

How I do it

Chronic osteomyelitis

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The problem defined

Chronic osteomyelitis may result from various primary infections of the bone: hematogenous, decubital, open fracture, osteosynthesis or prosthesis. It causes endosteal and periosteal bone appositions and dense, sclerotic bone, often with irregular cavities and bone bridges.

There are two main types: hematogenous and post-traumatic osteomyelitis. The hematogenous form in many cases shows irregular sclerotic changes diffusely in the diaphysis of a long bone with a spindle-shape enlargement and an occluded intramedullary canal but with intact metaphyses (Figure 1). The postoperative osteomyelitic changes are limited to the area of the trauma or operation, often with thin sclerotic boundaries of the osteosynthesis. Cortical defects remain where windows have been made during earlier treatment. The more the osteomyelitic bone has been operated on and the longer the infection has persisted, the more these forms become similar.

Healing of chronic osteomyelitis is difficult, and relapses may occur after very long relapse-free intervals, during which healing seems apparent. Adages such as "osteomyelitis is a time-bomb that ticks forever" and "once osteomyelitis, always osteomyelitis" express the pessimism of many surgeons and patients and explains why they are unwilling to treat chronic osteomyelitis, if not forced to do so by an active infection.

Healing in chronic osteomyelitis should be defined in terms of relapse-free years, and survival analysis makes more sense than healing percentages. *Healing* may be considered as *probable* when no clinical signs (swelling, tenderness, warmth, sinus, fever) are present and laboratory values (ESR, CRP) have normalized, but only when the antibiotic therapy has been stopped for a reasonable period, e.g., 1–2 years. A *relapse* should be defined as an exacerbation of an

infection after such a period of probable healing without any therapy. When an infection becomes apparent shortly after antibiotic therapy has ceased, this is not a relapse, but *no healing!* There should be unanimity about these definitions, when results of treatments are published and compared.

Diagnosis

Two questions must be answered before any treatment can be considered: whether an infection exists and its extent. The second question needs an answer, especially when operative procedures are planned, and it will therefore be discussed in the section about preoperative planning.



Figure 1. Chronic hematogenous osteomyelitis of the femur. The infection started 30 years ago in the distal metaphysis, and was debrided recently by a lateral approach.

For the diagnosis of chronic osteomyelitis, the patients' history remains the chief instrument. A history of cyclic pain, increasing to severe deep tense pain with fever, is characteristic, especially if pain, fever and redness disappear when pus breaks out in a fistula. Between relapses, pain and other signs may be absent. Such a history is pathognomonic. The relapse-free periods vary greatly. Intervals up to 80 years have been reported.

ESR, CRP and leucocyte count are elevated in the acute phase but may be normal in the chronic phase; laboratory findings are not informative when negative.

Radionuclide scintigraphy is sensitive but non-specific, especially when the bone has previously been fractured or operated on (Wegener and Alavi 1991, Nigro et al. 1992). Technetium bone scintigraphy, should be performed as a three-phase scan. Infection may be considered when the first 2 phases (arterial blood flow and venous phase) are positive. The third phase represents the bone uptake and may remain positive for years after all kinds of bone operations. The value of nuclear scanning increases when earlier scans are available for comparison. I regard nuclear scintigraphy to be of limited value in diagnosing chronic osteomyelitis. Even so-called infection-specific scans (IgG, indium-labeled leukocytes, gallium) may fail in difficult cases. However, the value of scintigraphy is unquestionable in acute cases and in children.

MRI may be of value, but it is also often not specific enough in chronic cases (Erdman et al. 1991). MRI gives reliable information about abscess formation, especially when combined with gadolinium. The anatomy is better visualized than on bone scintigraphy, and therefore it is especially important for preoperative planning.

Nonoperative treatment

No treatment may be reasonable for patients with mild relapses, who have exhausted conventional surgical treatment and are faced with extensive reconstructions or amputation. Incision of abscesses and short-term periods of suppressing antibiotics may sometimes still be necessary to avoid spread of the infection locally or systemically.

Lifelong suppression of the infection with antibiotics is an alternative. Such a treatment could be administered parenterally via a Hickman catheter or with an implantable pump, but I regard these invasive lines as not indicated in low-grade chronic infections. With oral antibiotics, the activity of an infection can often

be reduced. However, none of my patients wanted to use antibiotics lifelong. High age in itself is not a good reason for being less aggressive in the treatment since the immune capacity diminishes with age. Still, it remains difficult to recommend an extensive operation when an old patient has no pain.

Antiinflammatory drugs may be used to treat edema and pain, but there are no studies on their value in osteomyelitis.

Operative treatment

Indications

Healing of chronic osteomyelitis demands a well performed, often aggressive, combination of operative and antibiotic treatment. Avascular tissue that cannot sufficiently be penetrated by antibiotics should be removed. Antibiotics must kill the bacteria in the remaining contaminated tissues. Not all patients need or demand such a treatment.

Treatment is desirable in patients having an infection that stays active, even when the fistula temporarily closes. These patients may develop high fever when the secretion accumulates, causing a high stowing pressure. Dangerous bacteremia may then cause metastatic infections elsewhere. Such patients are mostly very willing to be treated in such an acute phase, but they often forget their acute problem when the fistula has spontaneously opened or the abscess has been incised. Treatment is mandatory in active chronic infections, with progressive damage of bone and soft tissues. Patients with less active chronic osteomyelitis have only a relative indication for operative treatment.

There is also an indication for operative treatment in cases with continuous secretion that is abundant or malodorous or when relapses are frequent.

Preoperative investigations

The preoperative screening includes general health and questions about allergies for antibiotics. The history for this is often unclear and objective information must be looked for in time. The base-line values for ESR, leucocyte differentiation and CRP must be determined. To calculate the maximal antibiotic dosage, body weight and length, as well as renal and liver function, must be known preoperatively.

Preoperative imaging of the exact localization of the infection is important for planning the operative procedure. Radiographs may be made in four planes, and when very sclerotic bone is present with extra high power (Figure 2). Tomography usually works better than CT in mapping the degree of sclerosis, and



Figure 2. Chronic hematogenous osteomyelitis for 40 years, after multiple operations. Radiographs have been taken in 4 planes. There are cortical windows at the lateral and medial sides. Rotated radiographs show a ventral fissure (right).

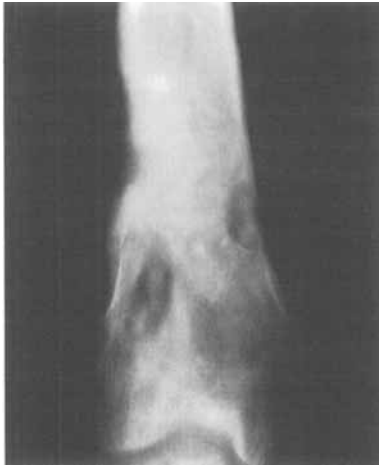


Figure 3. Tomograph of a distal femur with 2 sequestra and some sclerotic parts.

in detecting an isolated sclerotic structure, this could be a sequester (Figure 3).

CT helps in complex deformities of the metaphysis and a windowed diaphysis, especially when a three-dimensional reconstruction is then made. CT is mandatory in case of intramedullary, axial bone changes, as in hematogenous diaphysial osteomyelitis or infections after intramedullary nailing. The degree of cortical thickening and the presence of circular sequestra are easily seen on a CT scan. Moreover, the diameter the intramedullary canal has to be overreamed can be measured preoperatively.



Figure 4. MRI of the same femur as in Figure 2. A pedicled muscle graft runs from the medial to the lateral opening in the cortex. A relapse exists with an abscess at the medial side and edema in the medullary canal.

MRI is especially helpful when abscesses are present (Figure 4). MRI and scintigraphy cannot reveal how far an infection extends into the intramedullary canal; a reactive edema may simulate infected tissue.

Fistulography may reveal where, in a large area of osteomyelitic bone changes, the active infection is to

be found. It must be performed by an experienced radiologist, who must put sufficient pressure on the injected contrast fluid.

Preoperatively, I inject the fistula with methylene blue. The canal must be penetrated by the thickest possible cannula or a urine catheter and it should be occluded by manual pressure. The pressure that is built up must be high so that the dye can be injected as deeply as possible. The patients should feel the same pain as during stowing of secretion. One has to be careful when producing this high pressure: methylene blue may cause ineradicable stains on the clothes of patient and doctor. The injection must be done on the day before the operation. This permits excess methylene blue to leak out of the fistula, staining only the granulation tissue of the fistula and abscess. If the injection is done during surgery, the methylene blue will also stain healthy tissue, which doesn't help. I found, several times, the center of a chronic infection only by following the thin blue canal that guided me better than all other and more expensive preoperative investigations. This is a good reason to operate when the fistula is still open.

Bacteriology

Reliable information about the causative agent is decisive for successful antibiotic therapy. As surgeons, we are responsible for the way samples are taken. In case of a fistula, I take a sample after disinfection of the opening of the sinus and surrounding skin. A swab is placed deep in the fistula, which also gives some information about the direction of the sinus tract. A swab for anaerobic culture in a special medium is also taken, and must be sent to the laboratory within half an hour. In general, cultures from a fistula are not very reliable: the organisms cultured from a fistula have little value for predicting the pathogen isolated from the bone itself, except when *Staphylococcus aureus* is found (Mackowiak et al. 1978).

The best materials for culture are tissue fragments taken during operation at the center of infection. These tissue fragments also must be sent as soon as possible to the laboratory, and for anaerobic culture special media are recommended when some delay is expected. The fragments must be homogenized in the laboratory and inoculated onto several culture media. When pus is found, a closed syringe with the pus should also be sent in. It is important to mention which antibiotics were used during and shortly before the sampling, because some antibiotics may retain their activity during incubation of the inoculated material. Bacteriologic cultures may be falsely negative when antibiotics are used by the patient. To avoid this, antibiotics should be stopped at least one week

before culture.

When the primary cultures remain sterile, the material should be further incubated in enrichment broth for about two weeks, to allow slow-growing bacteria to be detected and to avoid false negative reports. To avoid false positive growth (e.g., contaminating skin flora), the material should be aseptically divided into 6 tubes with enrichment broth. If the cultured bacteria originate from the skin, they are nevertheless considered clinically relevant if they grow in 3 or more of these cultures.

When local antibiotic carriers are employed, information about antimicrobial susceptibilities of the organism cannot be used in the regular way, because it is based on the serum levels of the antibiotics obtained with systemic therapy. Since much higher concentrations are achieved with local antibiotic therapy, the minimal inhibitory concentration (MIC) of the offending organism is much more informative. Therefore, in our hospital, for organisms recovered from all orthopedic samples, the MIC value for gentamicin is always determined.

A discussion of the results with an interested bacteriologist, having knowledge of the special aspects of orthopedic infections and laboratory techniques, is decisive for good treatment.

The operation

During surgery for chronic osteomyelitis, intravenous antibiotic therapy is started after deep tissue samples have been taken for bacteriologic culture. If surgery is performed during an active phase, the debridement may be difficult. Hyperemia and blood loss may make it difficult to judge the vitality of the tissues. In such cases, the operation should be limited to incision of abscesses, removal of granulations and identification of the causative organism. During a second operation, after a short period of antibiotic treatment, scarred tissues, sclerotic bone and remaining implants can be removed. Only in very active infections with soft tissue involvement, must antibiotics sometimes be given preoperatively to reduce hyperemia and induration.

If possible, patients are operated on using an Es-march bandage, without exsanguinating the limb, to avoid spread of pus and bacteria by compression of the infected area. Blood is removed simply by elevating the limb a few minutes. An important advantage of doing this, is that the remaining blood in the extremity will indicate the vascularity of the tissues, which is especially valuable when judging the vitality of sclerotic bone. This is not called a "bloodless" field, but "blutsperre" (blood "blocking").

The incision should include excision of the fistula in the skin. The skin and sinus tract should be sent for

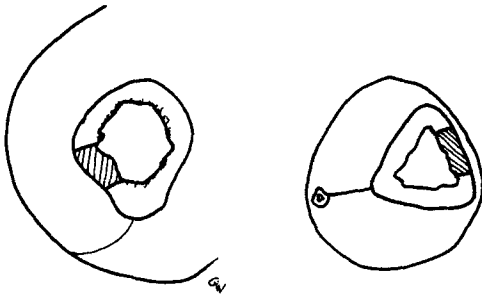


Figure 5. Diagram of femur (left) and tibia (right) to indicate the most suitable place for a window in the diaphyseal cortex.

histologic examination because the chronic irritation may have caused a malignant transformation. The fistula is followed to the center of infection and removed with the surrounding scarred tissue. When a fistula is not located at the site of exposure, it is left alone and curetted at the end of the operation. It will close spontaneously when the deep infection has healed.

Bone is exposed in the easiest and safest way. Since a relapse usually occurs in the exposed area, approaches near vital structures should be avoided. Bone that is close to the skin, such as the ulna and tibia, can best be exposed directly, removing skin, subcutaneous tissue and periost in a single layer.

The cortical diaphyseal bone is opened via a window giving access to the intramedullary canal. This window must be large enough to allow debridement of the inner surface, but should weaken the bone as little as possible. The cortex is predrilled and edges are rounded off. In chronic osteomyelitis, I never put back the removed cortical window, except in infected prostheses. The size in the femur and tibia is mostly about 1x10 cm its location in the femur should be lateral, in the tibia anteromedial. For strength, the linea aspera of the femur is kept intact, in the tibia all three cristae (Figure 5).

Inside the diaphysis, granulation and small sequestra are removed. I try to find an opening to the healthy intramedullary canal, without the risk of weakening the cortex by using a "wrong path". The thickened cortex is thinned from the inside, using small chisels and a high speed burr up to the diameter of a normal shaft (Figure 6). This facilitates antibiotic penetration and revascularization. Very sclerotic bone can be drilled with small holes for the same reason.

When, in case of an associated septic arthritis, an arthrodesis must be performed, the resection of the joint is performed in the same session, which forms the best radical debridement of the infected joint surfaces.



Figure 6. My favorite instruments are: two small chisels, a small long hooked spoon for the bone, and a large one for the soft tissues. A high speed burr to reduce the thickness of the cortex, and a pulse-lavage instrument for cleaning. A special introducer is used to put chains of gentamicin-containing beads in the intramedullary canal.

During debridement, a good balance must be found between removing avascular tissue that cannot be penetrated by the antibiotics and preserving the continuity of the bone to give sufficient strength. The vitality of the bone must be judged by looking for small droplets of blood coming out of the cortical bone, after flushing gently by hand with saline (Figure 7). It is not necessary to use such intravital staining, as in the past could be done with intravenous disulfine blue[®] given preoperatively. Such staining gives no more information than the blood droplets mentioned above.

Vitality of the bone is not a question of dead or alive, but is gradual. One need not remove all cortical bone that may be considered less vital, especially if it would cause a major defect with a need for an extensive reconstruction. Although there is a risk in leaving sclerotic bone, healing is not impossible if the sclerosis is not too thick to prevent antibiotic penetration.

An involucrum is an extensive cuff of subperiosteal calcifications due to elevation of a strong periosteum and is seen only in acute hematogenous osteomyelitis in childhood. Such an involucrum envelops a large diaphyseal sequestrum. This sequestrum must be removed, but as much as possible of the involucrum should be left, because a new diaphysis will form from it.

In case of diffuse diaphyseal infection, as in hematogenous osteomyelitis and after infected intramedullary nails, the debridement is performed by intramedullary reaming. The reaming is performed with the normal instruments and approaches used in nailing. Sclerotic occlusions of the medulla sometimes must be perforated using long hand-driven

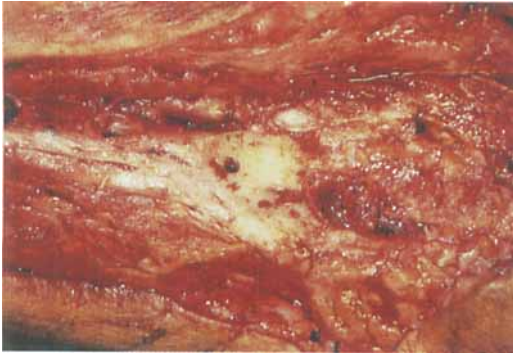


Figure 7. Vitality of the bone can best be judged by the presence of small blood droplets during surgery.

drills as in prosthetic revisions. To avoid intramedullary accumulation of debris distally, a small window of 1–2 cm diameter is made in the metaphyseal region: in the lateral femur condyle or just proximal to the medial malleolus in the tibia. The reamed granulation and sequestra can then be irrigated distally and removed via this window.

After debridement, a pulse lavage system with Ringer's solution is used to irrigate the debrided area copiously. In this way, all contaminated material is washed out and the bacterial contamination of the remaining tissues may be further reduced. Afterwards, chains of gentamicin-loaded bone-cement beads are introduced in the intramedullary canal with the help of a special introducer (Figure 8).

After debridement, a large defect may remain, especially in the metaphysis and after excision of scarred soft tissues. One of the advantages of local antibiotic treatment with non-resorbable carriers, such as gentamicin beads, is the temporary filling of these cavities to prepare reconstruction as a secondary step.

Stabilization

All implants must be removed if possible which, in general, will be the case in chronic infections. If the



Figure 8. A special instrument is used to introduce a chain of 60 beads in the intramedullary canal.

implant is still needed and is retained for bone consolidation, then this will impair the healing of the infection. The experience that instability impairs infection healing and the impression that after stabilization an infection heals better are based on clinical reports. However, there is no scientific evidence for a primary role of stability in healing of the infection in osteomyelitis.

There are two reports of animal experiments done to study the relationship between infection and stability. In a model of an infected tibia osteotomy in sheep, it was shown that bone consolidated in the presence of osteosynthesis material, despite infection. This experiment did not study the influence of stability on the infection itself (Rittmann and Perren 1974). In another experiment, in infected tibial fractures of rabbits, the difference between stable and unstable fixations was studied. Severe instability increased the degree of local bone infection, but the infection itself did not impair consolidation (Friedrich 1975). Thus both studies proved that bone could consolidate, despite infection, but not that stability is mandatory for healing the infection. Stabilization may be helpful to reduce the activity of the infection, especially in the diaphysis. Infection will heal, not because the bone is stable, but because of optimal debridement and antibiotic therapy.

If implants must be used for stability, I prefer external fixation, if technically possible. If the fixator pins risk catching intramedullary gentamicin beads, I apply the external fixator at the second operation, when the beads are removed and reconstruction is performed.

If internal fixation has to be used, then it must be stable. The implant and the surrounding fibrous tissue may become contaminated, if the infection is not completely eradicated. This is why a relapse of the infection sometimes occurs when the implanted material is later removed. The latter operation should therefore include a new debridement of the surrounding fibrous tissue and a short period of antibiotic therapy.

Systemic antibiotic treatment

Antibiotic treatment must be adequate regarding spectrum and dose. The spectrum must cover the causative bacteria, but preferably not more than these. Antibiotic therapy can be given systemically, locally or both.

The systemic intravenous treatment is started during debridement after culture. I start with broad-spectrum antibiotics, if the causative organism is unknown or if the patient is very ill or if there is an extensive soft tissue involvement. Amoxicillin-clavulanic acid (Augmentin®), in combination with gen-

tamicin, will cover gram-positive, gram-negative and most anaerobic bacteria. After a few days, when the organism is identified, the most suitable antibiotic is chosen. In the majority of my patients flucloxacillin can still be used, because *Staphylococcus aureus* is generally the causative bacteria and methicillin resistance is still rare in The Netherlands. A normal intravenous dose is 6x1 g, in serious infections up to 6x2 g. Especially in case of polybacterial infections, a bacteriologist is consulted to choose the antibiotic, also because the routine information on the resistance pattern may differ from the in vivo efficiency.

In general, intravenous antibiotic therapy is given during the whole hospital stay—if necessary, via a central line. When patients are discharged, antibiotics are given orally. There is some evidence that long-term therapy is more effective (Hedström 1974). Most patients with chronic osteomyelitis are treated for 6–12 weeks after the first operation.

Local antibiotic treatment

Local antibiotic therapy is possible, as gentamicin beads are commercially available in Europe since 1977. Like all antibiotic treatment in chronic osteomyelitis, it is secondary to an adequate debridement. When beads are placed in the debrided area, gentamicin will be released from the surface of the bone-cement to the hematoma. The local gentamicin concentration in the hematoma and the tissues will be much higher than can be achieved with systemic antibiotic therapy (Wahlig et al. 1978). The concentration in the serum, and therefore in the organs will remain very low, mostly undetectable (Walenkamp et al. 1986), even when renal function is impaired. Therefore no toxicity is found.

The beads must be used with good understanding of the diffusion process and measures must be taken to keep gentamicin in the wound. The gentamicin levels are sufficiently high up to only 2–3 cm from the beads. Therefore, to achieve adequate killing of bacteria, as many beads as possible must be implanted all over the area of treatment. A wound drain is used for one day, simply as an overflow drain, when there is much blood loss. The beads should never be used in combination with an irrigation system. Soft tissues must be closed watertight to keep the gentamicin inside, and I often use artificial skin for that purpose (Epigard®). In smaller cavities, I prefer minibeads, because they release 7 times more gentamicin, than the larger beads per wound volume (Walenkamp 1989). Handmade gentamicin beads can also be made with plaster of Paris in developing countries to reduce the costs (Mackey et al. 1982, Evrard et al. 1990).

Beads can be placed even in the subcutaneous tissues, if deeply implanted beads and systemic antibiotics are considered to be insufficient. Chains of beads may protrude from the skin via a separate incision, and these can be removed manually at the ward. This saves an operation for removal, but it can be done only when a few chains are used. In that case, gradual removal starts at one week and must be completed within 2–3 weeks.

When an infection heals properly, the wound will dry in about 5 days. If not, and secretion persists, infection must be considered as ongoing. If healing is appropriate, beads are removed and a reconstruction, if necessary, is done in a second operation. This operation can be performed 2 weeks after the first one. In this way, a treatment schedule with intervals of 2 weeks between operations is possible. This is convenient for patient and physician. A longer interval is pointless if healing seems to fail, since gentamicin concentrations will gradually diminish.

Inspection of the wound during surgical removal of beads is also informative in deciding if healing is likely. Healing is probable if beads are well encapsulated in granulation tissue. When in doubt, re-debridement with implantation of new beads for another 2 weeks is the best choice.

Resorbable carriers for antibiotics have been developed. Gentamicin-containing collagen fleeces are now frequently used. They produce a higher gentamicin concentration locally than beads do, but during a shorter time, 1–2 days (Sørensen et al. 1990). The collagen is resorbed in 4 weeks. Since I have used them in cases where no reconstruction was necessary, no further operation was needed. However, the resorption process of the collagen caused a wound secretion that started at one week and went on up to 4 weeks postoperatively. Therefore, judgement of healing with fleeces is more difficult.

Leaving gentamicin beads permanently behind, planned or in case of breakage of a chain is not absolutely contraindicated. Removal must be weighed against the risk of leaving the beads. If a relapse occurs, these beads will form the new center of infection. Moreover, the local gentamicin concentration decreases gradually when beads are left for a long period. The resulting subinhibitory concentration of gentamicin may induce resistance of bacteria by forming so-called small colony variants of *Staphylococcus aureus* (von Eiff et al. 1997). This recent finding is a strong plea for the treatment of infections as described: many beads during a few weeks result in high concentrations during a short period.

When bacteria are resistant and the MIC value for gentamicin is too high, as in methicillin-resistant

Staphylococcus aureus (MRSA), multiresistant *Staphylococcus epidermidis* (MRSE) and *Enterococcus faecalis*, osteomyelitis cannot be treated with gentamicin beads or fleeces. Arbitrarily, this is the case when MIC values are higher than 50–150 µg/mL. As long as no other antibiotic-loaded carriers are manufactured, hand-made beads could be prepared in these cases. Good results have been reported with such beads loaded with vancomycin (Scott et al. 1988).

In cases where no local antibiotic carriers can be used, one must rely on systemic antibiotic therapy or revert to suction irrigation systems.

Reconstruction

If needed, a reconstruction should, preferably, be done as a second step, at the same operation as the beads are removed. This will generally be after 2 weeks, if healing seems appropriate.

In case of a resected pseudarthrosis or other substantial diaphyseal defects, cancellous bone grafts are used. Autologous bone is preferred, without admixing heterologous bank bone. Cancellous bone grafts can be used even when the infection is not completely eradicated (Coleman et al. 1946, Papineau 1973, Enami et al. 1995). However, in active infection the cancellous bone graft will be resorbed (Werken et al. 1980), which is another argument for treating the infection first and reconstructing secondarily.

In general, I take the cancellous bone from the lateral proximal tibia plateau or from the posterior iliac crest and do not mix antibiotics or antibiotic-loaded collagen fleeces in the graft. The graft is compressed as much as possible during filling of the defect. If the cancellous bone graft cannot be covered by soft tissues, artificial skin (Epigard®) is used, with a chain of 20 minibeads to protect the graft. The artificial skin is left in place for 4–6 weeks, to promote fibrous tissue covering of the bone graft.

In case of arthrodesis, the external fixator, which was placed for stabilization and distraction during the first debridement operation, is used to apply compression. I prefer transfixation with a Hoffmann fixator, using 4 compression bars, according to Vidal. In knee arthrodesis, additional fixation in the sagittal plane is used (Figure 9).

In case of pseudarthrosis, individualized solutions must be used. In general, I do not like to use intramedullary nails in formerly infected areas since this may cause a relapse along the entire nail.

In metaphyseal defects, muscle flaps can help to fill a cavity (Figure 10). Probably the relapse rate diminishes, because of the vital muscle. However, plastic surgery to close the wound should not be per-

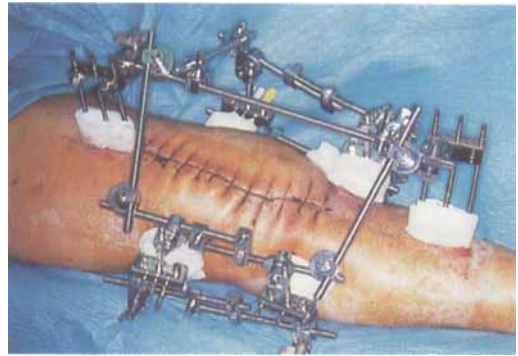


Figure 9. External fixation of a knee arthrodesis with transfixation pins in the frontal plane. Compression is applied with 4 compression bars, according to Vidal. Additional stability is achieved by using connecting pins in the sagittal plane.

formed before debridement or before healing of the infection becomes probable.

All later reconstructions in the osteomyelitic region must be performed with a short prophylactic antibiotic coverage, because these reoperations may induce a relapse, even after many infection-free years.

Other treatments

I have not yet gained experience of large resections of osteomyelitic bone, followed by segmental bone transport, as in the Ilizarov method. This might add an



Figure 10. An infected elbow prosthesis was debrided and treated with beads. A large dead space was filled with a free-pedicled muscle graft, permitting movement. The elbow is hinged on the collateral ligaments and has a range of movement of 60 degrees. Despite some persistent sclerosis and movement, healing was achieved with no recurrence after 5 years follow-up.

important technique to my armamentarium in the most difficult cases with probably high healing rates (Calhoun et al. 1993, Schmidt et al. 1992, Dendrinis et al. 1995). This kind of treatment is demanding for the physician and the patient and should be centralized.

I have not used implantable antibiotic pumps, bioelectrical effects or alternative resorbable carriers for antibiotics (Webster et al. 1981, Eitenmüller et al. 1985, Perry et al. 1988, Sharrard 1990, Jacob et al. 1991, Nelson et al. 1997).

Suction drainage systems and open drainage have been used extensively in the past for osteomyelitis, but have some serious disadvantages. They immobilize the patient, drains will clog and leak and intensive supervision by the nurses is needed. I use them only in case of highly resistant bacteria.

Evaluating healing after treatment

In chronic osteomyelitis, healing remains uncertain. The main parameter is wound healing. Twice a week, ESR, CRP and leucocyte counts are estimated. CRP is more helpful than the ESR when, in the short interval of two weeks, a decision must be made for further treatment. ESR is of value in the later follow-up.

I found almost all relapses in my patients in the first 1-2 years after treatment started (Walenkamp et al. 1997). I explain to my patients that they have a good chance to remain healed as long as the period elapsed since the operation.

The most difficult cases to heal, in my hands, are those with chronic hematogenous osteomyelitis, causing severe sclerotic changes in the whole diaphysis, especially the femur (Figures 2, 4). The easiest are localized infections around implants or a sequester (Figure 3).

Conclusions

Chronic osteomyelitis must be treated with a combination of operative debridement and antibiotic therapy. Failure results when one of these two treatments is neglected.

I use a treatment schedule with regular intervals of 2 weeks between operations. The operations can generally be performed with a limited number of instruments, and stabilization, if needed, can best be achieved with an external fixator. If local antibiotics can be used, they effectively help the systemic antibiotic therapy or may make it superfluous.

Nowadays one can achieve more than 90% probable healing and obtain better survival rates in terms of longer relapse-free periods (Vecsei and

Barquet 1981, Majid et al. 1985, Klemm 1993, Cierny 1990, Walenkamp et al. 1997). The view that chronic osteomyelitis cannot be eradicated is much too pessimistic.

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References

- Calhoun J H, Anger D M, Ledbetter B R, Cobos J A, Mader J T. The Ilizarov fixator and polymethylmethacrylate-antibiotic beads for the treatment of infected deformities. *Clin Orthop* 1993; 295: 13-22.
- Cierny G. Chronic osteomyelitis: results of treatment. In: *Instructional Course Lectures*, vol 34. American Academy of Orthopedic Surgeons 1990: 495-500.
- Coleman H M, Bateman J E, Dale G M, Starr D E. Cancellous bone grafts for infected bone defects. *Surg Gynec Obstet* 1946; 83: 392-8.
- Dendrinis G K, Kontos S, Lyritis E. Use of the Ilizarov technique of non-union of the tibia associated with infection. *J Bone Joint Surg (Am)* 1995; 77: 835-46.
- Eiff Ch von, Bettin D, Proctor R A, Rolauuffs, Lindner N, Winkelmann W, Peters G. Recovery of small-colony variants of *Staphylococcus aureus* following gentamicin bead placement for osteomyelitis. *Clin Infect Dis* 1997 (in press).
- Eitenmüller J, Schmidt K H, Peters G, Gelissen G, Weltin R, Reichmann W. Experimental and preliminary clinical experience with absorbable calcium phosphate granules containing an antibiotic or antiseptic for the local treatment of osteomyelitis. *J Hosp Infect (Suppl)* 1985; 6: 177-84.
- Enami A, Mjöberg B, Larsson S. Infected tibial nonunion: good results after open cancellous bone grafting in 37 cases. *Acta Orthop Scand* 1995; 66 (5): 447-51.
- Erdman W A, Tamburo F, Jayson H T, Weatherall P T, Bond Ferry K, Peshock R M. Osteomyelitis: characteristics and pitfalls of diagnosis with MR imaging. *Radiology* 1991; 180: 533-9.
- Evrard J, Kerri O, Martini M, Conort O. Traitement des infections osseuses par linguettes de plâtre de Paris imprégnées d'antibiotiques. *Pathol Biol* 1990; 38 (5): 543-7.
- Friedrich B. Biomechanische Stabilität und posttraumatische Osteitis. *Experimentelle Untersuchungen zur Ätiologie und ihre Konsequenzen für die Klinik*. Hefte zur Unfallheilkunde (Herausg.: Rehn J, Schweiberer L), Heft 122, Springer Verlag, Berlin, 1975. ISBN 3-540-07468-6.
- Hedström S Å. The prognosis of chronic staphylococcal osteomyelitis after long-term antibiotic treatment. *Scand J Infect Dis*, 1974; 6 (1): 33-8.
- Jacob E J, Setterstrom J A, Bach D E, Heath J R, McNiesh L M, Cierny G. Evaluation of biodegradable ampicillin anhydrate microcapsules for local treatment of experimental staphylococcal osteomyelitis. *Clin Orthop* 1991; 267: 237-44.

- Klemm K. Antibiotic bead chains Clin Orthop 1993; 295: 63-76.
- Mackey D, Varlet A, Debeaumont D. Antibiotic-loaded plaster of Paris pellets: an in vitro study of a possible method of local antibiotic therapy in bone infection. Clin Orthop 1982; 167: 263-8.
- Mackowiak P A, Jones S R, Smith J W. Diagnostic value of sinus-tract cultures in chronic osteomyelitis. JAMA 1978; 239 (26): 2772-5.
- Majid S A, Lindberg L T, Gunterberg B, Siddki M S. Gentamicin-PMMA beads in the treatment of chronic osteomyelitis. Acta Orthop Scand 1985; 56: 265-8.
- Nelson C L, Hickmon S G, Skinner R A. Treatment of experimental osteomyelitis by surgical debridement and the implantation of bioerodable, polyanhydride-gentamicin beads. J Orthop Res 1997; 17: 249-55.
- Nigro N D, Bartynski W S, Grossman SJ, Kruljac S. Clinical impact of Magnetic Resonance Imaging in foot osteomyelitis. J Am Podiatr Med Assoc 1992; 82: 603-615.
- Papineau L. L'excision-greffe avec fermeture retardée délibérée dans l'osteomyélite chronique. Nouv Presse Med 1973; 2: 2753-5.
- Perry C R, Davenport K, Vossen M K. Local delivery of antibiotics via an implantable pump in the treatment of osteomyelitis. Clin Orthop 1988; 226: 222-30
- Rittmann W W, Perren S M. Corticale Knochenheilung nach Osteosynthese und Infektion. Biomechanik und Biologie. Springer, Berlin 1974. ISBN 3-540-06884-8.
- Schmidt H G, Witte F, Faschingbauer M, Fink B. Die Behandlung der chronischen Osteitis am Oberschenkel. Unfallchirurg 1992; 95 (11): 562-5.
- Scott D M, Rotschafer J C, Behrens F. Use of vancomycin and tobramycin polymethylmethacrylate-impregnated beads in the management of chronic osteomyelitis. Drug Intelligence and Clinical Pharmacy 1988; 22: 480-3.
- Sharrard W J W. A double blind trial of pulsed electromagnetic fields for delayed union of tibial fractures. J Bone Joint Surg (Br) 1990; 72: 347-55.
- Sørensen T S, Sørensen A I, Mørser S. Rapid release of gentamicin from collagen sponge. In vitro comparison with plastic beads. Acta Orthop Scand 1990; 61(4): 353-6.
- Vecsei V, Barquet A. Treatment of chronic osteomyelitis by necrectomy and gentamicin-PMMA beads. Clin Orthop 1981; 159: 201-7.
- Wahlig H, Dingeldein E, Bergman R, Reuss, K. The release of gentamicin from polymethylmethacrylate beads. J Bone Joint Surg 1978; 60-B (2): 270-5.
- Walenkamp G H I M, Vree T B, van Rens T J G. Gentamicin-PMMA beads. Pharmacokinetic and nephrotoxicologic study. Clin Orthop 1986; 205: 171-183.
- Walenkamp G. Small beads improve gentamicin release. Acta Orthop Scand 1989; 60 (6): 668-9.
- Walenkamp G H I M, Klein L A, de Leeuw M. Treatment of osteomyelitis with gentamicin-PMMA beads. A survival analysis of 100 cases. Acta Orthop Scand 1998 (accepted for publication).
- Webster D A, Spadaro J A, Becker R O, Kramer S. Silver anode treatment of chronic osteomyelitis. Clin Orthop 1981; 161: 105-15
- Wegener W A, Alavi A. Diagnostic imaging of musculoskeletal infection. Roentgenography; Gallium, Indium-labeled white blood cells, gamma globulin, bone scintigraphy and MRI. Orthop Clin North Am 1991; 22: 401-18.
- Werken C van der, Burri C, Kinzl L. Qualitatives und quantitatives Verhalten des autologen Spongiosatransplantates im Röntgenbild. Unfallheilkunde 1980; 83: 142-5.