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Treatment of bone infections in children in low-income countries – A practical guideline based on clinical cases

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ABSTRACT

In low-income countries (LIC), the management of bone infections is a huge challenge. A high number of patients are in the pediatric age group. Children and adolescents exhibit good bone healing potential offering treatment options that mainly rely on the biological response of the infected bone. The purpose of this article is to highlight treatment options for these patients in LIC, which is based on clinical cases that illustrate the principles of the treatment, focusing on bone reaction and healing potential.

First, identification of emergency cases is of importance. Sepsis of the patient due to bone infections is a life-threatening disease that requires immediate surgical attention with abscess incision. It should be tailored to the surgeon's experience and local conditions to avoid unwanted complications, such as excessive bleeding, fracture or bone loss.

In non-septic patients, uncomplicated cases should be distinguished from complicated cases as the first might often require only abscess incision, particularly in small children, without any other major surgical intervention.

Biomechanical stability and bone formation capacity, soft tissue conditions and joint involvement are decisive factors differentiating uncomplicated from complicated cases. Central treatment column is the immobilization of the infected bone with simple methods, such as plaster of Paris, braces or external fixation. This is intended to provide sufficient stability to allow for new bone formation that subsequently downsizes the infection site and that can bridge previously infected non-union sites or bone defects. In most cases, antibiotic treatment is not performed as antibiotics are not available or affordable.

Severe soft tissue defects remain a major challenge as microvascular surgical experience is often required for reliable coverage, for which referral to one of the very few specialized centers is recommended. Major bone defects should also be treated in centers with sufficient expertise for bone reconstruction procedures. Regular follow-ups are important to ensure healing and to avoid aggravation of the disease.

Encouraging success rates can be achieved by these treatment principles. However, it should not be forgotten that poverty in these countries, including limited access to health care, remains one of the world's most important problems.

Introduction

Chronic bone infections, such as chronic osteomyelitis or fracture-related infections, remain a difficult-to-treat disease [1]. This is particularly true for low-income countries (LIC) with only very limited access to health care for patients. A high number of chronic bone infection patients in LIC are children and young adults [2].

In many regions of the developing world, the majority of cases are still managed by medical officers or general surgeons who might not be so familiar with the treatment strategies and surgical techniques required by the cases that they have to face in their daily routine. The needs, at the moment and in the foreseeable future, cannot be fully and comprehensibly met by the really scanty number of pediatric orthopedic surgeons in LIC. Surgical treatment has been, is and will be, for several years to come, the therapeutic stalwart in the treatment of osteoarticular infections in these age groups. There are several elements that a front-line surgeon has to consider before embarking in the surgical management of pediatric bone and joint infection. The decision-making process

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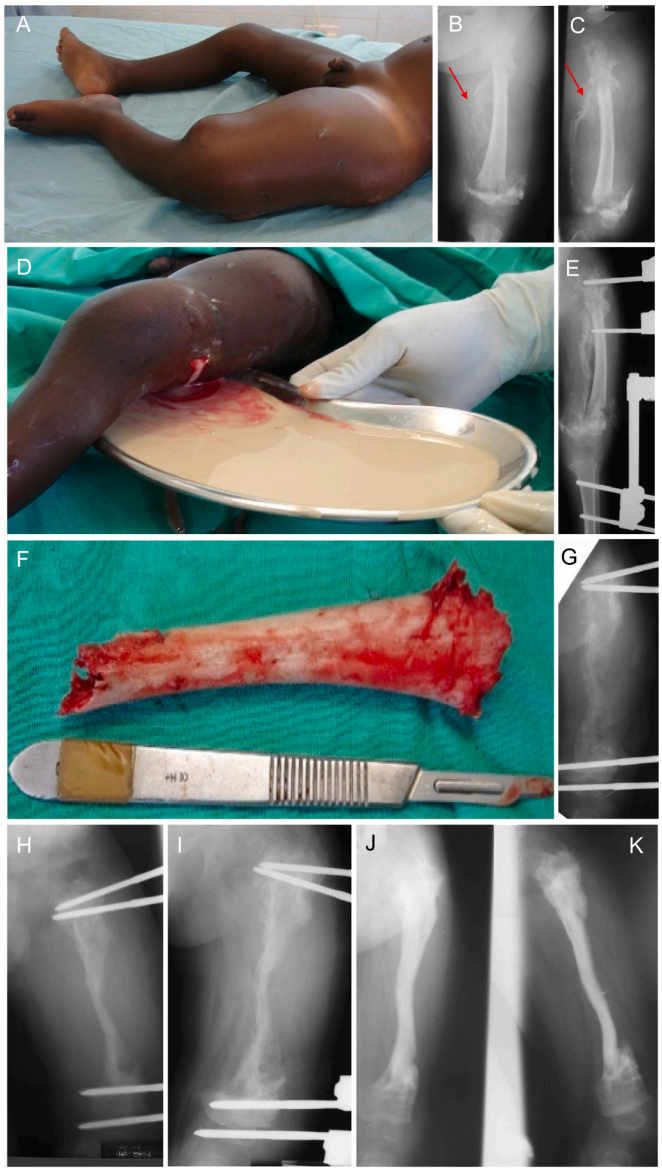


Fig. 1. Clinical presentation of a 2 years old boy with sepsis from an underlying osteomyelitis at the left femur. He presented with a severe soft tissue swelling with pseudoparalysis of the left lower extremity associated with high fever and shivering as symptoms of sepsis (A). X-rays showed sequestration of the entire femoral diaphysis with pathological fractures at both ends (B and C). Starting new bone formation at the medio-dorsal aspect of the femur is already visible on ap (B) and lateral (C) radiographs (red arrows). Incision and drainage of the abscess formation were carried out in emergency and a lot of pus was drained (D). The sequestrum was initially left in situ, acting as an anchor point for the proximal pins Two pins were also inserted in the tibia so as to extend the knee joint. Four weeks later, the new bone formation had progressed significantly in the meantime (E). A sequestrectomy of the femoral diaphysis was performed (F) and a new femoral fixator was applied (G). Follow-up X-rays at 3 (H), 8 (I) and 13 (J and K) weeks showed progressive bone formation with remodeling of the of the entire femoral diaphysis and preservation of the femoral length.

has to be grounded on several elements since clinical findings, radiological features, logistic and human factors all play a decisive role [3]. Fortunately, these patients often exhibit good bone healing potential offering treatment options that mainly rely on the regeneration potential of the infected bone. The purpose of this article is to highlight general treatment options for all physicians and surgeons facing pediatric bone infections.

Epidemiology

Children living in LIC, engaged as they are in daily battle to preserve a good health status, seem to be the preferred target of haematogenous osteoarticular infections. The incidence of paediatric osteomyelitis is fundamentally lower in high-income countries with 9–10 per 100,000 inhabitants, whereas in low-income countries, such as Sub-Saharan Africa, the incidence ranges from 43 up to 200 per 100,000 children [4–6]. Poor sanitation, deficient nutrition and fragile health systems are the common background in several papers originating from countries where poverty is widespread. In Subsahara Africa, bone and joint infections in children still represent a daily burden for the surgical departments. Reports from Malawi [7], Gambia [8], Nigeria [9], Ethiopia [10] Uganda [11] and Sudan [12] emphasize the importance of osteomyelitis as a reason for attending surgical services.

Personal data, collected from 2009 to 2014 in our department at CoRSU Rehabilitation Hospital, Kisubi, Uganda, where orthopedic and plastic surgery services are offered, confirm that the diagnosis of osteomyelitis was reached in over 1000 cases, representing one of the top five causes of admission in our unit. In the same time frame, more than 130 cases of septic arthritis required surgical attention, while other children with sequelae of osteoarticular infections attended the unit for corrective or reconstructive surgery.

Furthermore, in areas where tuberculosis (TB) is endemic and poorly controlled, the diagnosis of tuberculous osteomyelitis must be kept in mind. It represented more than 9 % of cases in the same time frame (96 cases) in our facility. The surgical principles are the same, but the final outcome relies on nutritional support and the long-term medical treatment, usually lasting 9–12 months in extrapulmonary TB [13,14].

Striking differences in treatment options between high- and low-income countries

Under the current circumstances, surgical treatment in LIC is and will be the most likely option for children in the developing world. Institutions where the child could receive a holistic treatment by a multidisciplinary team are still very few and this sounds quite strange in areas where osteoarticular infections are endemic and overwhelming.

Diagnostic suspicion, easy access to qualified centers and early imaging, the elements that could make non-operative treatment a possible option, are still missing in most areas. Time is lost when the child is taken to local healers as financial constraints do not allow transportation to the nearest medical facility and empirical antibiotic therapy is partially or not administered. The imaging techniques and the laboratory tests that would allow early diagnosis and detection of the causative pathogen are not available in most places. Ultrasound guided exploration of suspected lesions, blood cultures, clear radiograms, and MRI are still unavailable or extremely expensive and beyond the reach of the majority of families.

Treatment costs are on the shoulders of the child's relatives who often live in abject poverty, relying on a daily income of USD 2-3. It is therefore difficult to access medical services knowing that nothing, or almost nothing, will be free of charge.

This is the background that explains the clinical presentations seen in referral centers, months or years after the onset of the disease, just mirrors of the web of poverty and desperation, in which infections can apparently thrive.

Treatment principles in low-income countries

Emergency cases due to sepsis with underlying bone infection

Children presenting with bone, joint and soft tissues infections, coupled with systemic symptoms suggestive of toxemia and sepsis, need urgent or semi-urgent medico-surgical attention [15]. Great attention must be used to rule out cases of osteomyelitis-septic arthritis,

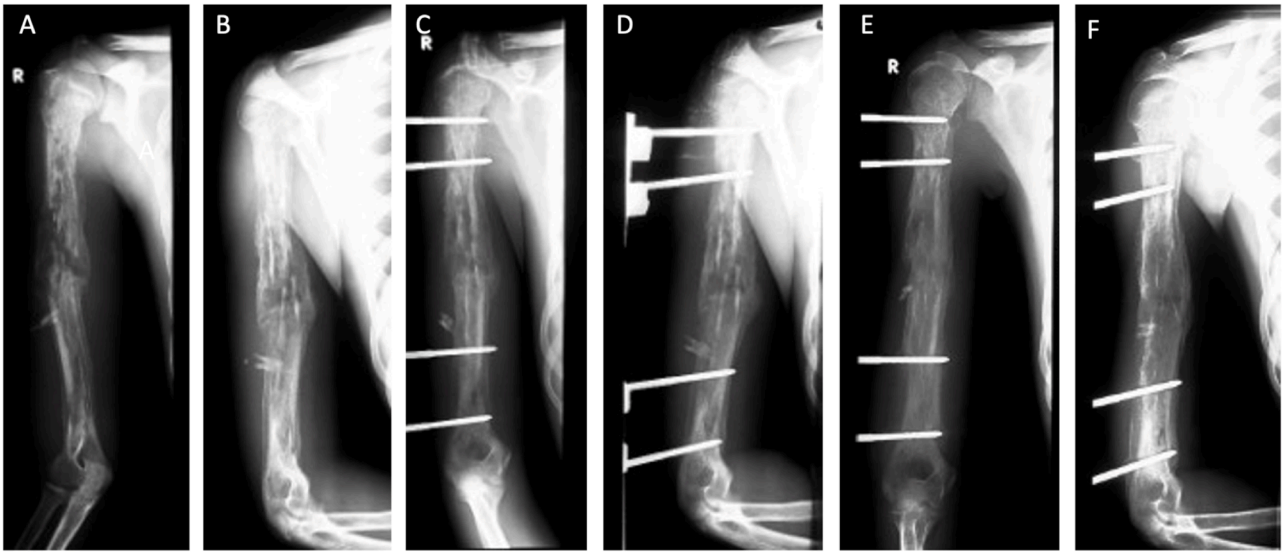


Fig. 2. X-ray series of a severe infection of the entire right humerus with pathological fracture and scattered sequestra in a 12 years old boy (A and B). No major, open surgery should be done in a case with no clear demarcation of dead bone, instability and poor bone texture. Stabilization or limb rest may be a great option, eventually associated with a mini approach for a biopsy in order to rule out a tuberculous infection. This case was managed by external fixation (C and D) resulting in healing of the pathological fracture after 24 weeks (E and F). Definitive and safe surgical debridment, if needed, can be delayed by weeks or months.



Fig. 3. Radiographs of a 4 years old boy who presented with a pathological fracture of the proximal tibia with underlying chronic osteomyelitis (A and B). The limb was just rested in a cast for 45 days, giving enough time for the fracture to heal and for a better demarcation of the sequestra (C and D). A simple sequestrectomy, safely done in a stable segment, at a later stage led to full recovery.

particularly of the proximal femur, proximal humerus and tibial metaphyseal areas in small children and in multiple localizations [16]. In addition, special attention must be given to children suffering from sickle cell disease since they are susceptible to osteoarticular infections [17] and the small children often present with a mixed picture of bone and soft tissues infections [18].

Large soft tissue abscesses can be the presenting picture in an irritable, feverish and crying child. They are mainly seen in the thigh and in the upper limb (Fig. 1). The underlying bone is usually involved in the process, with different degrees of severity. Radiologically, the features can vary from periosteal reaction to intramedullary abscess to extensive bone involvement and pathological fracture. Debridement of the abscessual cavities, not unusually containing huge amount of pus, must be urgently done. In the same surgical session other procedures can be carried out, such as specimen collection for biopsy and cultures, joint immobilization, joint mobilization and stabilization of the bone if impending fracture seems likely to happen. However, the intervention should be tailored to the surgeon's experience and local conditions to avoid unwanted complications, such as excessive bleeding, fracture or bone loss.

Chronic cases

The vast majority of infections are seen with delay of months or years

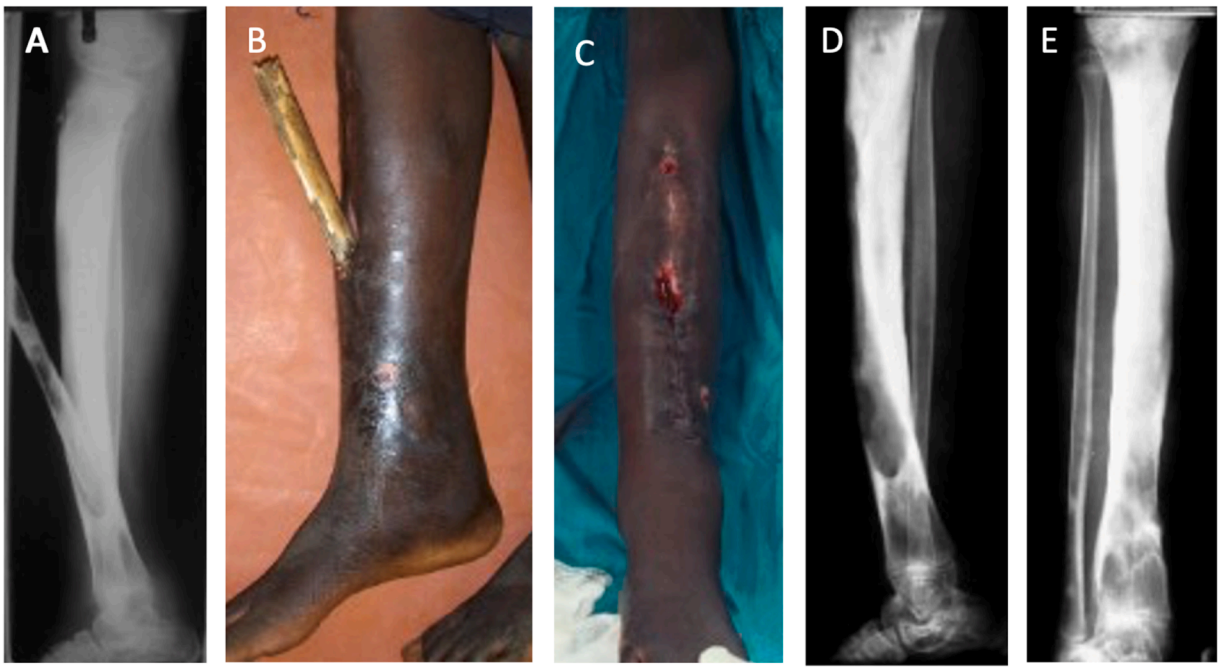


Fig. 4. A case of tibial osteomyelitis with extruded sequestrum and moderate soft tissue involvement (A and B). With radiographic features of bone stability, a safe sequestrectomy was performed (C). The soft tissue defect following sequestrectomy was minimal and healed by primary intention. Interestingly, the sequestered mid-diaphysis was completely replaced and remodeled in the course of the natural process of the disease, without any medical or surgical intervention, just in 18 months (D and E).



Fig. 5. A case of extensive sequestration with a severe soft tisse defect and an underlying pathological fracture (A and B) of the right tibia and lack of reactive involucrum, months after the onset of a chronic osteomyelitis with a severe soft tissue at the antero-medial tibial surface (C). This is a typical challenging case that should be referred and managed by an orthoplastic team in a special center with flap coervage of the soft tissue defect and bone reconstruction, whenever possible.

from the onset and the spectrum of their clinical presentation is really wide. When taking up a case, the physician should evaluate all the elements that allow her/him to assign it to the uncomplicated or complicated category [19]. The assignment must be based on the clinical, radiological, logistic and personal elements that include:

1 The surgeon's capabilities and working place factors.
2 Bone healing capacity.
3 Stability of the segment.
4 Status of the soft tissue envelope.
5 Involvement of the adjacent joints/number of sites.

Once a case is assigned to a specific group, a proper management plan should be laid down, including the possibility of referral to a qualified surgical center, particularly in case of severe soft tissue or bone defects.

- ***The surgeon's capabilities and working place factors***

The treating physician should always focus on crucial decision making including his own capabilities and the ones from his working place. Quite often, service delivery has to reckon with erratic water and electricity supply, drugs and consumables stock-outs, incomplete or old-fashioned surgical sets and staff frustration. All these elements are probably behind the long and inconclusive hospital stays that are sometimes reported by children's relatives at presentation in our facility. Regarding the surgical treatment itself, inappropriate planning, untimely surgery, overzealous approach including extensive damage to the periosteum, resection of large bone segments, lack of equipment or inadequate working facility may lead to clinical failures that will require huge medical, social and financial costs to fix (Fig. 2). Also, the patient's and family's environment should be taken into consideration with questions, e.g. can the patient be brought back to follow-up visits.

- ***Bone healing capacity***

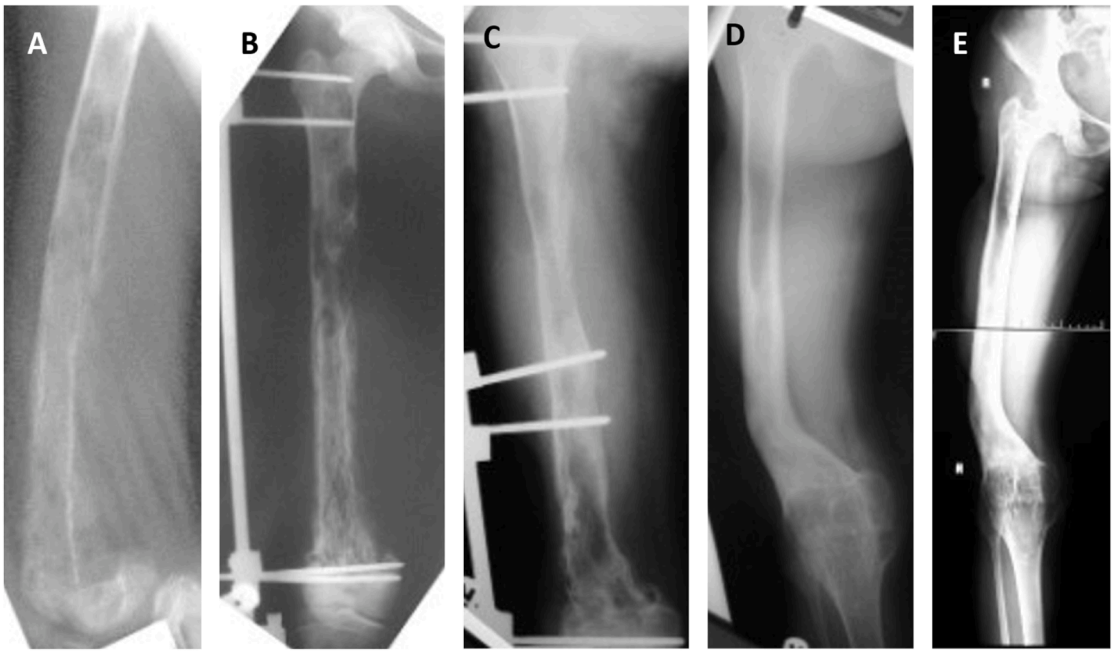


Fig 6. A 12 years old girl presented with a 3 months history of thigh pain, swollen and flexed knee, pus discharge and inability to use the right lower limb. The initial X-ray shows a fracture-separation of the distal femoral physics, septic arthritis of the knee and change of texture of the entire femur (A). The fracture was closely reduced with traction, an external fixator was applied, with an extension to the tibia for temporary knee extension, and specimen for biopsy were taken (B). Upon the biopsy results, the girl was started on anti-TB treatment for 12 months and the implant was strengthened by adding two supplementary pins (C). Follow-up X-rays at 1 year (D) and 7 years (E) show full bone reconstruction and the knee fusion that became necessary for the persistence of painful fibrous ankylosis.

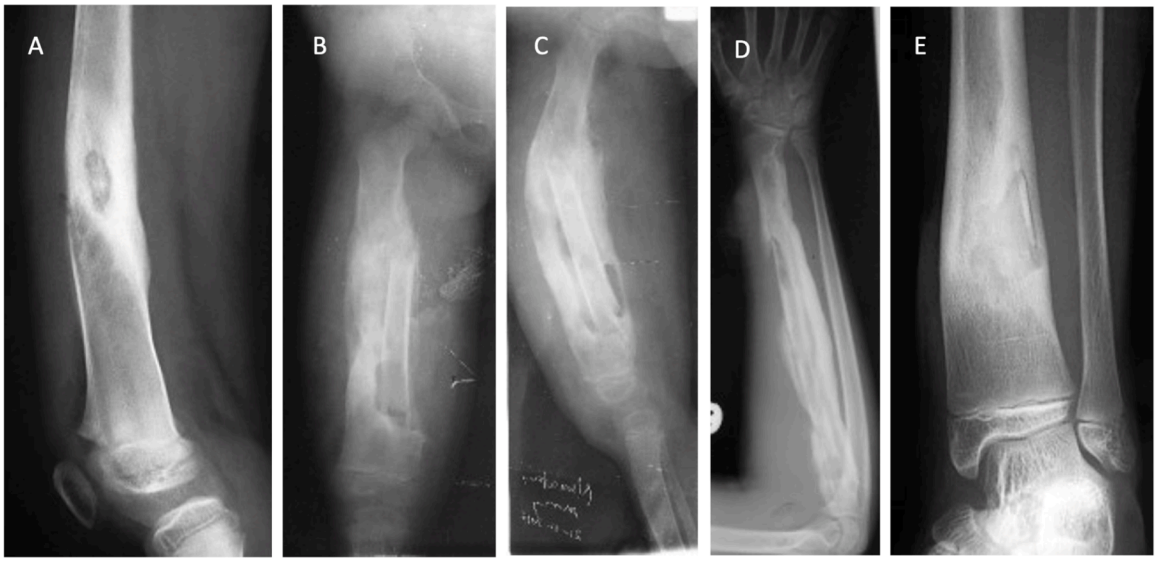


Fig. 7. Examples of uncomplicated cases of osteomyelitis. Localized infections, shown in the mid-femur (A) and in the distal tibia (E) of a 10 years old child, which can be fully cleared without jeopardizing the bone continuity. Extensive sequestration may coexist with intrinsic bone stability, which is of utmost importance. Sequestered mid-third of the femoral diaphysis in a 4 years old boy (B and C) and the sequestered proximal half of the radius in a 10 years old girl (D.) Both appear encircled by a solid, stable involucrum and bone continuity may be appreciated. Surgery is aimed at accurate debridement of the focus of infection, scooping out the sequestra and all the infected tissues that fill the cavities and that maintain the infection. Clearing of the existing sinuses is an important step since small, thin pieces of dead bone may lie in the fistula tract. If accuracy is obtained, the need for post-operative antibiotic therapy is debatable.

In general, children have a great, fascinating bone healing potential and this element must be always kept in mind and the surgeon's choices must go hand in hand with it. Quite often, in children below the age of five, good treatment outcome can be achieved without major surgical interventions or use of long term antibiotic therapy by limb rest, braces or plaster of Paris (Fig. 3) [20]. It is always worthy to buy time in this group of children, even in extensive bone involvement and pathological fractures. Involucrum forms usually quickly and can be really huge in size in some cases. Reabsorption of sequestra happen in the same time and it can be quick as well [21]. These are the clinical situations in which the surgeon must buy time, setting aside the urge to do something for the infected bone (Fig. 3). Spontaneous bone reconstruction is a real

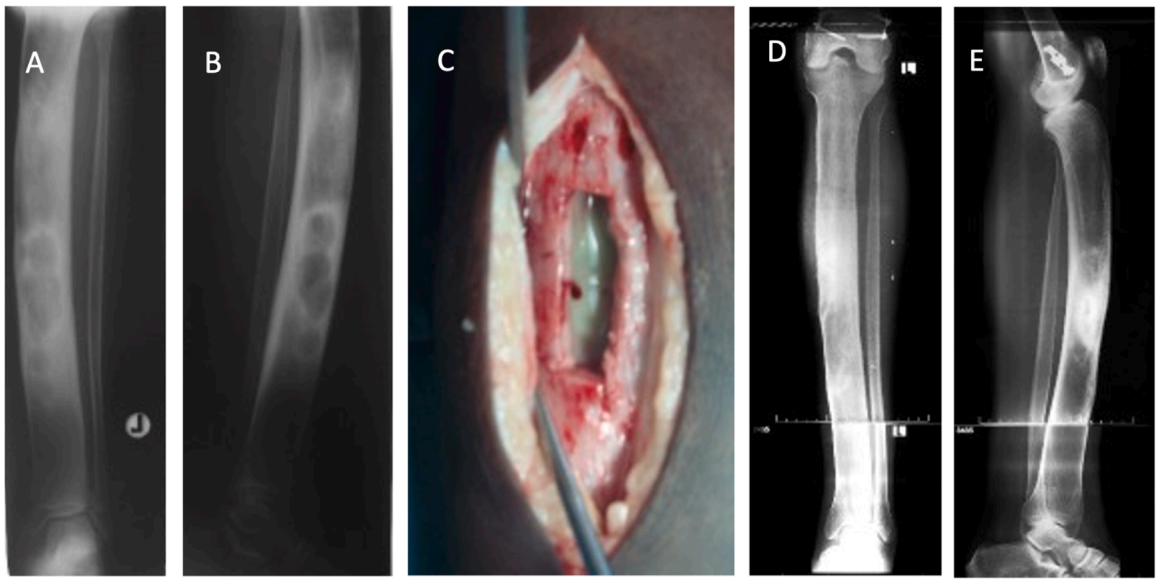


Fig. 8. Case example of an endomedullary abscess in a 13 years old boy in the of the left tibial shaft (A and B). In such a case, a long standing history of dull pain and limb swelling is often reported. Strangely this type of infection rarely leads to fistula formation. A proper bone window allows an accurate debridement of the medullary space (C). The bone windowing may be preceded by an explorative cortex drilling in order to localize the site and to confirm the suspicion. Seven years later there was need for another bone debridement for a nidus of infection in the sclerotic mid-third of the tibia (D and E).

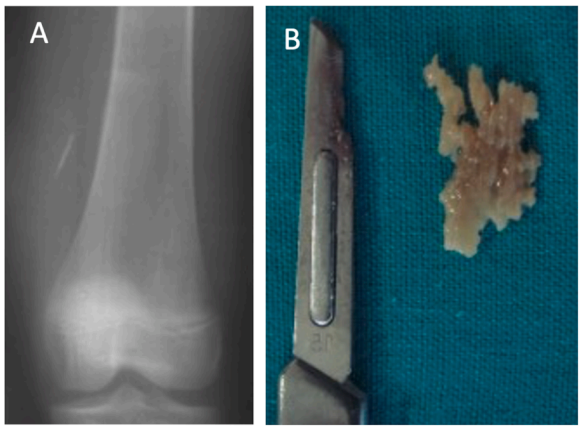


Fig. 9. Radiograph of the distal femur with a bone sequestrum in the soft tissue in an 11 years old girl who presented with a torpid medial sinus of 5 years duration. The sequestrum is usually found in a pocket of pus. The bone appears normal, apparently spared by the nearby infection. It is difficult to understand the pathogenesis of such a cases. Sequestrectomy leads to full recovery (B). There is no need of antibiotic therapy once the debridement has been accurate.

possibility in children. Minor surgical procedures, such as incision and drainage of limb abscesses, might be what is required for a good to excellent clinical and functional outcome [22].

- ***Stability of the affected bone segment***

Stability of the affected segment is the fundamental prerequisite not only for limb salvage procedures that might be required by the most challenging cases but also for its huge impact on the biology of the infected bone. Not to mention the clinical advantages in pain management, while restoring the child's mobility and allowing physical rehabilitation.

The processes of bone sequestration and involucrum formation are probably strictly linked and giving stability to the affected segment seems an option able to condition the biological battle which takes place between the host and the causative agents [23].

Besides the clinical experience, there are radiological features that can guide the surgeon in his/her surgical plan aimed at favouring the involucrum formation and, as a consequence, take a decision for early or delayed sequestrectomy [24]. The debate on the timing of sequestrectomy has not a clear answer if it is based on chronology alone, since it has to be tailored on individual basis [25]. It seems useful to remember that in several cases the sequestrum might act as a useful foreign body, an exploitable mean at surgeon's disposal both biologically and mechanically. Additionally, in our experience, a waiting period of 2–3 months before sequestrectomy seems to be helpful in order to evaluate the new bone formation during this time period. In many cases, significant bone formation around the sequestrum with an improved calcification does occur. However, if there is no progression of bone healing visible within the two months, a bone reconstruction procedure should be planned to shorten the overall treatment time.

- ***Status of the soft tissue envelope***

The status of the soft tissues envelope needs careful evaluation, particularly in the leg. Attention must be directed not only to the loss, which inevitably accompanies exposed sequestra (Fig. 4). Chronicity itself is often coupled with multiple sinuses, skin superinfections, and areas prone to necrosis and breakdowns [26]. This is extremely important on planning since the surgical incisions should be minimal, properly designed and done along the less-prone-to-damage zone. In cases of extruded sequestra, the skin loss may really vary in size. Short, small losses can be primarily closed while the major ones require the expertise of plastic surgeons for proper management in specialized centres (Fig. 5) [27].

- ***Multiple site infections***

Every child requires a thorough clinical examination to rule out multiple site infections. Sinuses in the axilla region, around the scapula, the clavicle and the groin area may be missed as well as old scars due to previous surgical interventions.

It is not a rare presentation at all to observe two or three segments concurrently infected, even children having six or seven sites have been managed in our institution. Multiplicity must raise the suspicion of



Fig. 10. Clinical case of a 17 months-old child with osteomyelitis of the left femur with concomitant septic arthritis of the left hip joint. Symptoms started 5 months before the X-rays were taken. The initial X-rays showed a pan-diaphysitis, a pathological fracture of the femoral mid-shaft and an increased shadow of the soft tissues with a concomitant abscess (A and B). An incision and drainage of the thigh abscess was performed. Antibiotics were administered for 2 weeks and a hip spica was applied for 45 days. Three months after the surgical intervention, X-rays demonstrated a clear sequestrum in the mid-femur without sound involucrum and fracture of the newly forming shaft (D and E). The loss of the cephalic nucleus of ossification of the femoral head was observed as well. This is an expected complication due to the intracapsular position of the metaphysis. No specific treatment was instituted, just observation. Another six months later, X-rays showed full reabsorption of the sequestrum with complete reconstruction and remodeling of the femur (G and H). The entire process shown by the X-rays series took 11 months to complete. The loss of hip joint will require further surgeries, most probably to handle the instability of the joint and to correct the inevitable limb length discrepancy.

sickle cell disease or disseminated tuberculosis [28]. These are cases where surgery must be staged, often requiring blood transfusions, with proper pre- and post-operative assistance.

- ***Concomitant septic arthritis***

The involvement of adjacent joints is of significant importance for the management and the outcome of the patient (Fig. 6). First, as mentioned above, a thorough clinical examination of the adjacent joints and the entire musculoskeletal system with all other joints should be done as hematogenous infection is possible [29]. Joint aspiration can be performed in case of suspicion of concomitant septic arthritis. Treatment mainly consists of surgical debridement and lavage of the joint [16]. When major joints are involved, debridement can lead to important bleeding or intraoperative complications which may be difficult to manage in hospital with basic facilities, a possibility that must be considered before surgery.

Treatment principles of uncomplicated cases

In a typical uncomplicated case, clinical examination shows that the affected segment is stable, the soft tissues are in acceptable conditions and that the adjacent joints are spared. Radiologically, the site of infection appears well demarcated, stable, with good bone healing capacity due to visible involucrum (Fig. 7). Cases of endomedullary abscess (Fig. 8), free sequestra in soft tissues (Fig. 9) and exposed sequestra in stable bone (Fig. 4) without major soft tissue defects are included in this entity as well. Here, treatment priority is infection control through debridement, with subsequent bone consolidation achieved by limb rest or other limited surgical intervention, without jeopardizing the bone continuity. Non-surgical treatment is often possible in small children under the age of 5 years.

Surgery can be made easier by the use of the tourniquet, either an Esmarch's bandage or a pneumatic one. Usually, there is no need for blood transfusion. A basic orthopedic set is sufficient to achieve an accurate debridement and a good knowledge of the most common surgical approach to the long bones is required.

Treatment principles of complicated cases

Complicated cases either exhibit compromised stability of the bone, severe soft tissues lesions, major bone defects lesions or the involvement of adjacent joints. The latter mainly affects hip (Fig. 10) and knee joint, less frequently the ankle, shoulder and wrist. Joint contractures or

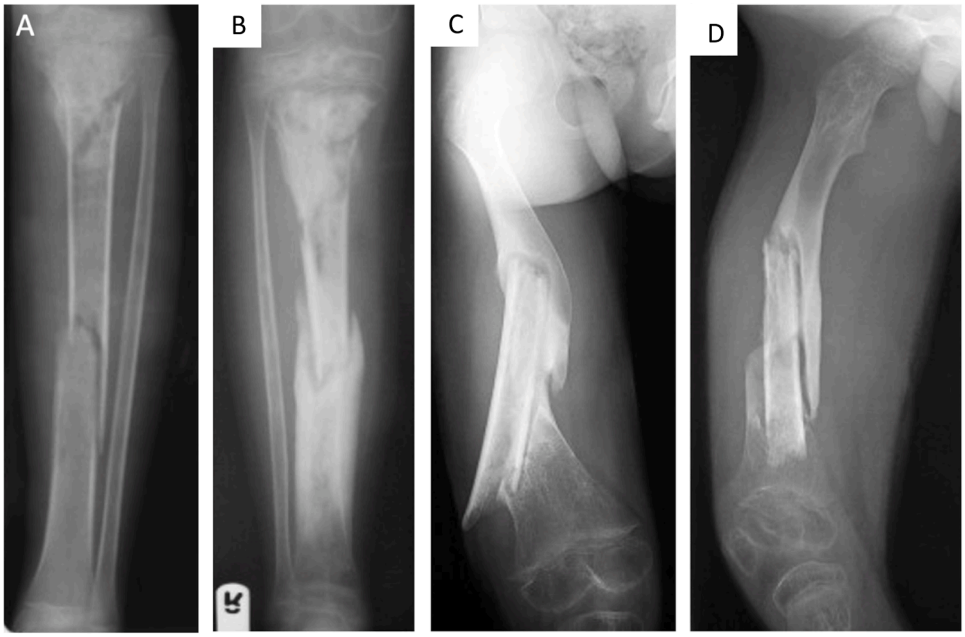


Fig. 11. Case examples of advanced infections, where the sequestra appear to be free, detached from the surrounding bone and fully devascularized with two examples of the tibia (A–C) and one of the femur (D and E). As a consequence, the sequestra are useless foreign bodies, unable to stimulate the formation of a solid involucrum. There is no reason to delay the sequestrectomy in such a cases. Bone reconstruction can be started concurrently, if allowed by conducive local conditions.

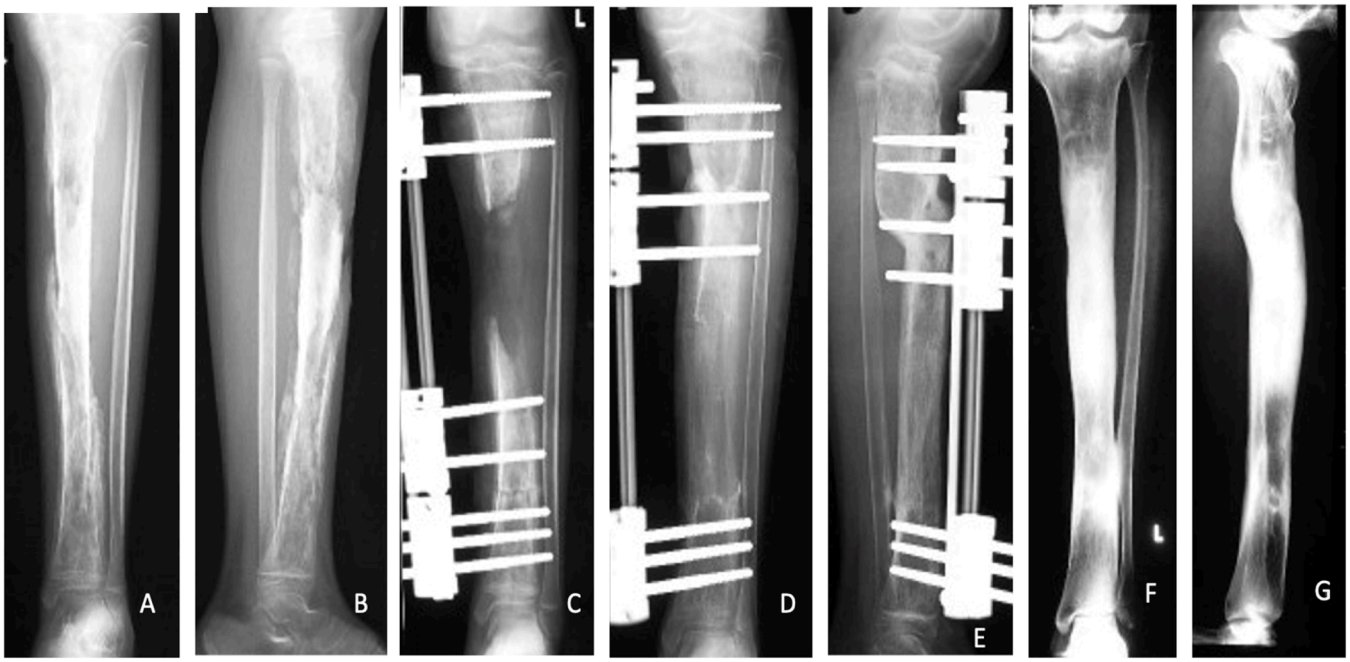


Fig. 12. X-ray series of a complicated case of a chronic osteomyelitis of the left tibia in a 10 years old girl, whose onset was apparently 5 months prior to presentation. X-rays showed a large sequestrum of the tibial midshaft with only minor involucrum formation (A and B). No further involucrum formation can be expected after such a long time from the onset of the disease. The local conditions were good and allowed for sequestrectomy and debridement with additional application of an Orthofix Rail fixator for a bone-segment-transport procedure with a corticotomy at the distal tibial shaft (C). After 8 months, there was a full bony regeneration of the former bone defect area with successful docking of the transported segment to the proximal tibia (D and E). Latest X-ray follow up after another 6 years showed excellent bone remodeling of the tibia in correct axis without any signs of reinfection (F and G).

stiffness may compound the clinical pictures. Multifocal lesions that require simultaneous surgical treatment are also included in this category. The priorities are the eradication of the infection and the immediate or delayed reconstruction of bone or soft tissues or both. Proper surgical equipment is required and blood for transfusion must be available, particularly in cases of multifocal involvement. Good surgical skills are needed, especially for surgery around the girdles or when further surgeries are needed for reconstruction.

The spectrum of clinical presentation is really wide, often challenging for frontline doctors and referral has to be considered depending on the capability of the surgeon and of set-up of the working place [26, 30]. When in doubt between early or delayed

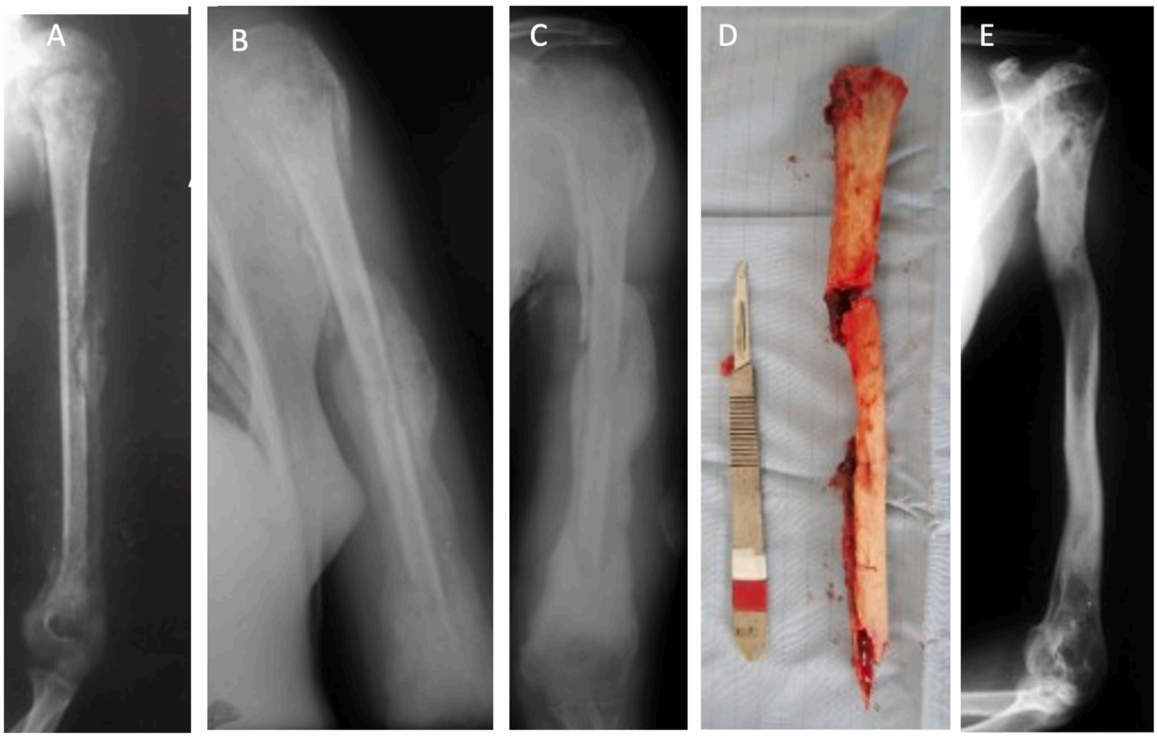


Fig. 13. Radiographic sequence of a case with severe chronic osteomyelitis of almost the entire left humerus in a 11 year old girl. Here, a plan of "wait and see" was primarily chosen, taking into consideration the involvement of the entire bone and the periosteal reaction seen along the infected segment (A). Buying time can lead to resizing and demarcation of the sequestrum and significant involucrum formation, without the use of antibiotics. Upon sufficient formation of involucrum after 5 months (C), the sequestrum was surgically removed (D). The removed sequestra must always match what is visible on the most recent radiograms. Splitting the long sequestra in the middle third makes the removal easier and requires only a partial windowing of the bone. To note, the remodeling of the humerus just two years after the surgery, with total reabsorption of the reactive involucrum (E).

sequestrectomy/debridement, the surgeon should refer the patient.

On one end of the spectrum, there are cases presenting with radiological features of free, sometimes large floating sequestrum, clearly separated from the viable bone ends (Fig. 11).

These are complex cases, often, but not always, seen late, where no valid periosteal reaction can be expected, since it has not occurred neither at the onset nor along the course of the disease. Here, stabilization alone cannot lead to a sound involucrum formation or to revascularization and reintegration of the sequestra [23]. As a consequence, there is no reason for buying time and delaying the procedure of sequestrectomy and stabilization [12]. Bone reconstruction technique, such as bone transport, might be done in the same surgical session, if allowed by the local conditions of the soft tissues envelope (Fig. 12). Otherwise staged treatment is an option. Furthermore, the surgeon's expertise is important and referal of the patient is recommended if there is a lack of knowledge in bone reconstruction procedures.

On the other end of the spectrum, there are cases presenting with active infection and radiological features that accompany a periosteal reaction. This periosteal reaction is of great prognostic importance and influence the treatment strategy (Fig. 13). This applies to a moderate number of cases, usually seen in the first few weeks from the onset of the infection. Scattered areas of consolidation of the regenerate, a kind of cotton flukes or clouds or a thin line along the infected segment, may be noticed on plain, clear radiographs. These are the cases, where stabilization by external fixation, cast or just limb rest must be considered in order to favor the development of a stable involucrum and to facilitate further surgeries [31]. The sequestrum may stay in place, acting as an internal stabilizer and helping in maintaning the bone length. In addition, it can act as an anchorage point for screws and wires, particularly when the viable stumps are short or the segment itself is small. Stability can lead to noticeable resizing of the sequestra, often coupled with involucrum formation or consolidation. Even in these cases, the biologic process may take place irrespective of antibiotic use.

For cases with significant soft tissue defects requiring plastic surgery, new surgical horizons, with the set-up of orthoplastic teams in Africa, have been opened in the last two decades,. Although still scanty in number, they have changed the prognosis for scores of children through reconstructive surgeries that were unthinkable just a couple of decades ago. External fixators and microvascular surgery have been the two elements that have contributed in a very significant way in the management of the most challenging cases [31]. In well equipped centers, local and free soft tissue flaps, but also bone transport, autologous and even vascularized bone grafting procedures are possible offering elegant solutions for soft tissue (Fig. 14) and bone reconstruction (Figs. 14,15), particularly in the leg.

Discussion

In low-income countries, the variety of clinical presentation of pediatric osteoarticular infections is both surprising and challenging, to say the least.

When the patient's history is taken, repetitive reports highlight that the disease started as a sudden, painful swelling on one or more body segment in an otherwise healthy child, sometimes followed by sinus formation and pus discharge [18]. Though similar at the onset, the progression of the disease leads to rather different clinical and radiological pictures, some of them described in the previous sections. They certainly represent a bane for the treating physicians, not only for those practicing in the remote areas of the sub-Saharan Africa, to whom this paper is dedicated, but also for those working in better equipped facilities in towns and big cities [3].

However, it is still in the poorly equipped hospitals of the periphery that the great majority of cases are seen, often in advanced stages, sometimes within a relatively short period from the onset. These are the



Fig. 14. A complicated case of osteomyelitis with concomitant severe soft tissue defect over an exposed sequestrum of the anteromedial proximal tibia (A and B) with pathological fracture and semicirumferential bone defect of the tibial shaft in a 12 years old girl (C). Stability was obtained in a first stage by Orthofix rail. A free gracilis flap was used to cover the soft tissue coupled with a fixator adjustment to allow for bone transport (D and E). Clinical and radiological aspects 10 years later with excellent soft tissue (F), bone (G and H) and functional outcomes.

cases requiring surgical attention, well beyond any conservative approach. Categorization of any specific case is, in our opinion, the first step to take.

For the attending surgeon, making a surgical decision requires clinical acumen, accurate analysis of the radiograms, intellectual honesty, a conducive background in terms of surgical equipment and ancillary services. Radiograms should be clear, recent, readable so as to spot the features that can guide our action plans. Unfortunately, proper imaging is still a tool available to a restricted number of health facilities.

When the surgeon assigns a case to the uncomplicated category, surgery can safely be accomplished in any hospital with a running surgical department. However, in case of any surgical doubt about the procedure to adopt, it is better to take time, or even to postpone the surgery. Involucrum may take 3 to 4 months to form before it comes visible on X-rays [24,32]. Waiting a few weeks is not going to worsen or change the course of the infection in these cases. Once the surgical decision is adopted, keeping in mind that stability is the core element in this category, overzealous debridement or excessive periosteal stripping and bone windowing must be avoided to preserve the viable bone and to eliminate the risk of iatrogenic fracture.

In the cases falling in the complicated category, every effort should be done in order to give stability to the affected segment. It is clearly a difficult task in many hospitals, where shortages of supplies, plaster of Paris included, are not uncommon. Limb rest, casts and local-made



Fig 15. A 10 years old boy with a longstanding osteomyelitis of the right tibia, with sequestration and exposure of the entire diaphysis (A and B). Sequestrectomy and external fixation were carried out leaving behind an extensive gap (C and D). Two and half months later, with quiescent infection, an osteocutaneous vascularized fibula flap was done (E and F). Bone integration took four months and a cast was applied for 45 days after removal of the external fixator (G and H). Excellent clinical and radiological outcomes two years after the procedure (I–K). The skin island of this particular harvest, which allowed for coverage of the anteromedial area of the leg (I), can be observed together with the hypertrophy, remodeling and transformation of the transplanted fibula into a full tibia-like bone (J and K).

external fixators or braces are still the available means in many hospitals in the sub-Saharan belt [3].

Limb rest may be a good choice. It is not uncommon to observe cases, in which a good bone reconstruction and stability were reached just by rest and homemade braces, without any significant medical intervention.

Casts have been and are still widely used, with their pros and cons. They can be indicated for forearm and leg but the stability that they offer to the femur or hip, humerus or shoulder is questionable. They easily become soiled and soft once the child is taken back home. However, hip spica or thoraco-brachial casts may still have a play to role in specific cases involving femur and humerus.

Transfixing Kirschner's wires, held by cast or wooden bars, have been utilized in the past for the tibia but the stability that was reached was mechanically dubious, of short duration and lacking the exploitable properties offered by the external fixators commonly in use.

In some regions of the African belt, in the last two decades, the clinical practice has been completely influenced by the availability of external fixators, of every type and size.

Sound stability allowed by the frames has changed the approach to the most challenging cases. Stability offered by external implants has dramatic clinical repercussions on the child's health status. Pain is relieved, mobility is restored, rehabilitation is allowed, wound care is made easier, further surgical procedures can be done with the frame in place. However, a proper assembly of the frame may prove difficult in short, deformed bones of small children, taking into consideration the bone quality, the presence of the growing plates and the physical space needed by the frame itself. Screws and wires should be inserted under X-ray guidance, when possible.

Along the years, it also appeared clear that, in presence of a viable periosteal tube, a mechanically sound frame had an impact on the biology of the infected bone, acting both on the sequestra and on the involucrum formation. It seems that a sound mechanical support may control or condition the infection, at least to some degree, irrespective of

antibiotic use. And it does so in just a short period of time, just a few weeks in small children. It has to be considered a tool, which enhances the natural reaction of the host to the causative agents. Our experience has shown that impending sequestration and extensive bone involvement may be greatly influenced by stabilization of the segment. Stability appears closely related to reabsorption, resizing, reintegration and revascularization of sequestering or already sequestered segments of bone. Incorporation of the sequestrum into the forming involucrum has beeen observed in dozens of cases in our setting.

There seems to be a "time frame", a window in the course of the infection, in which stability can deeply act on its evolution. Surgeon's aim is to take a complicated case to the uncomplicated category whenever possible. The infected bone, when mechanically stable, changes its texture and its strength, with clear changes on plain radiographs.

Close supervision is essential all along the process since stability must be always assured. Frame adjustment and screws changes are often needed for a reliable clinical outcome.

The aim is to carry out the needed surgery in more stable and partially or even totally reconstructed segments lowering the possibility of complications that are very likely in case of early surgery. As surgeons, we have to consider time and simple means of immobilization as a therapeutical tools in our struggle against infections, especially when working in frontline settings. It can lead to dramatic clinical and radiological changes, forcing us to adopt approaches different from what we had scheduled. Cases of significant bone loss can be reduced or contained to small gaps. Pathological fractures can unite. Reconstruction surgeries can be undertaken, either of bone or soft tissues, in a better recipient site.

Technology may help us in choosing the right plan since specific cases can be shared and discussed with qualified surgeons who, although far away from the actual working place, may give advice and directions in the management of the most challenging situations. Referral to a more qualified center may also be suggested and seriously considered. In our unit, specifically, an ortho-plastic team was set up and something new started, a post-infectious reconstructive surgery unit for the treatment of severe soft-tissue lesions and major bone defects.

Conclusions

The long term outcome of the surgery for pediatric osteoarticular infections is related to accurate pre-treatment evaluation. For doctors working in difficult settings, planning is the cornerstone. Emergency cases with sepsis have to be identified to save the child's life. In non-sepsis cases, differentiation between uncomplicated and complicated cases facilitates decision making and guides treatment. The choice is between direct involvement, provided that a system is in place, or referral. Surgery is certainly much more important than antibiotic therapy, but it has to be timely, accurate, backed by a careful and honest decision-making process. The recent set-up of ortho-plastic units with microvascular expertise now offers new options for cases with severe soft tissue or bone loss.

Declaration of Competing Interest

All authors confirm that there is no conflict of interest regarding the submission of this manuscript.

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