Osteitis

18

Matthias Militz and Volker Bühren

18.1 Basics

18.1.1 History

Since the antic the treatment of wound infections is known. With Lister, antiseptic procedures paved the way for a new era in surgery and wound management. Pasteur and Flemming transformed the treatment of septic surgery into an evolving era with the development of antibiotics. Furthermore, the rise in the number of complications shows a tendency of increasing operative fracture treatment. Even with the development of new implants, surgical techniques, and antibiotic drugs the problem of infections following trauma and orthopaedic surgery still remains. The economic aspect, in addition to the medical components, becomes and even more important factor. For prevention of infections in trauma and orthopaedic surgery and their effective treatment, knowledge of the pathophysiological pathways and experience in all established surgical procedures is necessary.

18.1.2 Anatomy

The incidence of osteitis depends on various factors and ranges between 1.5 % in cases of elective bone surgery up to 40 % in open fractures [1]. According to the occurrence of surgically treated fractures, the lower extremities are more often affected than the upper extremities [2]. Differentiation between cortical, spongiotic bone and joint infections is important for treatment. The interaction of soft-tissue covering, mechanical stability, joint movement, and preservation of neurological function is challenging in all types of treatment for osteitis.

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18.1.3 Pathophysiology

Every wound is associated with an invasion of bacteria in variable dimensions. The pathophysiological pathway of the "normal" inflammation reaction turns into infection under certain unfavorable conditions. Local, systemic, and outside influences determine further development.

Local factors are blood circulation, the concomitance of inflammatory substances, the number and type of bacteria, and the presence of implants. The critical number of bacteria was estimated using $2–8 \times 10^6$ [1]. Nevertheless, with the presence of implants the number decreases to less than 10^2 bacteria inducing an infection [3].

Furthermore, systemic factors also play a significant role in the development of infections. All systemic factors interfere with the local situation. The most important systemic factors in the alteration phase of switching from contamination to infection are older age, male gender, reduced general condition, diabetes, malignancy, immunodeficiency, adiposity, and malnutrition [3, 4].

The type and number of bacteria are the most important exogenous factors. The microbiological activity depends on the degree of contamination, the virulence, and the local conditions for growth. A certain number

H.-J. Oestern et al. (eds.), *General Trauma Care and Related Aspects*, European Manual of Medicine,
DOI 10.1007/978-3-540-88124-7_18, © Springer-Verlag Berlin Heidelberg 2014

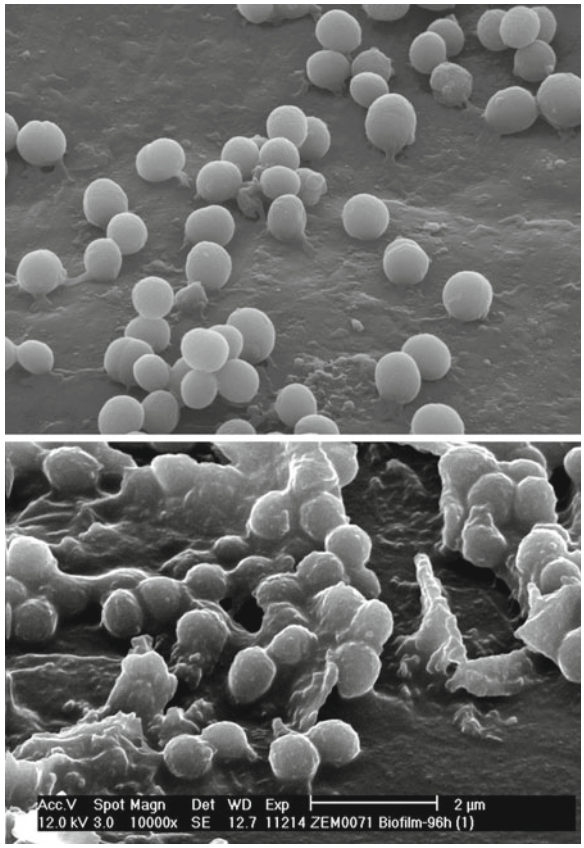

Fig. 18.1 Electromicroscopic slide of *Staphylococcus epidermidis*: Biofilm. *Upper figure*: *Staphylococcus aureus* from fluid culture; *lower figure*: *Staphylococcus aureus* in Biofilm (REM-slide from S. Sailer and I. Chatterjee, Homburg/Saar)

of bacteria are able to build up attaching themselves to artificial surfaces and generating a biofilm (Fig. 18.1). *Staphylococcus aureus, Staphylococcus epidermidis, Proteus mirabilis, Pseudomonas aeruginosa*, and other bacteria contain these characteristics. The biofilm can reach a thikness of 160 µm [1, 3, 5].

18.1.4 Prevention of Infections in Trauma and Orthopaedic Surgery

The treatment and healing process can be divided into three phases: preoperative, intraoperative, and postoperative.

In all three phases, the reduction of soft-tissue damage, the prevention of contamination, and the improvement of blood perfusion are necessary [6–8]. Therefore, the fracture should be reduced as early as possible, sufficient blood pressure should be reached, a examination of open fractures should be performed under sterile conditions in the operating room, and antibiotic drugs must be administered in the emergency room. The radical removal of dead tissue is required on open fractures. Additionally, the type of osteosynthesis and operative procedure chosen should prevent a decrease of local and systemic conditions for wound healing. In critical soft-tissue conditions, the method of choice is a temporary covering of the wound with a vacuum closure. Time plays a vital role in the third phase. By the time the surgeon reflects whether a revision procedure is necessary, the revision should be done.

The majority of severe infections and development of osteitis can be prevented with early and consequent management of complications in the third postoperative phase.

18.1.5 Principles of Clinical Examination

The usual principles for diagnosis of osteitis are valid.

In the clinical presentation of open fractures, operative fracture treatment, complications during wound healing, diabetes mellitus, and signs of general inflammation-like fever, swelling, and redness are indicative of osteitis.

Local signs of infection on clinical examination depend on the level of infection. The spectrum of local symptoms ranges from pain under stress to redness and swelling, up through the existence of fistula with purulent secretion, and in severe cases, systemic sepsis.

18.1.6 Laboratory Diagnostics

A specific laboratory parameter for detecting osteitis does still not exist.

In clinical practice, C-reactive protein (CRP) seems to be reliable parameter for evaluation of the activity of an inflammatory process [9, 10].

18.1.7 Imaging Methods

There are different imaging methods for diagnosing acute postoperative and the chronic osteitis. For the diagnosis of acute osteitis, the imaging methods are less helpful [9, 11].

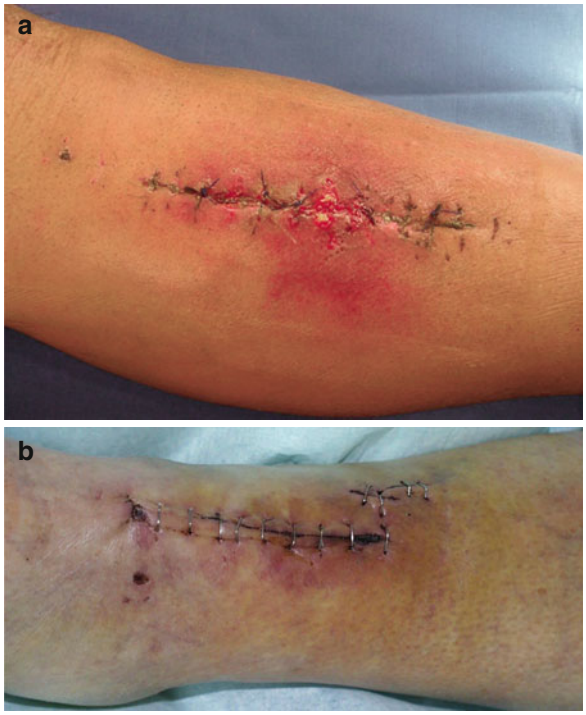

Fig. 18.2 (**a**, **b**) Acute osteitis: clinical aspect

For chronic osteitis, plain radiographs, computed tomography (CT), and magnetic resonance imaging (MRI) are methods of diagnosis. Thus, enclosed gas in a bone formation seen on CT scans is a strong argument for chronic osteitis. The uptake of contrast medium in the adjacency of a bone sequester is deemed to be strong evidence of chronic osteitis.

Ultrasound imaging is not appropriate for the diagnosis of osteitis because it is not highly specific. In recent years, results using fluorodeoxyglucose positron emission tomography (FDG-PET) have shown to be a valid method for the diagnosis of osteitis. Available studies report sensitivity with an of average 96 % and specificity of 91 % compared with bone scintigraphy (82 %/25 %), leukocyte scintigraphy (61 %/77 %), and MRI (84 %/60 %) [12]. Using FDG-PET CT should show an improvement of expressiveness (Fig. 18.2).

18.1.8 Bacteriology

A positive microbiological culture shows the highest evidence for the diagnosis of osteitis. The bacterial probes must be taken from the intraoperative situs. The tests must be representative for aerobe and anaerobe bacteria. The time between extraction of the material and the beginning of processing the microbiological investigation is important for the significance of the probes. If incubation of the probes begins too late, a false negative result can present for noninfected tissue. The same is essential for the extraction of the probes from the wound. Using gloves and instruments for avoiding contamination from the skin and other tissue areas is indispensable. In clinical cases with a high suspicion of infection without a positive microbiological result, specific infections must be excluded (e.g., tuberculosis, Lues).

18.2 Acute Osteitis

18.2.1 Synonyms

Acute posttraumatic osteitis

18.2.2 Definition

The definition of acute posttraumatic osteitis (APO) is the bacterial infection of bone and soft tissue adjacent to a fracture, and implants within 6 weeks after fracture treatment or joint replacement.

18.2.3 Epidemiology/Etiology

Depending on the type of fracture and the operative procedure the incidence of APO ranges between 0.5 % in elective orthopaedic surgery up to 40 % in acute trauma surgery of open factures [13, 14].

The level of soft-tissue damage, type and amount of bacterial contamination, presence of implants, and the general conditions of the patient are the most important parameters.

In addition to these factors, postoperative wound management plays an important role. The wound hematoma presents the bacteria with ideal conditions for growth. With the early removal of postoperative hematoma, effective prevention of the development of APO is possible.

The occurrence of APO is connected to an increase of number of days in hospital to an average of 13–24. As a result, additional costs for one case of APO are estimated to rise up to 14,000 € [6].

18.2.4 Symptoms

Clinical symptoms of APO are redness, swelling, fever, increasing CRP level, pain, and treatment of fracture within the previous 6 weeks (Fig. 18.2a, b).

18.2.5 Complications

The most important complication is absent and failed treatment of APO and has the potential consequence of turning into chronic osteitis. During the treatment of APO, dependant on localization, general conditions, type of bacteria, and type of previous treatment, surgical complications may occur. Because treatment of APO immobilization of the affected region requires, the risk of thromboembolism is high. The use of a cast imcontains the risk of pressure ulcer to prevent pes equinus. The risk for thromboembilism and pressure ulcer rise in the presence of bad general conditions and other factors (e.g., diabetes mellitus, arteriosclerosis).

18.2.6 Diagnostics

18.2.6.1 Recommended European Standard for Diagnostic Investigation

The diagnostic of APO is based on:

- Medical history
  - Operative treatment, open fracture, complications after primary surgery,
  - Bad general conditions
- Clinical investigation
  - Pain, redness, swelling, fever, decreased function
- Laboratory findings
  - Increasing CRP, positive microbiological blood culture
- Imaging
  - Radiographs for detecting loosening of the implant, CT for detecting gas in necrotic bone
- Microbiological culture
  - Positive microbiological culture from the affected tissue (aerobe and anaerobe testing).

18.2.6.2 Useful Additional Examinations

In preparation for surgical revision of a joint replacement, the puncture is helpful in detecting bacteria. The indication for the puncture must be handled carefully because contamination of the joint by the puncture is also possible.

18.2.7 Conservative Treatment

18.2.7.1 Recommended European Treatment Procedures

In consideration of the pathophysiological features a conservative treatment of APO is not reasonable.

18.2.7.2 Useful Additional Therapeutic Strategies

Additional systemic administration of antibiotics

18.2.8 Surgical Treatment

18.2.8.1 Recommended Surgical European Standard

Early revision of the affected wound, if necessary under emergency conditions

Revision of all parts of the wound

Removal of tissue probes for urgent bacteriological investigation

Change of the sterile covering, gloves and instruments after wound irrigation and before vacuum closure

Local antibiotics

Closure of the wound after revision surgery with vacuum technique

Immobilization (cast, external fixator)

Systemic antibiotic drugs (cephalosporin of the third generation or analogue)

Repetition of the revision procedure after 2–3 days

Administration of the antibiotic drugs according to the result of the first microbiological probes

Removal of the implant, if after repeated revision procedures a negative bacteriological result can not be achieved

18.2.8.2 Useful Additional Surgical Treatment

The low pressure jet lavage of long bone marrow hole is helpful, but not mandatory. For the lavage of soft tissue jet lavage is not favorable, because mechanical alteration occurs with decrease of tissue nutrition and possible impaction of residual bacteria into tissue.

18.2.9 Differential Diagnosis

The abacterial postoperative wound haematoma is the most important differential diagnosis, clarified always as the result of a surgical revision procedure.

18.2.10 Prognosis

Healing of APO is accomplished in the majority of cases if a consequent surgical revision concept is applied. In 40 % of cases, the removal of the implant cannot be avoided [15–17].

Nevertheless, therapy for APO is not successful in all cases, with 10–30 % progressing to chronic osteitis.

18.2.11 Surgical Procedure

18.2.11.1 Septic Operative Management

There is no question about the consequent realisation of the principles of aseptics and antiseptics during septic surgery in the operating room to prevent further contamination and osteitis [15, 16, 18, 19].

The goal of surgical therapy is the complete removal of necrotic tissue and therefore the decrease of the number of bacteria in the wound.

In addition to parameters such as general conditions, blood perfusion, soft-tissue covering, and antibiotic drug therapy, the amount of bacteria in the wound is a deciding factor for the emergence of osteitis (s. Sect. 18.1.3). Decreasing of quantity of bacteria in septic surgical procedures can be achieved by changing gloves, instruments, and sterile coverings after débridement of the necrotic tissue and lavage of the wound [20–22]. During the process of changing these items, an antiseptic solution can be used. The same handling is essential in cases of exchanging implants. A decrease of positive bacterial culture of 70 % was observed in laboratory investigations.

The first revision procedure is aimed at identifying the surgical problem, taking microbiological samples, and performing a sufficient vacuum closure. Whereas the first look must be done as an emergency procedure, the planned second and following procedures are elective. In preparation of revision procedures in long bones and joint replacements a major blood loss must be calculated. Usage of a cell saver or a self blood donation is not feasible.

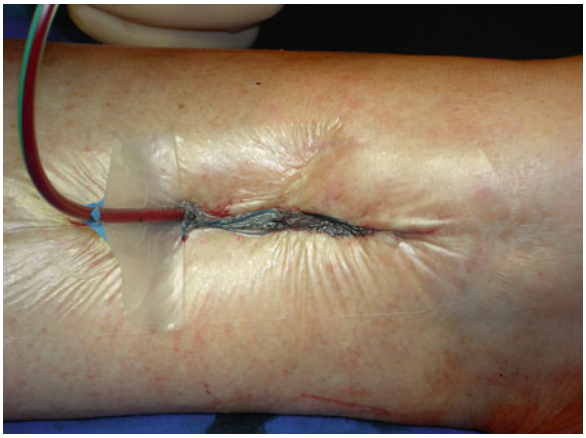

Fig. 18.3 Vacuum closure of the wound

At the beginning of revision procedure the closure of the wound must be taken into consideration because the soft-tissue covering is the basis for all further surgery. Under the revision concept, the edge of the wound has a tendency of retracting. With the vacuum closure of the wound the approximation of the edges of the wound *with* a continuous intracutane suture should be used (Fig. 18.3). Immobilization of the affected region is required during the revision procedure.

Proceeding with additional revision procedures is determined by the results of the microbiological samples.

18.2.11.2 Wound Revision

Technique

Removal of skin sutures, revision of all parts of the wound and necrotic tissue, excision of the affected wound edge, and taking tissue samples for microbiological testing must be done under sterile conditions.

Possible Complications

Possible complications include bleeding, wound closure inability, additional damage to bone and functional structures.

18.2.11.3 Removal of Implants

Technique

Removal of implants should be approached through existing scars if possible and with positioning of the patient on the table with possibility for intraoperative imaging. Removal of all implants should be achieved without additional soft-tissue damage. Planning should be undertaken the wound closure and bone stabilization after revision procedure, as well as preparation of casts for lower leg immobilization during the salvage procedure.

Possible Complications

Possible complications during removal of implants include injury of functional structures, implant breakage, incomplete removal, or instability after removal of implant.

18.2.11.4 Nail Exchange

Technique

Planning for availability of instruments and implants.

Reaming of the medullary canal after removal of the nail.

Positioning of the patient on the table with a possibility for reosteosynthesis.

Prevention of additional bone destruction.

Possible Complications

Possible complications include loosening of the locking bolts, shortening, torsional displacement, and additional fracture of the affected bone.

18.2.11.5 External Fixator

Technique

Placement of the pins should be in the center of the cortical bone with drilling before positioning the pins. Bicortical fixation. Adequate soft-tissue incision regarding to joint movement.

Possible Complications

Displacement of the pins, injury of functional structures, soft-tissue impairment, pin track infection.

18.3 Chronic Osteitis

18.3.1 Synonyms

Osteomyelitis

18.3.2 Definition

Bacterial infection of bone and implants over a period of 6 weeks or longer after treatment of fracture or joint replacement.

18.3.3 Epidemiology/Etiology

In trauma and orthopaedic surgery, the presentation of chronic osteitis is a major complication following primary surgery [16, 23]. Chronic osteitis is characterized as bacterially infected bone after a period of longer than 6 weeks following primary surgery. Chronic osteitis is a challenge for the patient, the patient's family, as well as the surgeon.

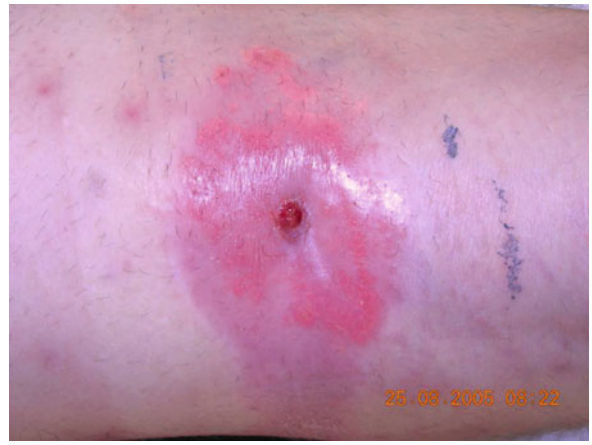

Fig. 18.4 Chronic osteitis: fistula in the hollow of the knee

In Germany, a change in condition from acute osteitis to chronic osteitis is estimated to occur in 10–30 % of all cases [24–26] (s. Sect. 18.2). The change to chronic osteitis as a result of inconsequent surgical management of acute osteitis, open fractures, and extensive soft-tissue damage.

Most detected bacteria are *Staphylococcus aureus*, *Pseudomonas*, *Proteus*, *Streptococcus*, and other types that include mixed flora bacteria [1, 27]. The causes for chronic osteitis are necrotic and avital tissue parts and implants colonized by bacteria.

Depending on the virulence of the bacteria, the local soft-tissue situation, and the immunological competence of the patient, different levels of infection can evolve. The clinical appearance can change from pseudarthrosis without signs of infection, to local infection with fistula, to septic shock.

The lower limbs, particularly the shank, are most affected with chronic osteitis because the soft-tissue covering in this region is inadequate.

18.3.4 Symptoms

Local and general signs of infection differ depending on the level of infection and localization (s. Sect. 18.3.3)

In low-grade infections, symptoms present with a clinical impression of pseudarthrosis with pain, marginal swelling, and redness. Existing fistula near the fracture region will sometimes demonstrate chronic osteitis (Fig. 18.4).

Classic signs of inflammation are seen in acute recrudescing chronic osteitis and with infection of joint replacements in the aforementioned interval. In cases of unknown fever, inflammation, and a positive medical history, an infection of the bone and joint replacement must be excluded.

18.3.5 Complications

Chronic osteitis that is left untreated can lead to septic shock and additional problems. If treatment is unsuccessful, amputation or exarticulation can result. Addicted to the type of method for salvage (eradikation) the chronic osteitis deformities of affected limbs and decreased function are feasible.

18.3.6 Diagnosis

A positive medical history of open fracture, additional infection, and indices for immunodeficiency are indices for chronic osteitis. Laboratory findings are not specific, but depending on the grade of infection, the signs of inflammation are typically positive. Progression of CRP indicates chronic osteitis.

Plain radiographs are mandatory, but not argumentative. An irregular periosteum will sometimes demonstrate a chronic inflammatory reaction and in advanced cases, sequestering of bone can be found. CT is required for detecting necrotic bone (Fig. 18.5a, b). Uptake of contrast medium adjacent to sequestering as well as gas formation in the bone are deemed as evidence for chronic osteitis (s. Sect. 18.1.7)

MRI can be helpful for viewing soft tissue, but it is not specific enough (Fig. 18.6a–c).

Various methods of scintigraphy will show regions of increased bone metabolism, but are not specific enough for proof of an infection.

PET scans can show pathologic glucose metabolism in the bone with highly specific information in connection with chronic osteitis (Fig. 18.7). Additional information about the localization of the infected focus is available. Microbiological samples from a suspect bone with a positive result typically verify chronic osteitis. False-positive results must be prevented.

The synopsis of clinical, anamnestic, laboratory, imaging, and microbiological findings can indicate chronic osteitis. Angiography may be required for the evaluation of perfusion in the perspective of a contingently microvascular surgical treatment.

18.3.6.1 Recommended European Standard for Diagnostic Investigation

Medical history, plain radiographs in two planes, CT, PET, microbiological probes, CRP

18.3.6.2 Useful Additional Examinations

MRI

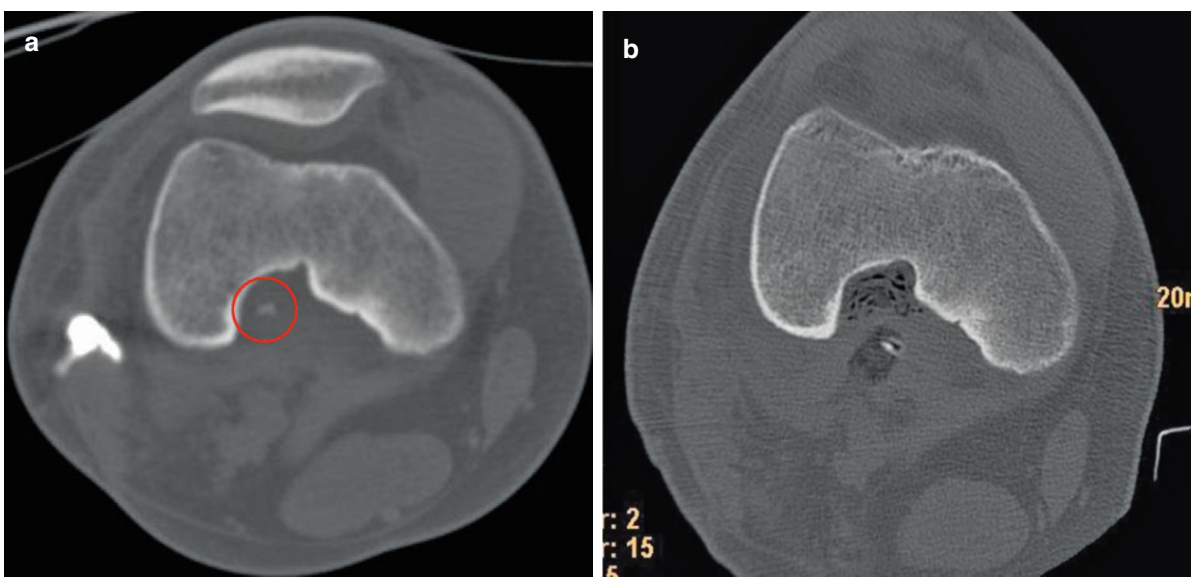

Fig. 18.5 (**a**, **b**) Chronic osteitis: bone sequester in the popliteal fossa before and after removal. In the center of the *red circle* a small piece of bone was detected as a sequester which was the cause for chronic infection (**a**). After removal of this piece of necrotic bone the infection was healed

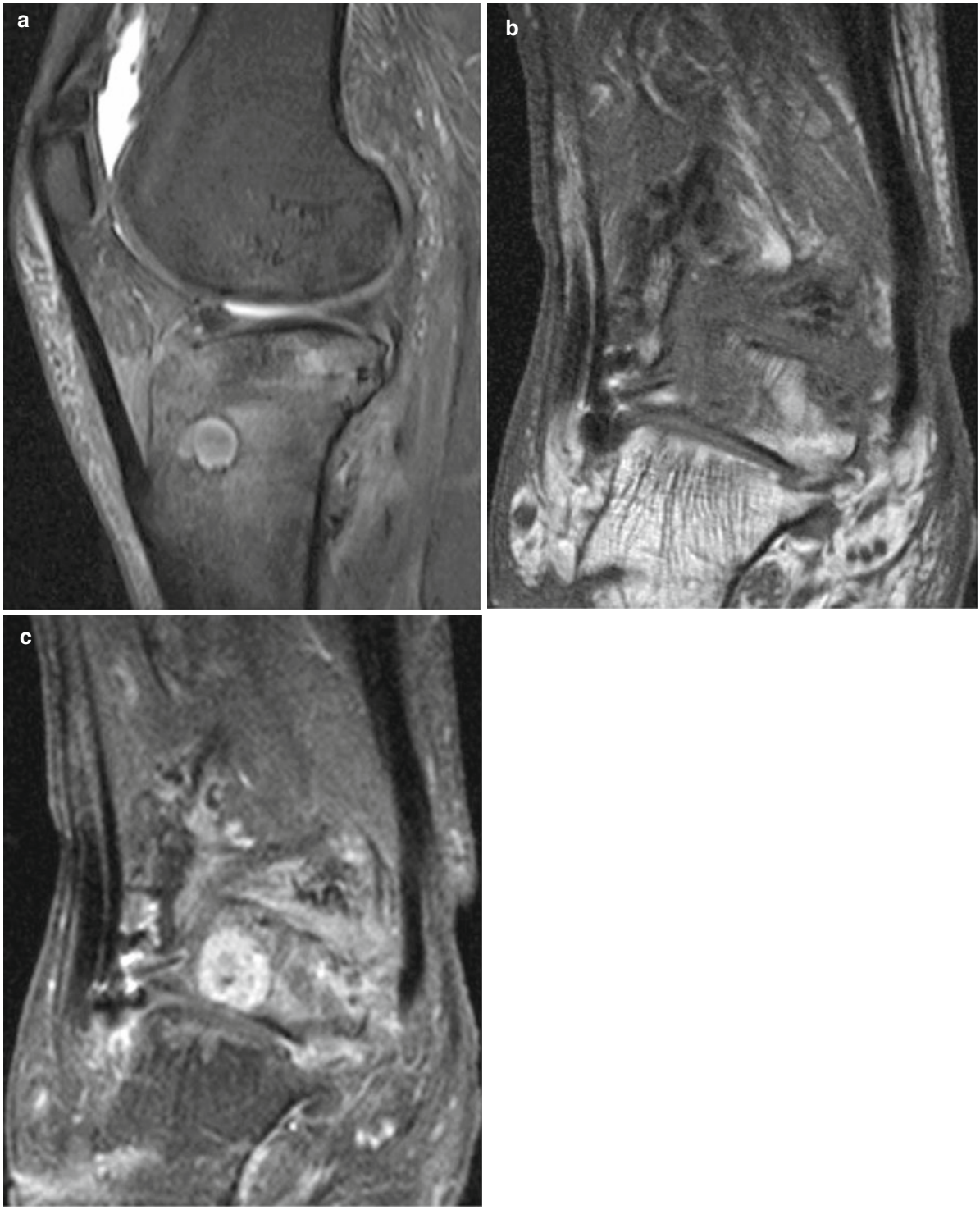

Fig. 18.6 (**a**) Chronic osteitis: increased signal on MRI. (**b**, **c**) Chronic osteitis: increased signal in MRI and uptake of contrast medium in T1 sequences

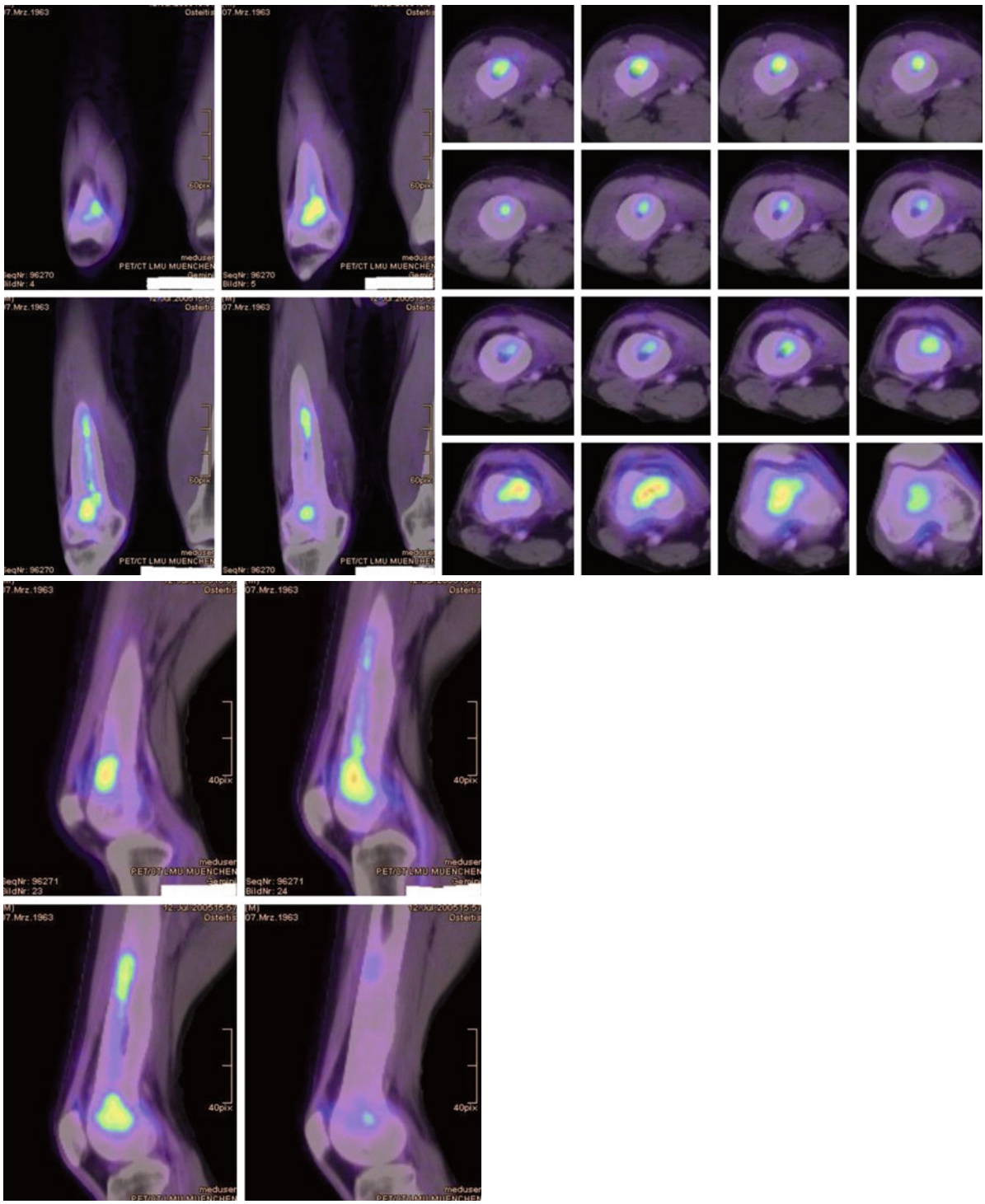

Fig. 18.7 Chronic osteitis: image of right femur with FDG PET CT

18.3.7 Therapy

In contrast to the therapy for acute posttraumatic osteitis, three steps for therapy of chronic osteitis can be taken.

Focus on the first step of therapy is the priority with eradication of the infection. The second step is characterized by reconstruction of the soft-tissue covering. Bone reconstruction can be performed after successful completion of steps one and two. During the salvage procedure, a combination of step two and three can be helpful.

18.3.7.1 Conservative Therapy

Recommended European Standard of Therapy

The issue of chronic osteitis can be resolved with conservative treatment. Conservative treatment of chronic osteitis is possible even with the long and uncertain period of therapy as well as procedures that are not accepted by the patient, particularly in elderly patients.

Useful Additional Conservative Treatment

Cast

18.3.7.2 Surgical Treatment

Surgical therapy must be planned in order to solve the chronic osteitis in dependence from local and general conditions. The duration of therapy must be discussed with the patient to gain acceptance for further procedures. In preparation for surgical treatment, predictable instability must be prevented through the use of a customized cast.

The first step is characterized through evaluation of the situs, extraction of microbiological samples, resection of infected bone, and vacuum closure of the wound after placement of a spacer. The bone cut should be done by using a saw. Heating of the bone must be prevented by lavage and resection should be straight and parallel, which will make the reconstruction of the bone easier. Following the salvage procedure, replacement of instruments, covers, and gloves is required.

Sufficient vacuum closure without leakage, dead space, and unneeded covering of intact skin is essential for the success of the salvage procedure.

Following the successful completion of step one, the reconstruction of the bone is determined using various methods, depending on the size and localization of the defect. In a defect in the long bones of more than 3 cm, callus distraction is a safe and successful method in chronic osteitis. Callus distraction with internal stabilization using a nail is comfortable, but demands sufficient fixation of the nail, and an additional transport mechanism outside of the skin by an external fixator or cable traction (Fig. 18.8a–c). Segment transportation begins 7 days following surgery with a speed of 0.5 mm/day in the lower leg and 1 mm/day for femur distraction. Using plain radiographs, periodic measurement during transportation once a week is necessary. The fixation of the transported segment with a small plate after completion of the distraction is advised. Callus formation can be advanced using low-intensity ultrasound stimulation. One month per centimeter of distraction must be calculated for callus duration [28, 29].

Recommended European Standard of Surgical Therapy

A complete resection of the infected bone, the complete removal of implants, a vacuum closure of the wound, an external temporary stabilization (external fixation or cast), antibiotic drugs administered in accordance with microbiological findings, repeating the revision procedure until negative bacteriological probes can be extracted, sufficient soft-tissue coverage, and reconstruction of bone defects respectively to the dimension of the bone loss if necessary for plastic surgery procedures.

Useful Additional Surgical Treatment

Administration of hyper bar oxygen therapy is optional, however, firm data regarding the treatment are not available.

18.3.8 Differential Diagnosis

Pseudarthrosis (s. Chap. 17)

18.3.9 Prognosis

Depending on the grade of infection, type of therapy, general conditions of the patient, and patient compliance, a successful treatment can be achieved between 60 and 80 % of cases.

18.3.10 Surgical Procedures

18.3.10.1 Removal of Implants

Instrument check before removal, blood supply; approach of choice using existing scars if possible; complete

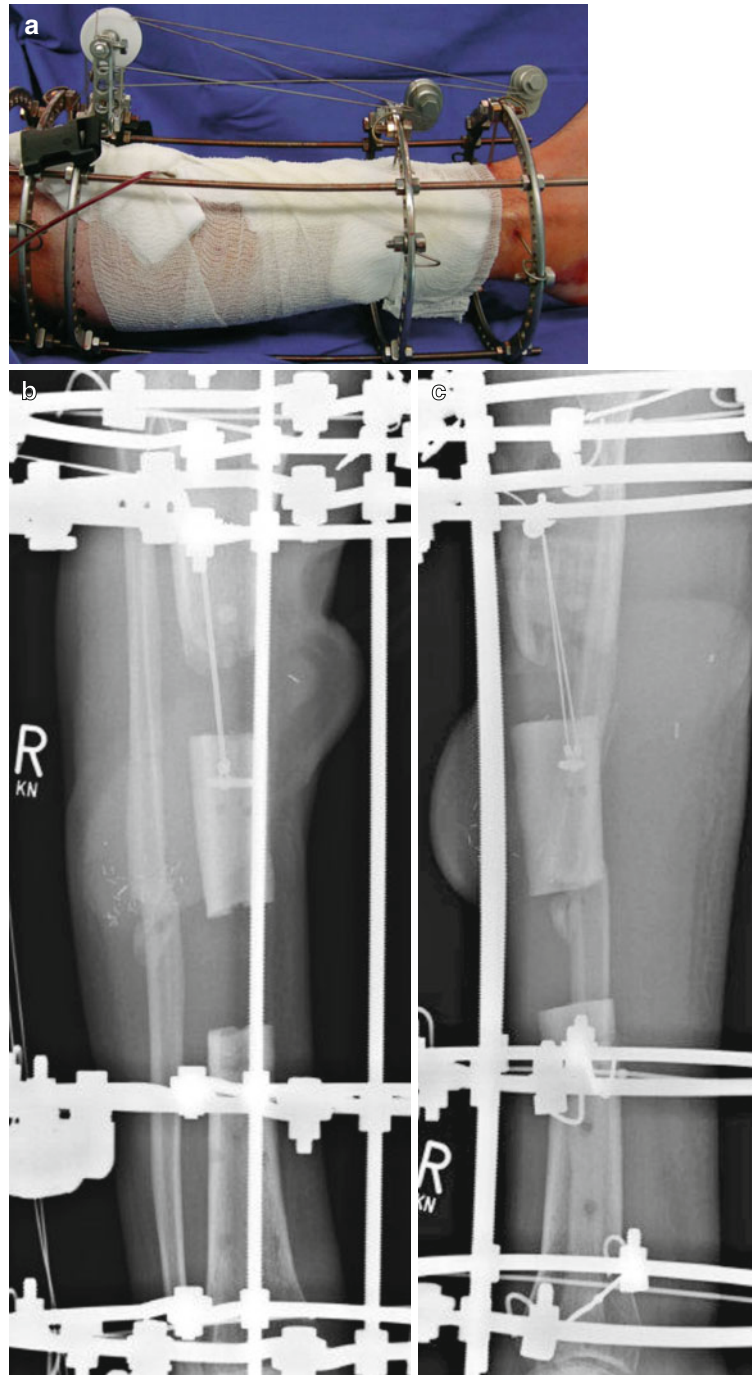

Fig. 18.8 (**a**–**c**) Chronic osteitis: segment transportation with cable system

removal of implants and cement as well as broken screws; control of complete removal using image intensifier; refill of defects using sterilized metal or cemented spacer

Technique

The technique will depend on the existing condition; prevention of additional trauma and soft-tissue damage

Possible Complication

Additional bone loss; bleeding by injuring vessels; opening of adjacent joint

18.3.10.2 Segment Resection

Technique

Detection of infected bone through microbiological probes; determination of cutting level; assessment of resection length; shortening of bone, if necessary; planning further method of stabilization and segment transportation

Possible Complication

Injury of adjacent functional structures depending on the localization

18.3.10.3 External Fixator

Technique

Checking of available instruments and implants; plain radiographs obtained in two views; positioning of region of interest on the operating table for a possibility of intraoperative imaging; skin incision and soft-tissue protection with drill sleeve under sterile conditions; bicortical and central positioning of pins; fixing of clamps with adequate distance to soft-tissue surface; reconstruction of length and torsion by connecting distal and proximal clamps with rods

Possible Complication

Injury of function structures (vessels, nerves, tendon, joint); soft-tissue impairment; pin track infection; additional fracture of bone

18.3.11 Special Remarks

In consideration of the the complex issue influenced by local and general conditions of the patient, hygenic and antimicrobial aspects and surgical challange the treatment of such patients should be done in specialised and experienced departments.

Despite clear basic treatment guidelines the therapy options mostly have to adapted individually.

18.4 Special Forms

18.4.1 Joint Infection

18.4.1.1 Synonyms

Empyema

18.4.1.2 Definition

A bacterial infection of the joint with an inflammatory reaction

18.4.1.3 Epidemiology/Etiology

Joint infections are specific affects of trauma and orthopaedic surgery with the contamination and infection of preexisting space. Furthermore, during the treatment of joint infections, the function of the joint plays an important role for further guarantee of mobility.

Immediate arthroscopic salvage procedures have priority in joint infection treatment. Arthroscopic revision should be performed after 48 h with the removal of necrotic tissue and hematoma. Additional antibiotic drugs, drainage, and immobilization are obligatory. An adjustment in the administration of systemic antibiotics according to the results of the microbiological testing is strongly recommended. In the majority of cases, *Staphylococcus aureus* and *Staphylococcus epidermidis* are detectable [29, 30].

Arthrotomy and open synovectomy are necessary if within the course of three revision procedures no negative microbiological result is achieved.

A preexisting degeneration can prevent salvage of the infection making removal of the cartilage surface essential in the preparation for further joint replacement.

Depending on general conditions such as age and mobility after the successful treatment of the joint infection, further surgical therapy must be adjusted. A joint replacement procedure can be planned only following a time period of 6–8 weeks without any infection.

18.4.1.4 Symptoms

Fever, pain, decreased function, swelling, flowing, redness, hyperthermia

18.4.1.5 Diagnosis

Plain radiographs; puncture with microbiological probes (under sterile conditions!!!); arthroscopy; CRP; inflammatory parameters; positive microbiological culture

18.4.1.6 Therapy

Immediate arthroscopic lavage; immobilization; antibiotics; planned arthroscopic; revision after 48 h

18.4.1.7 Complication

Joint destruction; stiffening of joint mobility; amputation

18.4.2 Infection of Joint Replacement

18.4.2.1 Synonyms

Periprosthetic infection

18.4.2.2 Definition

Bacterial infection of implanted artificial joints and adjacent bone and soft tissue

18.4.2.3 Epidemiology/Etiology

Infections of the endoprothesis are problematic in joint infection.

In addition to cartilage, soft tissue, and bone, implants can be affected by bacterial contamination.

The incidence of a surgical site infection after joint replacement ranges between 0.5 and 5 % [31–34]. Early and late infections can be distinguished by the moment of incidence 29].

An early infection of the joint prosthesis requires a similar procedure as in acute osteitis.

Sensitive implant surfaces must be protected against damage. Removal and temporary substitution of moving parts are also essential. Consequent and radical surgical management can save an infected endoprosthesis. If the salvage procedure is not successful, a change into a chronic infection with infected loosening is nearly inevitable. Successful treatment of revision joint replacement can be achieved in 60–80 % depending on multifactorial influences and time [35, 36].

18.4.2.4 Diagnosis

Plain radiographs, inflammatory laboratory parameters, arthroscopic, (better) open revision with microbiological probes, PET, scintigraphy, puncture of joint.

Low-grade infections present with the difficulty of differentiation for aseptic loosening because results from imaging the marginal pathologic and joint puncture can be negative in normal nutrition mediums. Common inflammatory signs such as mild fever, night sweats, and local signs of an infection are indicative of infection. An existing fistula is evidence of an infection.

The sensitivity and specificity with PET is reported in approximately 88 and 78 %, respectively[37, 38].

Bone scintigraphy and leukocyte scintigraphy have an accuracy of approximately 50–80 % for detecting a joint infection [39].

18.4.2.5 Imaging

Ultrasound is not useful because only zones of poor echo will demonstrate a fluid conglomeration.

Plain radiographs are mandatory for the diagnosis of an infected endoprosthesis. A loosening edge and hyperostosis are indicators.

CT and MRI are not helpful because of implant disturbance.

Scintigraphy is suitable for detecting regions of increased bone metabolism, but because of its low specificity, it is not possible to use it as a quantitative measurement for the differentiation of aseptic loosening.

A semi-quantitative determination of the infection in the endoprosthesis is possible using PET, additionally, a three-dimensional display is helpful. The puncture of a suspect artificial joint can generate informative bacterial probes, but includes the risk of an iatrogenic contamination of non-infected joints. False-positive results resulting from skin contamination are also possible.

18.4.2.6 Therapy

(a) Conservative

Conservative treatment of infected artificial joints cannot be recommended because the diagnosis is only certain in cases of an existing fistula and without the removal of infected vital material, salvaging of an infection using antibiotics cannot be expected.

(b) Operative Therapy

The operative treatment of an infected endoprosthesis can be performed with and without the preservation of the prosthesis.

Salvaging of the prosthesis is the goal in an acute postoperative infection. Because of an implanted prosthesis, not all regions of joint space can be reached. Mobile parts of the implant must be removed, particularly polyethylene.

Careful management for the protection of sensitive surfaces is required during the revision procedure; as a

result of this, arthroscopic revision is limited, and orientation is mainly given through reflecting surfaces. In addition, polyethylene revision is not possible arthroscopically, therefore, early open revision is preferable.

The condition for successfully finishing the salvage procedure is three consecutive negative bacterial tissue probes.

18.4.2.7 Revision with Removal of Implant

An early decision for the removal of all implants, including cement, is needed in cases without negative bacterial probes after three revisions. The removal must be performed carefully in expectation of further reimplantation of the endoprosthesis. Additional bone and soft-tissue damage must be avoided. Temporary stabilization, using a conventional or self-made spacer, is helpful and reduces pain and shortening.

Vacuum wound closure is the method of choice. After a successful salvage procedure, the decision regarding further treatment must be made. According to general patient conditions, age, bone situation, and claim of the patient, further endoprosthesis or arthrodesis can be planned. If a salvage of the infection is not achievable, amputation is an acceptable alternative with a good function and rapid recurrence to work and familiar ambiance.

18.4.2.8 Symptoms

Pain, especially on weight bearing, inflammatory local and general reaction, decreased function, fistula

18.4.2.9 Diagnosis

Plain radiographs, CRP, scintigraphy, PET, puncture

18.4.2.10 Therapy

Open revision procedure, early removal of implants, and salvage procedure until verification of negative bacterial probes.

Additional administration of antibiotics until wound healing completion.

18.4.2.11 Complications

Thromboembolism, injury of function structures (vessels, nerve, tendon, joint)

Bone loss and destruction, shortening, general infection, septic shock syndrome, bleeding

18.4.3 Spondylodiscitis

18.4.3.1 Synonyms

Spondylodiscitis, discitis

18.4.3.2 Definition

Bacterial infection of vertebral body and discs

18.4.3.3 Epidemiology/Etiology

The incidence of all bacterial bone infections is less than 5 % [40]), in 1–50 % of the cases they are caused hematogenously [41, 42], occurs after invasive procedures at the spine postoperatively with an incidence of 3–12 % [43]. The spectrum of bacteria depends on the origin of contamination which is mostly *Staphylococcus aureus*, and in rare cases tuberculosis. Elderly people are predominantly affected.

18.4.3.4 Symptoms

Most cases are characterized with light inflammatory clinical and laboratory signs, pain, and neurological failure, but severe septic progression is also possible.

18.4.3.5 Diagnostic

Plain radiographs of the affected spine area, neurological investigation, laboratory parameters (CRP), scintigraphy, MRI, CT with guided puncture

18.4.3.6 Therapy

The conservative treatment is through immobilization and administration of systemic antibiotic drugs over a period of 6–8 weeks.

Operative treatment entails the removal of the infected tissue, refill with spongy bone, stabilization of affected segments, and administration of antibiotic drugs. Early postoperative mobilization and elimination of the infected area are relevant advantages. The indication for surgery can be prevented by a rapid diagnosis so that spondylitis can be successfully treated through consequent immobilization in a plaster bed and administration of appropriate antibiotics [44, 45]

18.4.3.7 Complications

A neurological palsy can arise in cases of an increasing abscess with the spinal cord and adjacent vertebral bodies being affected, development of psoas abscess, and septicemia. Recurrence of spondylodiscitis is a

deficiency of primary therapy and improper elimination of the area of infection.

18.4.4 Infected Pseudoarthrosis

18.4.4.1 Synonyms
Infected nonunion

18.4.4.2 Definition
Bacterial infection of a non-healed fracture at least 6 months after injury

18.4.4.3 Epidemiology/Etiology
The incidence correlates with the number of open or surgically treated fractures and ranges between 0.5 and 1 % after surgical fracture treatment [46]. The spectrum of bacteria depends on the origin of the injury or operation, mostly *Staphylococcus aureus, Staphylococcus epidermidis,* and bacteria such as those presenting in osteitis.

18.4.4.4 Symptoms
Pain, particularly with weight bearing; local signs of inflammation; fever, taps pain

18.4.4.5 Diagnosis
Plain radiographs, CT, scintigraphy, PET, light to severe increase of infection parameters (CRP)

18.4.4.6 Therapy
A salvage procedure for the eradication of an infection (s. Sect. 18.3) after three negative bacterial probes and sufficient soft-tissue covering re-osteosynthesis according to the present situation.

18.4.4.7 Complications
S. Sect. 18.3.

18.4.5 Hematogenous Osteomyelitis

18.4.5.1 Synonyms
Juvenile osteomyelitis, myelitis, periostitis

18.4.5.2 Definition
A purulent infection of the bone marrow mostly in the childhood, caused by hematogenous spreading from the infected area to other locations (tonsillitis, otitis media, and pyodermia)

18.4.5.3 Epidemiology/Etiology
The incidence ranges between 2 and 4 arthritides in relationship to 10,000 children under the age of 16 years in industrialized countries [31, 49, 50]; more than 50 % are under the age of 5 years. The ratio between girls and boys is 1:2. More than 80 % of the isolated bacteria are *Staphylococcus aureus*. The pathogenetic pathway seems to be a mismatch between the virulence of bacteria, the age at vascularization, and the microcirculation of the bone and local/general conditions of immune deficiency. Predominantly, the long bones are affected after bacteremia of other infected areas. Osteomyelitis is rare in adults and occurs mostly under poor general immunologic conditions.

18.4.5.4 Symptoms
Local and general signs for infection presenting in different grades. There is no correlation between the level of clinical signs and the dimension of infection. Severe septic courses are possible during childhood. Local pain appears in the affected region.

18.4.5.5 Diagnosis
Bacterial blood culture, puncture of bone marrow for bacteriological investigation in children, plain radiographs, scintigraphy, or MRI (highest specificity and sensitivity) for the differentiation of neoplasm. Ultrasound is convenient for detecting soft-tissue edema and abscess formation in early childhood. A guided puncture is possible.

Increasing CRP disguised by antibiotic therapy shows the progression of the infection.

18.4.5.6 Therapy
Therapy is based on the administration of the antibiotic drug cephalosporine of the third generation for at least 3 weeks, if necessary a correction according to the antibiogram arises. Immobilization is mandatory. Surgical intervention is necessary for opening of abscesses, revision of fistula, and removal of sequester corresponding to salvage procedures in acute osteitis (s. Sect. 18.2).

18.4.5.7 Complications
During childhood, the most important complication is the destruction of the epiphyseal gap. A change to chronic osteitis occurs in 10 % of the cases.

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