating wound located over the calcaneus, especially in diabetic patients with vascular compromise, or as hematogenous bone infection [2, 3, 4]. Up to 60% of the open calcaneal fractures, especially with intra-articular involvement, is accompanied by infection [5]. Optimal therapy for chronic CO should combine eradication of infection, preservation of the bone stock and attachment of the Achilles tendon as well as retaining of ambulation [6, 7]. There are various ways of surgical therapy of CO. Standard treatment for CO usually includes partial or total calcaneotomy and below-the knee amputation. In the

extensive inflammatory involvement of spongiotic substance of the calcaneus it is difficult, however, to distinguish which part of bone could be defined as sequestrum [8]. Thus, the classical sequestrectomy with preservation of viable surrounding tissues is not possible. Most of the published case studies of CO present the experience with calcaneotomy or soft tissue transfer. The mode of treatment depends on whether the team is an orthopedic or plastic surgical team. From the functional point of view the therapy for CO should rather be bone sparing than radical. Bone sparing procedures - regarded as alternative for calcaneotomy seem to be functionally more satisfactory, but provide worse infection control. To deter-

mine the extent of inflammatory process and the surgery planning, Cierny-Mader (CM) classification has been proposed [8]. The classification distinguishes medullary (CM I), superficial (CM II), localized (CM III), and diffuse (CM IV) involvement of the bone. Superficial type of CO is diagnosed in cases of deep wound with exposure of the bone substance of the calcaneus. Localized type of CO is diagnosed when inflammatory changes on X-ray (sclerotic or osteolytic) or on MRI scans (abnormal signal with contrast enhancement) involve strictly localized region, or less than 50% of the volume of the calcaneus [10, 11]. Changes with the extension within the calcaneus greater than 50% are classified as diffuse CO.

The aim of this study has been to compare the clinical and functional treatment results in 32 consecutive cases treated for chronic CO either by bone preserving protocol or by partial or total calcanectomy as well as to evaluate the influence of the extent of the infection in the bone and of the performed operation on the final outcome.

Patients and methods

The retrospective study includes 32 consecutive patients treated due to chronic bacterial osteomyelitis of the calcaneus from 1993 to 2010. The follow up ranges from 3 to 15 years (average 4,5 years). The study included 14 women and 18 men, aging from 17 to 78 years of age (average 42 years). All patients had suffered from exogenic CO and were treated at the orthopedic department, and whenever necessary in cooperation with a plastic surgeon. The microorganisms cultured from bone specimens have been: *Staphylococcus aureus* (13 cases), *Staphylococcus epidermidis* (5 cases), *Pseudomonas aeruginosa* (4 cases), *Proteus mirabilis* (3 cases), *Enterococcus faecalis* (2 cases), and *Propionibacterium* spp. (1 case). Negative biopsies have been obtained in 4 cases.

The following types of calcaneal osteomyelitis have been treated according to Cierny-Mader classification: 8 cases of type II, 12 cases of type III, and 12 cases of type IV. Patients with CO have been classified according to Cierny and Mader (CM) host classification: 14 cases were class A, 13 class B1 and 5 class Bs. In 14 cases CM class A, CO developed as sequelae of pressure ulcer (3), due to puncture wound (6), due to traumatic wound over calcaneus (2) and in 3 cases of calcaneal fractures managed with pin fixation. Local compromising factors in 13 cases class B1 included neurological problems: sciatic or tibial nerve injury (5), other peripheral neuropathy (4), spinal cord injury (4). Compromising factors in class Bs cases included: diabetes (4) and chronic renal insufficiency (1). 28 from 32 patients have been ambulatory prior to the treatment and 4 cases with spinal cord injury have

been non-ambulatory. Characteristics of treated cases and performed operations is shown in table 1.

The treatment aimed to preserve the bone stock and the shape of the calcaneus as well as to achieve good skin coverage. The author's own bone preserving technique for chronic diffuse CO has been developed with the expectation to preserve the cancellous bone of the calcaneus, deliver the antibiotic to the bone and maintain the function of the foot. The calcaneus is approached either through the existing skin defect, through the split heel approach (fig. 1a) or through the lateral incision [9]. After the exposure of the calcaneus and debridement of potentially infected tissue covering the bone, 6 to 9 holes are drilled in the cancellous bone of the calcaneus, each 4 mm in diameter (fig. 1b). As the next step the "pegs" formed from one piece of collagen-gentamicin sponge (CGS) containing 130 mg of gentamicin sulphate are introduced into drill holes (fig. 1c). According to the authors' experience 6 to 9 drill holes does not weaken the mechanical strength of the calcaneus (fig. 1d).

Locally introduced CGS enables the antibiotic to diffuse into cancellous bone, resulting in eradication of infection and maintenance of important part of the calcaneus. When the skin defect over the calcaneus is present, local skin flap for coverage of the bone is performed at the same stage. Application of CGS to the drill holes has been based on the sensitivity of infecting bacteria to high concentrations of gentamicin.

In cases of known preoperative bacterial sensitivity (cultures from bone exposed within the wound) as well as cases without preoperative calcaneus exposition - the application of CGS has been the form of prophylactic and preemptive antimicrobial therapy of bone infection. Postoperative antimicrobial therapy has been based on biopsies taken intraoperatively from the bone. The protocol included intravenous or oral antibiotics - initially empiric (in cases with unknown etiological factor) and having obtained results from tissue cultures - culture specific antibiotics for 4 weeks. Cases treated with drilling and application of CGS received postoperative suppressive antibiotic therapy for 2 weeks.

The type of the surgical treatment has been tailored to the extension of inflammation determined by X-ray or MRI, according to CM classification (table 1). Debridement, with or without local flap, has been performed in 9 cases: in 8 cases with type II and in one case type III of CO (4 cases: without flap; 5 cases of type II CO and with pressure ulcer: combined with local flap). Debridements without flap have been performed through the split-heel approach and in cases with pressure ulcers - through the skin defect. In one case two debridements have been performed.

Table 1. Characteristics of 32 patients and 41 operations performed for calcaneal osteomyelitis. Table legend: *staged or repetitive surgery; Operations: OP1- Drilling + Collagen Gentamicin Sponge; OP2 - Debridement; 2a - Debridement + fasciocutaneous flap; 2b - Debridement + cross-leg fascio-cutaneous flap; OP3 - Partial calcaneotomy; 3a - Partial calcaneotomy +Antibiotic Loaded Acrylic Cement Spacer; OP4 - Calcaneotomy; OP5 - Below-the knee amputation.

Pat No	Sex /age	CM type	Risk factor for calcaneal osteomyelitis	OP1	OP2	OP3	OP4	OP5	Healing of infection	Walking ability	Satisfaction with treatment
1	M17	IIA	Puncture wound over heel		2				+	+	+
2	F36	IIA	Puncture wound over heel		2				+	+	+
3	F48	IIA	Puncture wound over heel		2				+	+	+
4	M21	IIA	Puncture wound over heel		2				+	+	+
5	M37	IIBL	Pressure ulcer over heel, sciatic nerve injury, loss of skin sensation		2a				+	+	+
6	M53	IIBL	Pressure ulcer over heel, tibialis nerve injury, loss of skin sensation		2a				+	+	+
7	M71	IIA	Pressure ulcer over heel		2a				+	+	+
8	F62	IIA	Pressure ulcer over heel		2a				--		
						3			+	+	+
9*	M32	IIIBL	Traumatic wound, tibialis nerve injury, loss of skin sensation		2a				--		
					2b				--		
						3			+	+	+
10	M18	IIIA	Puncture wound over heel			2			+	+	+
11	M25	IIIA	Puncture wound over heel			2			+	+	+
12	F46	IIIBL	Pressure ulcer over heel, sciatic nerve injury, loss of skin sensation			3			+	+	+
13	M43	IIIA	Pressure ulcer over heel			3			+	+	+
14	F56	IIIBL	Pressure ulcer over heel, neuropatic foot, loss of skin sensation			3			+	+	+
15	F75	IIIBL	Pressure ulcer over heel, neuropatic foot, loss of skin sensation			3			+	+	+
16	F69	IIIA	Calcaneal fracture managed with pins			3			+	+	+
17	F41	IIIBL	Pressure ulcer over heel, spinal cord injury			3			+	not able to walk	+
18	M36	IIIBL	Pressure ulcer over heel, spinal cord injury			3			+	not able to walk	+
19	M52	IIIA	Calcaneal fracture managed with pins			3			+	+	+
20	M59	IIIBs	Pressure ulcer over heel, diabetes			3			+	+	+
21	F25	IVBL	Pressure ulcer over heel, neuropatic foot, loss of skin sensation	1					+	+	+
22	F31	IVBL	Pressure ulcer over heel, neuropatic foot, loss of skin sensation	1					+	+	+
23	M54	IVBs	Pressure ulcer over heel, diabetes	1					+	+	+
24	M38	IVBL	Puncture wound over heel, tibialis nerve injury	1					+	+	+
25	F48	IVA	Traumatic wound with exposition of the calcaneus	1					+	+	+
26	M19	IVA	Traumatic wound with exposition of the calcaneus	1					+	+	+
27	F17	IVBL	Pressure ulcer over heel, spinal cord injury	1					---		
								5	--	not able to walk	
28	M33	IVBL	Pressure ulcer over heel, spinal cord injury	1					---		
								5	--	not able to walk	--
29*	M78	IVBs	Calcaneal fracture managed with pins, diabetes			3a			---		
								5	+	not able to walk	--
30*	F56	IVA	Calcaneal fracture managed with pins			3a			--		
								5	+	+	+
31*	F71	IVBs	Calcaneal fracture managed with pins, renal failure			3a			--		
							4		+	+	+
32	F69	IVBs	Pressure ulcer over heel, diabetes			3			---		
							4		+	+	+

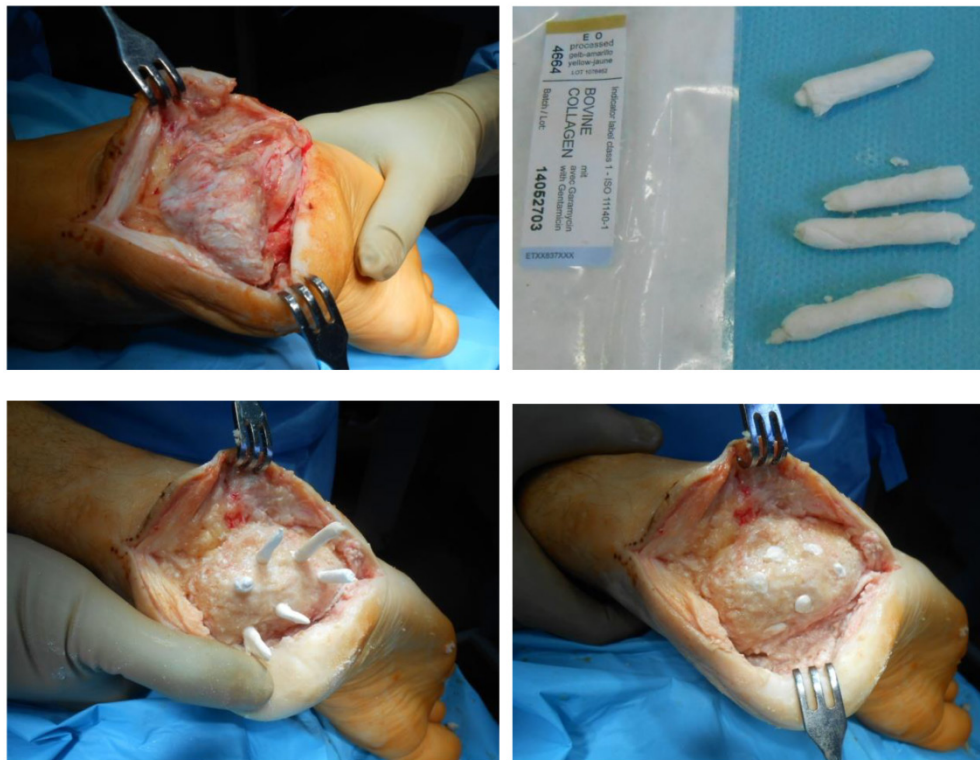


Figure 1. a. Split heel approach to the calcaneus. b. Preparation of collagen-gentamicin sponge “pegs” c. Introduction of collagen-gentamicin sponge “pegs” into drill-holes. d. Appearance of calcaneus after application of local antibiotic carrier into drill-holes.

In two cases treated initially by debridement, partial calcaneotomy has been performed because of flap failure. Drilling of the calcaneus and application of CGS in bore holes has been performed in 8 cases with type IV of CO. The treatment has failed in 2 cases and consequently resulted in below-the knee amputation. Partial calcaneotomy has been performed in 17 cases: as primary treatment in 11 “localized cases” and as secondary salvage procedure in 2 cases after failed debridement with local flap. Partial calcaneotomy has also been attempted in 4 “diffuse” cases with cavitory defect of the bone, with cavity volume larger than 2-3 cm³. In 3 from 4 mentioned cases hand-made acrylic cement spacer, containing low-dose of gentamicin (less than 1,0 g of antibiotic within 40 g of cement) has been introduced into the defect. The treatment has failed and total calcaneotomy has eventually been performed in 1 case and below-the knee amputation in 2 other cases with diffuse CO. Total calcaneotomy has been performed as a final treatment in 2 cases. Below-the knee amputation has been performed as final procedure after failed drilling operations (2 cases) and after failed partial calcaneotomies with cement spacer (2 cases).

The final results of therapy have been assessed based on wound and bone infection healing, maintenance of walking ability and subjective assessment

performed by the patient. Infection control has been assessed based on clinical examination, inflammatory markers (ESR, CRP, WBC) and radiological signs of healing. The radiological signs of homogenous remodeling, resorption or sclerosis of the calcaneus have been analysed on standard lateral and axial X-ray of the calcaneus. Functional assessment has included walking ability and the use of orthopedic devices. In subjective assessment patients have expressed satisfaction with treatment results. The study was performed following the Declaration of Helsinki principles and informed consent has been obtained from each patient prior to inclusion to the study. The study has been approved by the responsible authorities of Medical University of Warsaw.

Results

Finally the results of 37 operations have been assessed: 10 debridements, 8 drilling procedures, 17 partial and 2 total calcaneotomies. Complete wound healing and the absence of bone infection for at least 2 years (minimal follow-up) has been obtained in 30 of 32 cases (93,75%). Debridement has been effective in 7 of 10 operations, drilling procedure in 6 of 8, partial calcaneotomy in 13 of 17, and total calcaneotomy in 2 of 2 cases (table 1). In 4 cases with diffuse CO partial calcaneotomy has been

ineffective and finally a total calcanectomy has been performed in 2 cases and in 2 other cases a below-the knee amputation. Acrylic cement spacer containing low-dose gentamicin have turned out to be ineffective. In total, the bone preserving operations (debridements or drilling with application of CGS) have proved effective in 13 of 17 cases (76,47%) and partial or total calcanectomy in 15 of 17 cases (88,24 %). The results assigned to bone involvement are summarized in table 3. Cure of infection has eventually been obtained in all cases with superficial and localized CO and in 10 of 12 cases with diffuse CO.

The assessment of functional results and walking ability has revealed that from 32 patients, 4 with spinal cord injury had been non-ambulatory prior to the treatment (table 1). From 28 ambulatory patients, 27 have retained the ability to walk after treatment. One patient has become non-ambulatory after amputation due to poor acceptance of prosthesis (elderly patient amputated due to CO complicating calcaneal fracture). In total, 13 of 13 (100%) patients who had been ambulatory before treatment retained the ability to walk after bone preserving operations and 14 of 15 (93,33%) patients who had been ambulatory before treatment were able to walk after partial or radical calcanectomies. 24 patients have required orthopedic device: shoe inlay (12), heel containment orthopedic shoe (11), prosthesis (1 of 4 amputated), whereas 4 non-ambulatory patients could do without an orthopedic device.

Table 2. Results of surgical treatment assigned to type of operation.

Type of treatment	Operation	Healing of infection	Failure	Total	
Bone preserving operations	Debridement	7	3	10	18
	Drilling + CGS	6	2	8	
Radical operations	Partial calcanectomy	13	4	17	19
	Total calcanectomy	2	0	2	
Total		28	9	37	

Table 3. Results of surgical treatment assigned to bone involvement.

Cierny Mader type	Healing of infection	Relapse of infection	Total
Superficial (II)	8	-	8
Localised (III)	12	-	12
Diffuse (IV)	10	2	12
Total	30	2	32

After bone sparing operations 3 of 15 ambulatory patients did not use any device; 7 used shoe inlay and 5 orthopedic shoe. All 13 ambulatory patients after

partial or radical calcanectomy needed orthopedic devices: 2 after total and 11 after partial calcanectomies used custom made heel containment orthopedic shoe or walker, and 1 of 4 amputated used prosthesis after below-the knee amputation. 29 of 32 patients have been satisfied with treatment (table 1): all those that have undergone debridement (9) or partial calcanectomy (17), 6 of 8 after drilling procedure, 2 patients after total calcanectomy and one after amputation. Three patients after definitive amputation have shown dissatisfaction. In total, 15 of 17 (88,24%) patients after bone preserving operations and 19 of 19 (100%) after partial or radical calcanectomies have been satisfied.

Discussion

Calcaneal osteomyelitis accounts for 7%-8% of all osteomyelitis cases in adults [1]. Hematogenous origin of CO is uncommon. The differential diagnosis includes tumors and tumor like lesions which may mimic CO [12]. Infectious process becomes apparent on plain radiographs when bone density drops to at least 60% [6]. Magnetic resonance imaging (MRI) findings include decreased T1 signal and increased T2 signal in the affected region, geographic pattern of bone destruction, abscess formation, cortical destruction and cellulitis [13]. The goal of therapy for CO is an infection-free foot with durable soft-tissue coverage and maximal preservation of function [2]. In children the treatment is mainly nonsurgical. In diagnostically clear cases it includes several weeks of antibiotic administration, initially intravenously and then orally [4, 6, 3]. In adults the surgery is more common and requires bone preserving procedures and skin flaps for soft tissue coverage or amputations. The surgical therapy for CO requires good balancing between the extent of bone resection and expected function. It acts towards eradication of infection within the bone and soft tissue, soft tissue reconstruction and preservation or reconstruction of the bone [7]. Local antibiotics provide high *in situ* concentration and – depending on their biocompatibility and time of action can contribute to preserving of the calcaneus. However, there are only few reports regarding local antibiotic application in CO therapy. The major disadvantage of the polymethylmethacrylate (PMMA) beads impregnated with gentamicin is the need of their surgical removal at the completion of antibiotic release. The biodegradable carriers like collagen-gentamicin sponge (CGS), hydroxyapatite blocks, polylactide/polyglycolide implants and the polylactate polymers release antibiotics at local concentrations exceeding those of the minimum inhibitory concentrations (MICs) for the most common pathogens of chronic osteomyelitis, without producing

toxic systemic concentrations and adverse effects [14]. The superiority of CGS over PMMA beads has been proven in clinical and animal studies [15, 16, 17]. Also calcium phosphate cements have proved to be a viable carrier of local antimicrobial agent allowing prolonged release of gentamicin sulfate or tobramycin [18, 19]. Depending on the extend of the infection within calcaneus and presence of skin defect, the spectrum of surgical procedures includes partial or total calcanectomy and lower leg amputation. Skin defect, whenever present, plays crucial role in successful therapy of CO. Surgical decompression of active CO can be done either through the split heel approach (Gaenslen's approach) or lateral approach [9]. Wounds up to 1 cm accompanying CO are suitable for Negative Pressure Wound Therapy (NPWT) or delayed primary closure. Local pedicled flaps like M. abductor digiti minimi flap laterally or M. abductor hallucis medially can be used [20]. If local muscle flap is not sufficient to close the defect, a free microvascularized flaps are indicated, preferably anterolateral upper leg flap [7]. Also distally based saphenous and sural neurofasciocutaneous flap can be used for wound closure after resection of infected part of the calcaneus [21]. Radical debridement of infected part of the calcaneus requires either reconstruction or acceptance of the bone defect resulting after calcanectomy. Del Pinal reported staged technique that preserves the bone shape in diffuse CO: removal of the whole spongy bone with preservation of the cortical shell and filling of the dead space using free muscle flap [22]. At the second stage autologous bone grafts are used for reconstruction of the calcaneus. Defects larger than 6 cm in diameter are regarded as unsuitable for filling up with cancellous bone grafts [7]. Free osteo-muscular flaps can also be used for reconstruction of the hindfoot after calcanectomy like vascularized double barrel ribs combined with free serratus anterior muscle flap, free osteomuscular peroneus brevis flap as well as osteocutaneous flap including the medial femoral condyle [23, 24, 25]. Even distraction osteogenesis can be used to restore calcaneus after debridement for CO [26]. Partial calcanectomy is preferred in CO with non healing ulcers and infected nonunions after calcaneal fracture as functionally more satisfactory and regarded as alternative to amputation. Partial calcaneal resection may be performed if the inflammatory process involves less than 50% of the heel [10, 11]. Functional and cosmetic results are better than after calcanectomy or below-the-knee amputation [27, 28]. Total calcanectomy is regarded as disabling and is indicated in CO involving more than 50% of the bone with accompanying skin defect not amenable to reconstruction and can be an alternative to transtibial amputation [7, 29].

After calcanectomy complication like talonavicular subluxation has been reported, but 50% patients can maintain the same ambulation level postoperatively in a modified heel-containment orthosis [30]. Amputation should be considered if restoration of an infection-free foot covered with durable soft-tissue on plantar surface with satisfactory walking ability is unlikely, especially in patients with compromised skin sensation or motoric function [7].

The aim of the study has been to compare the effectiveness in eradication of the infection, walking ability and patient satisfaction with treatment after operations preserving the shape of the calcaneus and after partial or total calcanectomy. Four operative procedures, differing by increasing surgical radicalism: debridement alone or with flaps, drilling and application of CGS, partial and total calcanectomy have been performed in 32 cases. In total 37 limb sparing operations have been performed: 18 preserving the shape of the calcaneus and 19 less or more radical operations. In the assessed groups the difference in the cure rate of infections between bone preserving and radical operations (76,47% vs 88,24%) has been observed. It has been noted that bone preserving operations have been usually performed in cases with lesser destruction of the bone stock, which was not equivalent to bone involvement in MRI, and infection healing has been noted mainly, but not exclusively in less extensive cases of CO (table 3). In the study operations preserving the whole calcaneus were associated also with worse patient satisfaction with treatment as compared to the radical operations (88,23% vs 100%) but with better walking ability after operation (100% vs 93,33%) in ambulatory patients. Attention has also been given to assessment of author's bone preserving technique of drilling and introduction of CGS pieces into drill holes in the calcaneus. As far as the authors know, the technique described in the paper has not been reported previously as local antibiotic delivery and bone sparing procedure in therapy of CO. This technique seems to be a promising alternative to more radical treatment options for chronic CO, contributing to salvage of the calcaneus in 6 from 8 treated cases. On the other hand the application of hand-made acrylic cement spacer, containing low-dose of gentamicin in 3 "diffuse" cases with cavitory defect of the bone, following partial resection (debridement of cavitory defect) was not effective. Because temporary antibiotic-containing spacers have proved to be effective in periprosthetic infections, the role of antibiotic spacers in CO requires further studies. Radical calcanectomy performed in 2 cases has proved to be clinically successful and functionally accepted.

The limitation of this study is a considerably low

number of cases representing each type of CO according to Cierny-Mader classification, resulting from the rarity of CO in our population. Also influence of infecting organism and subsequent systemic antibiotic treatment has not been analysed due to seemingly increased complexity of assessment, resulting in difficulty to draw conclusions.

Conclusions

As compared to partial or total calcanectomy, bone preserving operations (debridement alone or with flaps, drilling and application of CGS) performed for chronic calcaneal osteomyelitis provided inferior infection control (76,47% vs 88,24%) and worse patient's satisfaction with treatment (88,24% vs 100%) and almost comparable walking ability (100% vs 93,33%). Drilling of the calcaneus with application of collagen sponge containing gentamicin performed in chronic diffuse calcaneal osteomyelitis seems to be attractive alternative to partial or radical calcanectomy for ambulatory patients with acceptable effectiveness and functional results.

Competing Interests

The authors have declared that no competing interest exists.

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