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T. W. Riebel
R. Nasir
O. Nazarenko

The value of sonography in the detection of osteomyelitis

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T. W. Riebel (✉) · R. Nasir · O. Nazarenko
Department of Pediatric Radiology,
Virchow Clinic, Humboldt University,
Reinickendorfer Strasse 61,
D-13347 Berlin, Germany

Abstract *Purpose.* A retrospective study was carried out in order to determine the role of sonography in establishing the diagnosis in extremity osteomyelitis.
Materials and methods. The imaging documents of 24 infants and children aged from 2 weeks to 13 years with osteomyelitis (acute 21, chronic 3) were reviewed. Sonograms and conventional radiographs were available in all patients. Additional skeletal scintigraphy had been performed in 13 patients and MRI in only 3. Special emphasis was put on the different ultrasound findings and their onset in the course of disease.
Results. Intra-articular fluid collections (in 15 cases) and/or subperiosteal abscess formation (in 12) were the most frequent early sonographic findings, and preceded any radiographic changes by several days in 11 of these cases. Together with positive clinical signs of inflammation, they were usually sufficient to establish the correct diagnosis. In selected cases, fluid or abscess puncture for immediate microscopic and later bacteriological studies was carried out under sonographic control. In addition, sonography was also able to detect superficial cortical erosion and even an intramedullary focus in a very young patient.
Conclusion. Ultrasonography is a very helpful tool for establishing the correct diagnosis in osteomyelitis and reducing the frequency of additional imaging studies.

Introduction

The sites of predilection for osteomyelitis in infants and children are the growth-intensive end regions of the long bones. Not infrequently, the inflammatory process also affects the articular region adjacent to these meta- and epiphyseal sites. The course in the overwhelming majority of infants and children in particular is acute and purulent, the bacterial pathogens being few and typical. The percentage of subacute and primarily chronic, as well as atypical forms with a more variable bacterial and viral spectrum increases as the children grow older.

The imaging documentation above all of the early or earliest phase of the disease has been greatly enriched within the last 20 years. The tools now available include scintigraphy [1, 2], via computed tomography [3], and magnetic resonance imaging (MRI) [4, 5]. In view of the still limited number of reports on ultrasound in this field [6–15], it seemed interesting, as well as important to determine the value of sonography especially in establishing the diagnosis of osteomyelitis in the limbs of infants and children within the framework of a clinical study.

Materials and methods

The medical records and imaging documentation of 24 infants and children with osteomyelitis during a period of 7 years and 10 months were analyzed retrospectively. The study group consisted of 16 boys and 8 girls with a mean age of 4 years (2 weeks to 13 years). With one exception (clavicle), the disease was located in one of the limbs (Table 1). The course of the osteomyelitis was

Table 1 Skeletal distribution of osteomyelitis in 24 infants and children

Site	Number of cases
Femur ($n = 14$)	
Proximal	11
Distal	3
Humerus ($n = 5$)	
Proximal	4
Distal	1
Tibia ($n = 2$)	
Distal	2
Clavicle	1
Metatarsal	1
Toe	1

acute in 21 children and more chronic in the others. The diagnosis was confirmed by puncture of the effusion in the simultaneously affected joint or of the subperiosteal abscess in seven patients, in the course of a local surgical procedure in six and by a positive blood culture in another five. Diagnosis and therapy in the other cases were based solely on the results of clinical, biochemical and imaging examinations.

Imaging

Ultrasonography

As part of the diagnostic imaging work-up in all patients, repeat ultrasound studies were done at the start of their hospital stay and in the further course of the disease. All examinations followed a strict protocol by evaluating the whole circumference of the soft-tissue and bone segment localized by clinical symptoms (pain, swelling, reddening) as completely as possible. Scanning always was performed in sagittal and transverse sections. All sonograms were obtained with 7.5- or 7-MHz linear transducers (RT 3600, General Electric Milwaukee, Wis., or Acuson 128 XP, Mountain View, Calif.). In cases in which the process lay very close to the transducer (e.g. in the distal tibia or clavicle), a so-called water lead was also used, in order to document the uppermost superficial soft-tissue structures as well.

Constellations with respect to the number and time point of the ultrasound studies were as follows: five children underwent only one sonographic examination. Up to five studies were performed in all the other patients, most of them within the 1st week but at the latest 1 month after the start of diagnostic imaging. In 20 children, the initial ultrasound examination was performed within 24 h after the patient's admission to the hospital. In the other four (all from the early evaluation period), it was performed later in the course of the disease.

Plain radiography

Plain radiographs were likewise available for all patients. Films documenting the local course of the disease existed in all cases, and films made at the time of admission were also available in most. In individual patients with a typical ultrasound finding and a positive puncture result, we were able to dispense with a simultaneous complementary radiographic examination at the end of the evaluation period and, in fact, postpone it till a later date.

Scintigraphy and MRI

Skeletal ^{99m}Tc scintigrams were available in 13 children. They had been performed as part of the initial diagnostic work-up in seven of them. In the others they had been employed only to monitor the local activity at a later stage of the disease. MRI was available in only three patients. In one it had been performed for complementary primary clarification of the diagnosis, and otherwise for exact determination of the local spread of the inflammatory changes either initially or in the course of treatment.

Diagnosis

The above-mentioned imaging methods were not always performed in the same sequence or at exactly the same stage of the disease in individual patients. Their respective use also varied from the start to the end of the evaluation period. In the case of sonography and conventional radiography, however, these differences were not so great that they precluded a systematic comparison of the results. On the basis of the small number of examinations available we were not able to compare the scintigraphic and MRI documents with respect to ultrasound. So, the main aim of this study was a thorough analysis of the nature, severity and timing of the sonographic findings and their importance in particular as regards the diagnosis.

Results

The following constellations were found with respect to the temporal sequence of primary sonographic and radiographic imaging: in only seven patients did the date of initial plain radiography precede that of sonography. All of these cases occurred in the early part of the evaluation period. In all others, the ultrasound studies were performed before radiography – in 10 patients earlier on the same day and in the remainder one to 19 days earlier.

In seven of the studied patients, the first plain radiographs displayed no pathological findings at all. Sonography performed either on the same day ($n = 5$) or only 1 to 2 days later invariably revealed a conspicuous change corresponding to hyperechogenic articular effusion in one case and/or to further changes (described in detail below) even more clearly indicative of an inflammatory osseous process in the others. Characteristic radiographic changes were subsequently seen at later, different times (9 days to 2 months) in five of these patients. In the others who had clinical, sonographic and scintigraphic confirmation of the diagnosis, repeat radiographic examinations remained negative.

With one exception, ultrasound consistently revealed pathological changes. In this one case, sonography was performed only once and in the initial phase of the disease. Radiography performed at the same time was also negative. A positive imaging result was obtained 2 days later by means of a radionuclide study.

The evaluated spectrum of sonographic changes covered the following anomalies: the commonest initial

Fig. 1 a–c Acute osteomyelitis in the distal tibia of a 13-year-old boy. **a** Initial longitudinal sonograms of the distal lower leg on the day of admission (*left,* affected leg; *right,* healthy leg for comparison) showing a hypoechogenic area along the surface of the distal tibia *(arrows)* expanding into the ankle region and representing subperiosteal abscess formation (proven by aspiration) and articular effusion. There is additional cortical erosion *(open arrow).* **b** Plain radiograph (same day) showing discrete moth-eaten lytic area in the medial portion of the distal tibial metaphysis *(arrows).* **c** MRI scan (T1-weighted) 7 days later showing diffuse diminished signal intensity of the complete distal tibia

findings ($n = 20$) were intra-articular collections of fluid ($n = 15$; Fig. 1) – hypoechogenic in most cases but hyperechogenic in five – and/or spindle-shaped soft-tissue swelling along the bony surface (subperiosteal abscess formation ($n = 12$; Fig. 2). In 11 cases, the sonographic findings preceded the radiographic changes by several days (Fig. 3). Periosteal reactions were demonstrated in four children, in two of them at the initial examination (Fig. 2). Ultrasound even detected osseous cortical erosion in nine children (Fig. 4), albeit only in the course of imaging follow-up in four of them. Because there were only a few cases of chronic osteomyelitis ($n = 3$) in the study population, no useful comparison with the acute forms was possible and also no definite differences were demonstrable for the constellation of primary sonographic findings. In two of these cases, however, the initial sonogram already showed cortical erosion in the absence of other changes elsewhere.

Discussion

Conventional radiography is still used as the standard imaging procedure for the qualitative demonstration of osseous changes. As regards osteomyelitis, however, it has been known for a long time that at least 1 to 2 weeks must pass from the onset of the disease before local inflammatory destruction of the osseous tissue is demon-

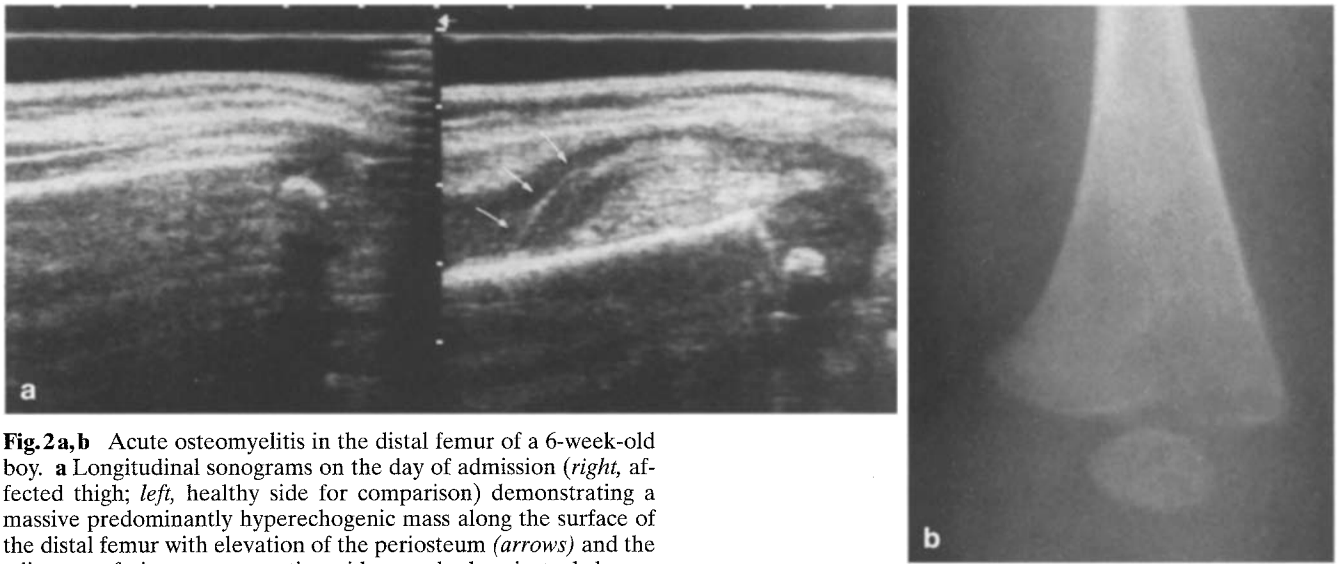


Fig. 2 a, b Acute osteomyelitis in the distal femur of a 6-week-old boy. **a** Longitudinal sonograms on the day of admission (*right,* affected thigh; *left,* healthy side for comparison) demonstrating a massive predominantly hyperechogenic mass along the surface of the distal femur with elevation of the periosteum *(arrows)* and the adjacent soft tissues representing widespread subperiosteal abscess formation. **b** Plain radiograph (same day) showing localized lytic destruction of the distal femoral metaphysis and swelling of the adjacent soft-tissues

strable [16]. Thus, radiography is unable to provide the early diagnosis on which the therapy depends.

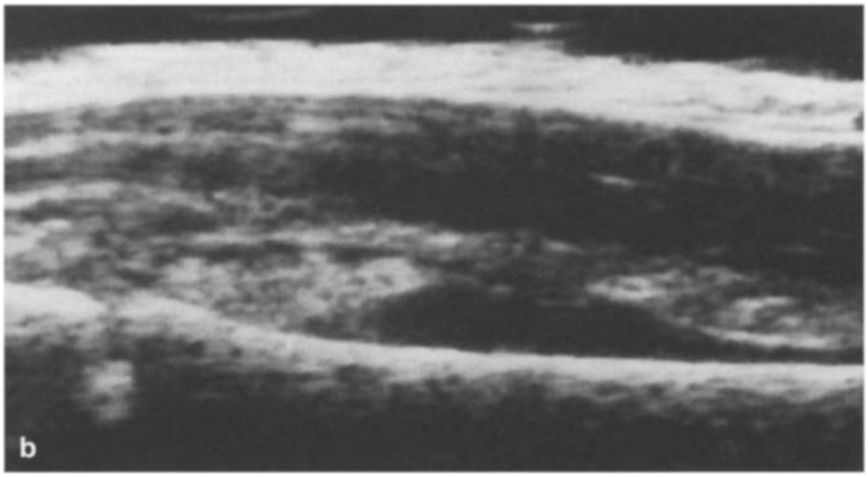
Radionuclide studies are able to demonstrate the local changes in the suspect part of the skeletal system (both in the blood pool and, above all, in the late uptake phase) a few days earlier [1, 2]. This is, however, bought at the expense of radiation exposure which, in a child's growing skeleton, weighs rather heavily, particularly in the region of the metaphyses with the adjacent growth cartilages. Although computed tomography can make an important contribution to the detailed visualization of osseous cortical and medullary structures, it is likewise unable to provide an early diagnosis of osteomyelitis [3]. Moreover, it is also burdened with not inconsiderable radiation exposure.

MRI with its ability to demonstrate the most minute changes not only in the soft tissues, but also, and most importantly, in the medullary region as well, allows depiction of the vaso-edematous process in the early phase of inflammation even before the later involvement of osseous elements [3–5]. Consequently, it is currently regarded as the most sensitive and – because it is devoid of ionizing rays – also the best imaging modality for verifying osteomyelitis in its entirety just a few days after onset of the disease. The comprehensive use of MRI is, however, restricted even within the framework of osteomyelitis by the fact that MRI scanners are not available everywhere and at all times, and by the high organizational and material costs of such examinations.

For some years now, ultrasound has also been used to an ever increasing degree for the diagnosis of joint and soft-tissue changes [3, 6, 7, 10–12, 17]. In the meantime, the technique is able not only to demonstrate small amounts of effusion in the joints of the extremities, particularly in the hip and knee, but also to visualize various changes of the soft-tissue structures of different origin and consistency. In most cases, however, interpretation of the sonographic findings is possible only in association with the other clinical findings, since the images represent not the histology, but only boundary-surface phenomena.

Continual technological development has led to high-resolution transducers, with which it is now also possible to demonstrate the soft-tissue region close to the bone and the surface of the bone itself in great detail, particularly in the extremities. Thus, sonography is now also able to detect early changes in inflammatory osseous processes as soon as they have spread beyond the level of cortical bone [8, 9, 14–16]. In acute hematogenous osteomyelitis the changes are demonstrable just 1 or 2 days after the onset of symptoms [15], albeit on condition that the sound can reach the affected area unimpeded by other structures. This condition is met for the greater part only in the extremities (including the hips), the ribs and the clavicle. For this reason, in the case of these sites, sonography is rapidly becoming a valid alternative to the much more expensive method of MRI in the diagnostic imaging particularly of early changes in osteomyelitis.

Our results as presented here illustrate the great value of ultrasound not only as regards the initial detection of inflammatory bone disease, but also with respect to the therapeutic plan and the imaging follow-up. This is



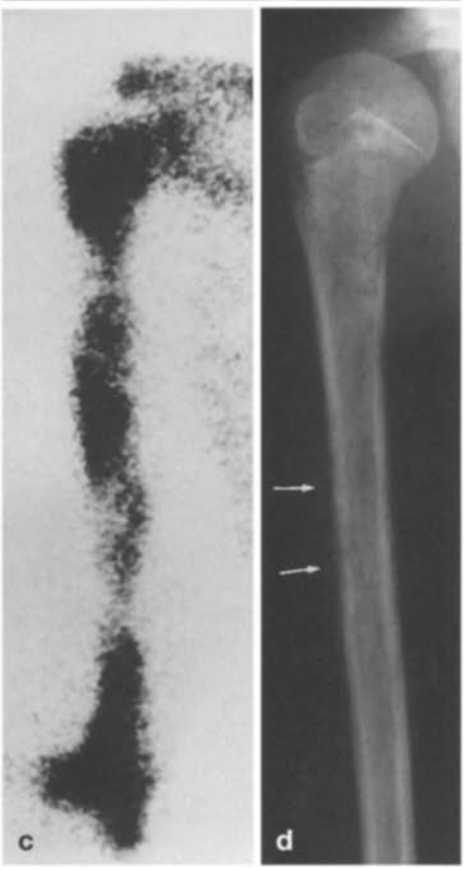


Fig. 3a–d Expanded acute osteomyelitis in meta- and diaphyseal parts of the humerus in a girl aged 12 years and 5 months. **a** Initial plain radiograph of the proximal right humerus without pathological changes. **b** Longitudinal sonogram of the proximal humerus (4 days later) showing an area of mixed hyper- and hypoechogenic character along the outer surface of the bone, with elevation of the periosteum expanding from the proximal physis down to the humeral diaphysis, i.e., subperiosteal abscess formation. **c** Skeletal ^{99m}Tc scintigraphy (3 weeks later) demonstrating irregular diffusely increased uptake throughout the humerus. **d** Repeat plain radiograph (3 days later) showing widespread diffuse lytic osseous destruction reaching up to the distal shaft area where the *arrows* indicate discrete lamellar periosteal reaction

true primarily for the acute form of osteomyelitis, but also for more chronic variants. The following constellations of ultrasound findings should be noted:

1. The demonstration of an articular effusion in a highly febrile child with clinically unequivocal signs of bacterial infection should prompt local puncture. Microscopic examination of the material obtained should clarify the situation and, if a purulent effusion is demonstrated, should lead on to antibiotic therapy. At this stage it will not be possible to distinguish between simple septic arthritis and joint involvement in osteomyelitis [17].
2. If, in addition, a hypo- to hyperechogenic change directly contiguous with the bone surface and with displacement of adjacent structures is demonstrable, a subperiosteal abscess should be considered. This then makes osteomyelitis an etiologic probability. In this situation, too, local puncture of the affected soft-tissue region is desirable – preferably under sonographic control – in order to confirm the diagnosis as quickly as possible and to identify the pathogen.
3. In a somewhat more advanced stage of the disease, it is not infrequently possible to demonstrate superficial cortical bone defects or even periosteal reactions by means of sonography. The osseous origin of the disease is obvious in these cases.

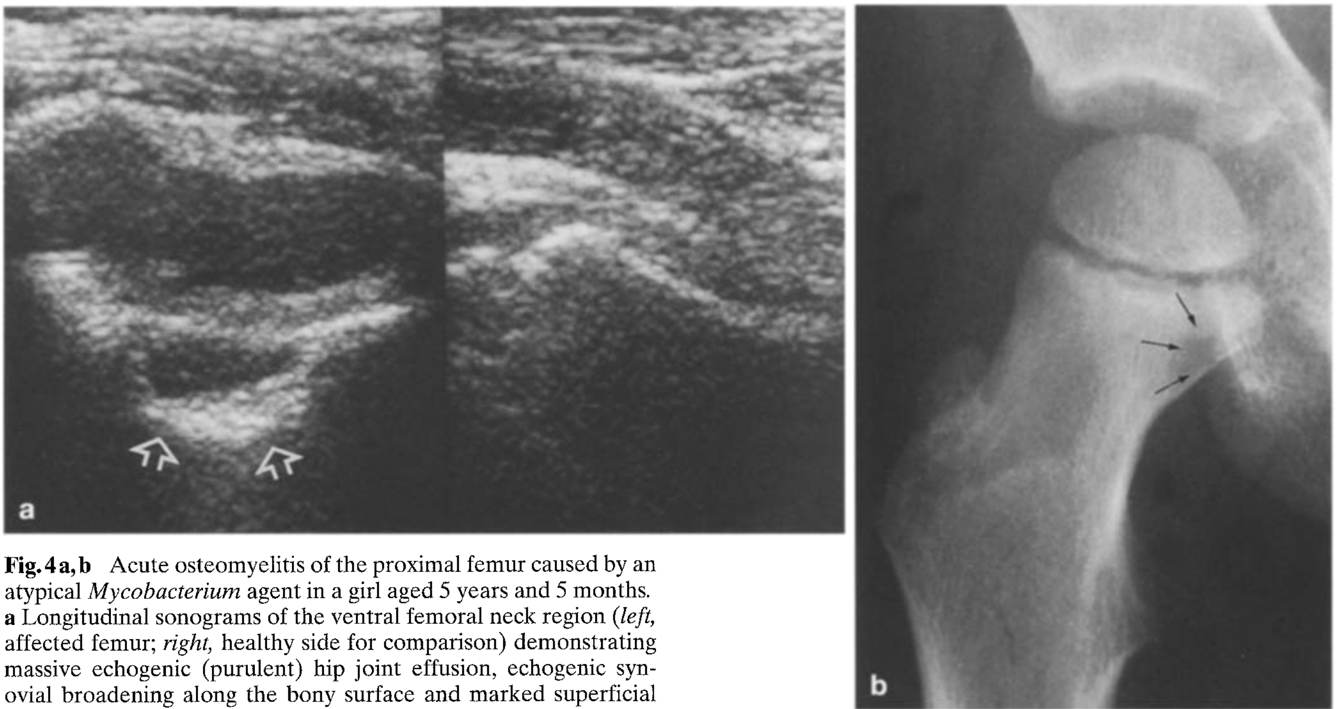


Fig. 4 a, b Acute osteomyelitis of the proximal femur caused by an atypical *Mycobacterium* agent in a girl aged 5 years and 5 months. **a** Longitudinal sonograms of the ventral femoral neck region (*left,* affected femur; *right,* healthy side for comparison) demonstrating massive echogenic (purulent) hip joint effusion, echogenic synovial broadening along the bony surface and marked superficial cortical defect *(open arrows).* **b** Plain radiograph (taken elsewhere 4 days before admission) showing a distinct localized subcortical lytic area in medial parts of the femoral neck without complete cortical destruction or periosteal reaction *(arrows)*

4. In young infants, with the relatively thin cortical layer of their long bones, it is even possible in exceptional cases for ultrasound to visualize the inflammatory focus directly in the medullary space.
5. Sonography should be repeated a short time later if the initial examination is non-diagnostic in patients with definite signs of acute bacterial infection and additional local symptoms (e.g., pain, tenderness, restricted articular freedom) in an extremity, rib or clavicle. The effusion or even a subperiosteal abscess is often demonstrable just 1 day later.

A knowledge of these constellations and increasing experience gave us the self-assurance to modify the diagnostic work-up specifically in our own patients. Instead of performing multiple parallel or even complementary imaging procedures, we have tended recently to ask for local puncture straight away. If this confirms the diagnosis of osteomyelitis beyond all doubt, then radiography can be postponed. The use of MRI in children with osteomyelitis in the sites under discussion here can be limited to those cases which remain undiagnosed. Scintigraphy should be resorted to as an alternative only when MRI is not readily available or in cases with suspicion of polyostotic osteomyelitis. There is no need at all for computed tomography.

Sonography is also a valuable and conclusive method for monitoring regression of the articular and soft-tissue changes and the course of periosteal and/or superficial cortical structures during therapy. It goes without saying that comprehensive demonstration of the overall – including medullary – bone changes remains a domain of plain radiography. However, ultrasound can reduce the number of such ionizing examinations especially in the early course of osteomyelitis.

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