Early diagnosis of acute osteomyelitis in children by high-resolution and power Doppler sonography

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KEYWORDS
Osteomyelitis; Ultrasound; Color Doppler; Orthopedic radiology; Pediatric radiology

Abstract  Aim of the work: Our study purpose is to evaluate the diagnostic values of high-resolution and power Doppler sonography in early diagnosis of acute osteomyelitis using surgery, aspiration cytology, and follow up as a standard.

Patients and methods: Twenty seven children (below age 18 years) with symptoms suggesting acute osteomyelitis were included in our series. Plain radiograph was done to each patient followed by gray-scale and power Doppler sonography.

Results: Twenty five patients (92.6%) were finally diagnosed to have osteomyelitis. Twenty three patients (85.2%) were confirmed by surgery, while two patients (7.4%) were diagnosed by ultrasound guided aspiration of pus. Five sonographic signs could be detected in the disease: (1) deep soft-tissue swelling was the earliest sign which could be seen in the first day of symptoms;
1. Introduction and aim of the work

Acute osteomyelitis in childhood is difficult to diagnose because of the lack of specific clinical signs and symptoms. Making the final diagnosis as soon as possible is very important for the prognosis (healing and growth) (1). With early diagnosis, however, appropriate antibiotic treatment is usually curative without the need for surgical intervention (2).

The term acute osteomyelitis is used clinically to signify a newly recognized bone infection; the relapse of a previously treated or untreated infection is considered a sign of chronic disease. Clinical signs persisting for more than two weeks correlate roughly with the development of necrotic bone and chronic osteomyelitis (3).

Imaging studies play an important role in diagnosis of osteomyelitis. Various modalities, including conventional radiography, bone scintigraphy, sonography, computed tomography (CT) and magnetic resonance (MR) imaging, have all been used (4).

Conventional radiography stills the mainstay and the initial imaging modality. To assess plain radiographs in a non-ossified skeleton is very difficult. At the beginning of the disease plain radiographs can be negative. Changes on radiographs are seen only when significant bone destruction has occurred. It appears within 10–14 days; at first, swelling of the soft tissue is present and later the destruction of the bone and periosteal reaction occur (1,3–5).

CT scanning allows for 3D examination of the bone and surrounding soft tissue. CT is an excellent for depicting periosteal new-bone formation, cortical bone destruction, and sequestrum or involucrum if present. CT is the modality of choice for revealing sequestra and cortical erosions in chronic osteomyelitis. The accuracy, sensitivity, and specificity of CT in assessing chronic osteomyelitis are reportedly 96.7%, 99.1, and 80.0%, respectively (4). Chandnani et al. (1990), however, found that MRI was more sensitive than CT in the detection of acute osteomyelitis (94% vs. 66%, \( P < 0.025 \)) and abscesses (97% vs. 52%) (6).

MRI is considered to be the most sensitive modality. MRI offers improved soft tissue resolution and multiplanar abilities (5,7,8). But it has limited availability and is relatively expensive. MRI is also contraindicated in patients with certain implant devices and metallic clips, and it is not tolerated by all patients because of claustrophobia or morbid obesity. In addition, young children may require sedation; good MRI requires patient cooperation because patient motion can degrade the images (4,8).

Although radionuclide studies are sensitive, they can be time-consuming, and they have lower spatial resolution (4).

The physical properties of bone do not usually lend themselves to ultrasonic investigation, because of the reflection of sound waves at a soft tissue–bone interface. However, the periosteum, early new-bone formation, and soft-tissue changes alongside dense bone can be imaged (4).

Ultrasound (US) is a rapid, cheap, easily available, non-ionizing and reasonably accurate diagnostic modality. It also helps in localizing the lesion for diagnostic aspiration. Serial ultrasound and technical innovations such as color Doppler sonography further help in monitoring the progression and resolution of the disease (9).

The most important additional value of US in diagnosing pediatric musculoskeletal infections over other imaging modalities is the capability to detect fluid and the possibility to perform ultrasonographically guided aspiration (10). Ultrasonography is useful in the acute phase and shows the presence and extent of any subperiosteal abscess collection (4).

Sonography is not only more sensitive than radiography in evaluating metaphyseal bony lesions but also useful in assessing concomitant joint and epiphyseal involvement of acute osteomyelitis in infants. Sonography is, therefore, useful in establishing the diagnosis of acute osteomyelitis and its complications before radiographic changes are seen (11,12).

Many studies were done to evaluate how Ultrasound may be useful in early detection of acute osteomyelitis. Mah et al. (2) found that deep soft tissue swelling is the earliest sonographic sign of acute osteomyelitis; with high sensitivity at about (94%), in the next stage there will be periosteal elevation and a thin layer of subperiosteal fluid and in some cases this progresses to form a subperiosteal abscess, with a sensitivity of (40%), the later stages were characterized by cortical erosion, which commonly present in those who had had symptoms for one week, with very high sensitivity at about (100%).

Larcos et al. (1994) found that ultrasound can be misleading in early osteomyelitis as they found that the sensitivity of ultrasound was only 63% and the diagnostic accuracy 58% with two false positives (13).

A more recent study done by Azam et al. (9) found that sensitivity of Ultrasound to diagnose acute osteomyelitis is 76.3% depending on demonstration of anechoic fluid accumulation contiguous with bone.

Color Doppler study in previous studies revealed increased vascular flow within or around the affected periosteum, in which subperiosteal abscess had been developed in follow-up serial sonography. Those with early stage acute osteomyelitis usually showed no vascular flow within or around the infected periosteum. Thus, color Doppler sonography allowed detec-
tion of advanced osteomyelitis and revealed the progression of inflammation during antibiotic therapy, and justifying the need for operation (9,14).

Our study purpose is to evaluate the diagnostic values (sensitivity, specificity, and positive & negative predictive values) of high resolution and power Doppler sonography in early diagnosis of acute osteomyelitis in children.

2. Patients and methods

Twenty seven pediatric patients referred to the radiology department of Suez Canal University Hospital from July 2006 to May 2007

2.1. Inclusion criteria

- Pediatric age group (below age of 18) due to lack of relevant signs and symptoms rendering early diagnosis of acute osteomyelitis is a difficult challenging task.
- Children with clinical suspicion of acute osteomyelitis (fever, local tenderness, etc.)
- Negative or equivocal conventional plain radiographic findings.
- Within two weeks from the onset of symptoms.

2.2. Exclusion criteria

- Chronic osteomyelitis (i.e., more than two weeks after the onset of symptoms).
- Presence of any chronic disease with signs and symptoms similar to acute osteomyelitis.

Examinations were performed using the Philips (DH 11 EX revision 2.0 and revision 1.0.8 scanners) with a 7.5–10 MHz linear probe.

Each patient included in the study was subjected to the following:

1. History and clinical examination:
2. Conventional plain radiograph:

Initial radiographs including two basic views (AP& lateral views) of the affected bone were done at the time of hospitalization. Additional special views could be obtained if needed.

These radiographs are evaluated for radiological evidences of acute osteomyelitis (focal area of bone opacity in the metaphysis, well-defined ovoid lucency with surrounding sclerotic margins, soft tissue swelling, periosteal reaction, and/or cortical erosion).

3. Sonography

Both gray-scale and power Doppler sonography were done for each patient.

Comparative study between both normal and painful limbs was performed by the authors within first two weeks from the onset of symptoms.

2.2.1. Technique of examination

- Longitudinal and transverse scans covering the area of maximal tenderness and relevant areas including adjacent joints were performed.
- The contralateral side was examined also to obtain equivalent views for comparison. This allowed detection of subtle changes.
- Ultrasound guided aspiration of fluid seen during sonography was performed in two patients under local anesthesia, and complete aseptic conditions.
- Patients who underwent conservative treatment (antibiotic therapy), follow-up sonography with power Doppler at different intervals was performed to judge the effectiveness of antibiotic therapy and to predict the need for surgical intervention.

2.2.2. Abnormal sonographic findings

- Deep soft tissue swelling is the earliest (1–3 days after onset of symptoms) and an accurate sign of acute osteomyelitis.
- Periosteal thickening and elevation with a thin layer of subperiosteal fluid.
- Subperiosteal abscess.
- Cortical erosions, in later stage.
- Increased flow within or around periosteum on power Doppler sonography.
- Follow up sonography for whom sonography revealed only increased periosteal flow to detect subperiosteal abscess formation.

Authors considered one criterion is sufficient to make the diagnosis.

4. Follow-up to confirm the sonographic diagnosis

One of these methods had been used for each patient to confirm his/her sonographic diagnosis:

1. Results of surgical intervention,
2. Clinical improvement: resolution of signs and symptoms after effective antibiotic therapy, with follow up conventional radiograph and US.
3. Cytological analysis of the aspirated fluid.

2.3. Data analysis

After using the available standard method; (surgical findings, bacteriological analysis of aspirate fluid, or follow up) the diagnostic values (sensitivity, specificity, & positive, and negative predictive values) of high-resolution and power Doppler sonography in early diagnosis of acute osteomyelitis in children were calculated with commercially available PC-based software package (SPSS).

Also a relation between each sonographic sign and duration of symptoms was studied to arrange them chronologically.
2.4. Ethical considerations

This work has been carried out in accordance with ‘The Code of Ethics of the World Medical Association’.

3. Results

Twenty seven patients were included in the study (18 males and 9 females) with mean age of 10 years old. All patients were referred by the orthopaedic surgeon as they were clinically suspected to have acute osteomyelitis.

Twenty five patients (92.6%) were finally diagnosed to have acute osteomyelitis while only two patients (7.4%) had not.

Twenty three patients (85.2%) were confirmed by surgery, while two patients (7.4%) were diagnosed by ultrasound guided aspiration of the detected fluid which proved to be pus by cytology (Table 1).

Two patients (7.4%) underwent one week follow up (clinical, radiographic and sonographic) that revealed no osteomyelitis, just hematoma that was absorbed later on (Table 1).

Initial conventional radiographs were done to each patient involved in the study that revealed normal study or equivocal findings (i.e. non-conclusive tests).

Patients were categorized according to the time of presentation into three groups (Table 2).

Then high resolution and power Doppler sonography were done at the day of presentation revealing these signs (Table 3).

3.1. Signs detected by B-mode

– Deep soft tissue swelling in 8 patients (29.6%), periosteal thickening and elevation with subperiosteal fluid (abscess) in 8 patients (29.6%), fluid adjacent to infected bone in 12 patients (44.4%), cortical erosion in 13 patients (48.1%), and adjacent joint effusion seen in 7 patients (25.9%).

3.2. Signs detected by power Doppler

– Increased flow within or around periosteum seen in 18 patients (66.7%).

Table 1 The definitive diagnosis of patients according to confirming methods.

<table>
<thead>
<tr>
<th>Modality of final diagnosis</th>
<th>Number</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery</td>
<td>23</td>
<td>85.2%</td>
</tr>
<tr>
<td>Aspiration cytology</td>
<td>2</td>
<td>7.4%</td>
</tr>
<tr>
<td>Follow up (clinical, X-ray, &amp; US)</td>
<td>2</td>
<td>7.4%</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>92.6%</td>
</tr>
</tbody>
</table>

Table 2 Duration between onset of symptoms and time of presentation among patients.

<table>
<thead>
<tr>
<th>Duration</th>
<th>Number</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 4 days</td>
<td>3</td>
<td>11.2</td>
</tr>
<tr>
<td>4–6 days after onset of symptoms</td>
<td>12</td>
<td>44.4</td>
</tr>
<tr>
<td>1–2 weeks after onset of symptoms</td>
<td>12</td>
<td>44.4</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>100</td>
</tr>
</tbody>
</table>

Because acute osteomyelitis is a progressing disease, relation between each sonographic sign and duration of symptoms was studied revealing (Table 4):

Relation between deep soft tissue swelling and duration of symptoms is highly significant (P-value = 0.00). The relation between cortical erosion and duration of symptoms is also significant (P-value = 0.03).

While insignificant relations present between subperiosteal abscesses, fluid adjacent to infected bone, increased periosteal flow, and adjacent joint effusion with duration of symptoms.

Deep soft tissue swelling is the earliest sign. It was detected in 8 patients, 7 cases were detected before one week, while in late presentation it could not be clearly identified, only one case showed deep soft tissue swelling (Figs. 1 and 2).

Periosteal thickening, elevation, and/ or Subperiosteal abscess are considered late signs of acute osteomyelitis, they were seen in 7 cases, the majority (71.5%) were seen in (1–2 weeks), while no periosteal changes or abscess could be detected in the first 4 days (Figs. 1 and 2).

Fluid adjacent to the infected bone without intervening soft tissue was detected in 12 cases seen mainly in late presentation 1–2 weeks (58.5%), and 4–6 days (41.5%), while no fluid was detected in the first 4 days (Figs. 1 and 2).

Cortical erosion is the latest finding to be detected. It was seen in 13 patients (61.5%) seen in the 1–2 weeks after onset of symptoms, (38.5%) detected 4–6 days after onset of symptoms, while no erosion could be identified in the first 4 days.

Increased flow in power Doppler sonography within or around periosteum was evident in 18 cases with the following distribution: (16.5%) within first 4 days, (33.5%) in 4–6 days interval, and (50%) in late presentation (Figs. 4 and 5).

Adjacent joint involvement is considered as one of the complications of acute osteomyelitis and was seen in 7 cases, it is an age related process more than duration dependent (Table 5, Fig. 6).

Highly significant relation (P-value = 0.00) is evident between adjacent joint involvement and small age of patients.

Only 5 patients out of 18 who had increased flow within or/ and around periosteum in power Doppler study presented early then sonographic examination done at time of presentation revealed only this sign without other late signs.

Follow up sonography was done to these 5 patients at different intervals revealing subperiosteal abscess formation in 100% of this group despite extensive course of antibiotics. And surgery was the definitive management (Fig. 3).

So power Doppler sonography is highly sensitive (100%), with high positive predictive value reaching (100%) in prediction of subsequent subperiosteal abscess formation and unre-
sponsiveness to antibiotic therapy entailing surgical interference.

Table 5 shows sensitivity = 53.8%, positive predictive value = 100%, specificity = 100%, negative predictive value = 13.3%, accuracy = 60% of the deep soft tissue swelling by U/S in diagnosis of Osteomyelitis.

Table 6 shows sensitivity = 32%, positive predictive value = 100%, specificity = 100%, negative predictive value = 10.5% and accuracy = 37% of SubPeriosteal abscess by U/S in diagnosis of Osteomyelitis.

Table 7 shows sensitivity = 48%, positive predictive value = 100%, specificity = 100%, negative predictive value = 13.3% and accuracy = 37% of the sign of Fluid adjacent to infected bone by U/S in diagnosis of Osteomyelitis.

Table 8 shows sensitivity = 52%, positive predictive value = 100%, specificity = 100%, negative predictive value = 14.3 and accuracy = 55.6%. Of Cortical erosion by U/S in diagnosis of Osteomyelitis.

Table 9 shows sensitivity = 72%, positive predictive value = 100%, specificity = 100%, negative predictive value = 22.2% and accuracy = 80 of increased flow within and around the periosteum by U/S in diagnosis of Osteomyelitis.

4. Discussion

Our study purpose is to evaluate the diagnostic values of high-resolution and power Doppler Sonography in early diagnosis of acute osteomyelitis in children using surgery, aspiration cytology, and follow up as a standard.

Twenty seven patients were included in our study; twenty five (92.6%) were finally diagnosed to have acute osteomyeli-
Figure 3  Sonogram showing periosteal elevation 3.5 mm from the patellar cortex, with subperiosteal echogenic collection denoting subperiosteal abscess formation, (arrows in Rt. small image).

Figure 4  (A) Increased periosteal flow in power Doppler study in left side. (B) Healthy right side showing no flow within or around periosteum.

Figure 5  Spectral analysis of periosteal flow to confirm true flow and to exclude Doppler artifacts.
Early diagnosis of acute osteomyelitis in children by high-resolution and power Doppler sonography

All patients were referred by an orthopedic surgeon as they were clinically suspected to have the disease. Initial conventional radiograph was done and revealed normal or inconclusive data. Then high-resolution and power Doppler sonography was done at time of presentation. We identified five sonographic signs in acute osteomyelitis: deep soft tissue swelling, periosteal thickening, elevation, &/or subperiosteal abscess, fluid adjacent to infected bone, cortical erosion, and increased flow within or around periosteum using power Doppler sonography, (authors considered one criterion is sufficient to make the diagnosis).

**Table 5** Deep soft tissue swelling by U/S in diagnosis of Osteomyelitis ($n = 27$).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitive diagnosis</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Osteomyelitis</td>
<td>Not Osteomyelitis</td>
</tr>
<tr>
<td><strong>US findings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep soft tissue swelling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Insignificant relation is evident ($P$-value > 0.05).
Sensitivity = 53.8%, positive predictive value = 100%.
Specificity = 100%, negative predictive value = 13.3%.
Accuracy = 60%.

**Table 6** Subperiosteal abscess by U/S in diagnosis of Osteomyelitis ($n = 27$).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitive diagnosis</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Osteomyelitis</td>
<td>Not Osteomyelitis</td>
</tr>
<tr>
<td><strong>US findings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subperiosteal abscess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Insignificant relation is evident ($P$-value > 0.05).
Sensitivity = 32%, positive predictive value = 100%.
Specificity = 100%, negative predictive value = 10.5%.
Accuracy = 37%.

**Table 7** Fluid adjacent to infected bone by U/S in diagnosis of Osteomyelitis.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitive diagnosis</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Osteomyelitis</td>
<td>Not Osteomyelitis</td>
</tr>
<tr>
<td><strong>U/S findings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid adjacent to infected bone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Insignificant relation is found ($P$-value > 0.05). Sensitivity = 48%, positive predictive value = 100%.
Specificity = 100%, negative predictive value = 13.3%.
Accuracy = 51.8%.

**Table 8** Cortical erosion by U/S in diagnosis of Osteomyelitis ($n = 27$).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitive diagnosis</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Osteomyelitis</td>
<td>Not Osteomyelitis</td>
</tr>
<tr>
<td><strong>U/S findings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cortical erosion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Insignificant relation is found ($P$-value > 0.05). Sensitivity = 52%, positive predictive value = 100%.
Specificity = 100%, negative predictive value = 14.3%.
Accuracy = 55.6%.

**Table 9** Increased flow within and around the periosteum by U/S in diagnosis of Osteomyelitis ($n = 27$).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitive diagnosis</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Osteomyelitis</td>
<td>Not Osteomyelitis</td>
</tr>
<tr>
<td><strong>U/S findings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased flow within and around the periosteum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Insignificant relation is found ($P$-value > 0.05). Sensitivity = 72%, positive predictive value = 100%.
Specificity = 100%, negative predictive value = 22.2%.
Accuracy = 80%.

Figure 6 Turbid fluid collection in the knee, with a needle inside appeared as a hyperechoic metal in the center of collection with posterior acoustic shadow (arrows). It revealed pus by cytological analysis.

Table 5 Deep soft tissue swelling by U/S in diagnosis of Osteomyelitis ($n = 27$).

<table>
<thead>
<tr>
<th>Variables</th>
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<tbody>
<tr>
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<td><strong>US findings</strong></td>
<td></td>
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</tr>
<tr>
<td>Deep soft tissue swelling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Insignificant relation is evident ($P$-value > 0.05).
Sensitivity = 53.8%, positive predictive value = 100%.
Specificity = 100%, negative predictive value = 13.3%.
Accuracy = 60%.

Table 6 Subperiosteal abscess by U/S in diagnosis of Osteomyelitis ($n = 27$).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitive diagnosis</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Osteomyelitis</td>
<td>Not Osteomyelitis</td>
</tr>
<tr>
<td><strong>US findings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subperiosteal abscess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Insignificant relation is evident ($P$-value > 0.05).
Sensitivity = 32%, positive predictive value = 100%.
Specificity = 100%, negative predictive value = 10.5%.
Accuracy = 37%.
In attempts to arrange these signs chronologically, we categorized our studied patients according to duration of symptoms at the time of examination into three subgroups: one to four days (three patients), four to six days (twelve patients) and one to two weeks (twelve patients).

This classification based on the pathophysiology and stages of the disease. The first stage represents the initial inflammation with vascular congestion and increased intraosseous pressure and occurs in first three days. Followed by stage of suppuration when pus within the bones forces its way through the haversian system and forms a subperiosteal abscess. By the end of the week; increased pressure, vascular obstruction, and infective thrombus compromise the periosteal and endosteal blood supply, causing bone necrosis and sequestrum formation (4).

We observed the frequency of each sonographic sign in all groups, and then a relation between each sign and duration of symptoms was studied.

Mah et al. (2) work was the only study that categorized their patients. Their findings were categorized into four groups according to the duration of symptoms: 1–3 days (20 patients); 4–6 days (8 patients); 1–2 weeks (6 patients); and 2–4 weeks (4 patients).

We did not include the fourth group (2–4 weeks) in our study because we considered the second week is the start of subacute osteomyelitis as mentioned by Sia et al. (2006)(13).

We found that deep soft tissue swelling is the earliest sign which was detected in 8 patients (out of 27 patients). It was seen in high proportion (87.5%) in the first two groups, i.e. within first 6 days of symptoms, while in late presentation it could not be clearly identified. This is in agreement with Mah et al. (1994) they detected deep soft-tissue swelling adjacent to the affected bone in a high proportion of cases presented in the first week (92%), but its incidence was less in group 4, so they considered it as the earliest sign of acute osteomyelitis (15).

Periosteal thickening, elevation, and/or subperiosteal abscess are considered late signs of acute osteomyelitis in our work. They were seen in 8 cases (out of 27 patients); with a high incidence (71.5% of these 8 patients) among patients in group three, and a less incidence among patients in group two (28.5%) while no periosteal changes could be detected in group one (first 4 days).

Mah et al. (1994) concluded that subperiosteal collections were most commonly found in group 3 (40%). They were less frequent in group 2 (33%) and least common in group 1 (13%). We also had the same conclusion that subperiosteal collections have an increasing frequencies from group one to group three (15).

The absence of subperiosteal collection in group one in our patients might be explained by the small number of this group (only three patients), compared to (twenty patients) in Mah et al.’s work (1994). Note also that 13% as a result in their work represent only two patients.

We detected fluid adjacent to the infected bone without intervening soft tissue in 12 cases seen mainly in group 3 (58.5% of these 12 patients), and in a lesser percentage in group two (41.5%), while no fluid was detected in group one.

We included this sign in our series because it is a sign of acute osteomyelitis as mentioned by Abiri et al. (1988), Wright et al. (1995), Hwang et al. (2002), Skotáková et al. (2004), and Khan et al. (2007) (1,4,12,16,17).

This sign presents in an increasing frequency from group one to group three, similar to the subperiosteal abscess denoting that detection of fluid adjacent to bone means late stage in acute osteomyelitis with a tendency for subperiosteal abscess formation.

Azam et al. (2005) found that anechoic fluid accumulation contiguous with bone was highly suggestive of osteomyelitis, whereas presence of soft tissue between the bone and the fluid suggested a non-osseous origin of the fluid. Subperiosteal accumulation of fluid was seen in 42 cases (76.3%). A subperiosteal with periosteal reaction was demonstrated in 35 children (63.6%) (9).

Wright et al. (1995) concluded that the US findings of a fluid collection lying adjacent to the bone with no intervening soft tissue were considered positive for a subperiosteal abscess (16).

We found that cortical erosion was the latest finding to be detected in our patients, it was seen in 13 patients (out of 27 patients): the highest incidence was seen in group three (61.5% of these 13 patients), followed by (38.5%) in group two, while no erosion could be identified in group one. In agreement with Mah et al. (1995) who found that Cortical erosion is a feature of established osteomyelitis and was seen with increasing frequency from group 1 (7%) to group 4 (100%). But we have not fourth group in our study because we considered the second week is the start of subacute osteomyelitis as mentioned by Sia et al. (2006) (13).

Concurrent septic arthritis is considered as one of the complications of acute osteomyelitis and was found in 7 patients (out of 27 patients). We observed that it is an age related process being most frequent in infants. We found 80% of patients below 2 years had developed septic arthritis, while only 13% of patients older than 2 years had adjacent septic arthritis.

It is quite logic since the epiphyseal plate acts as a barrier after age of 2 years and separates between the epiphyseal and metaphyseal blood supplies making spread of infection to joint space less common after age of 2 years except when the infection is severe, in which case infection may break through the bone and produce joint infection (18).

In our study increased flow in power Doppler sonography within or around periosteum was evident in 18 cases (out of 27 patients) with increasing incidence from group one (16.5%) to (33.5%) in group two, and (50%) in group three.

Five patients out of 18 who had increased flow within or around periosteum had presented early and their initial sonography revealed only this sign without associated late signs. Follow up sonography of these 5 patients was done at different intervals (within one week) revealing subperiosteal abscess formation in 100% of these patients, despite extensive course of antibiotics. And surgery was the definitive management.

So power Doppler sonography is highly sensitive (100%), with high positive predictive value reaching (100%) in prediction of subsequent subperiosteal abscess formation and unresponsiveness to aggressive antibiotic courses entailing surgical interference.

We could not evaluate specificity or negative predictive value of this sign due to lack of true and false negative cases in our series.

Azam et al. (2005) found subperiosteal abscess with periosteal reaction in 35 children (63.63%). Color Doppler study revealed increased vascular flow within or around the affected periosteum in all cases (9).
Chao et al. (1999) studied Duplex ultrasonography in detection of the progression of osteomyelitis in six patients, who eventually required surgery. They all had persistent or increased color Doppler vascular flows within or around the affected periosteum. These CDUS features indicated the progression of osteomyelitis and correlated with clinical acute osteomyelitis at later stages (14).

We calculated sensitivity and specificity for each sonographic sign, we found that increased power Doppler flow within and around the periosteum had the highest sensitivity (72%) followed by deep soft tissue swelling (53.8%), then Cortical erosion (52%), fluid adjacent to infected bone (48%) ended by subperiosteal abscess that had the lowest sensitivity value (32%). While specificity of all signs was very high reaching (100%).

This high specificity of each sonographic sign because of our selection of cases; our studied patients were clinically suspected to have acute osteomyelitis, in addition radiograph was done to each patient to exclude other causes of pain (e.g. tumors, fractures, etc.), so we narrowed our list of differential diagnosis to obtain this high specificity.

We obtained lower sensitivity values than expected because of the nature of the disease which has a progressive course, so these signs represent a spectrum of findings along the course of the disease. Early stages are characterized by certain signs that fade in later stages, and late stages are characterized by another signs that would not appear early.

In a study done by Collado et al. (2008) they described only 2 children complaining of leg pain associated with elevated C-reactive protein levels in whom power Doppler (PD) sonography suggested the diagnosis of early osteomyelitis. PD sonography detected increased blood flow that resulted in a high-intensity signal area adjacent to the symptomatic tibia surface. Antibiotic therapy led to prompt improvement. These cases suggest that PD sonography is useful in the evaluation of reactive protein levels in whom power Doppler (PD) sonography detected increased blood flow that resulted in a high-intensity signal area adjacent to the symptomatic tibia surface. Antibiotic therapy led to prompt improvement. These cases suggest that PD sonography is useful in the evaluation of possible early osteomyelitis in children (19).

Balanika et al. (2009) stated that statistically significant differences between patients with and without reactivated chronic osteomyelitis were found for fistulous tracts (P < 0.0001), juxtaarticular fluid collections (P < 0.001) periosteal thickening (P < 0.01), distension of pseudocapsule (P < 0.05), and periosteal vascularity (P < 0.0001). Low-resistance arterial flow of periosteal vessels presented the highest sensitivity (92%), specificity, and PPV (100%), yielding only two false negative results in two obese patients. Among gray-scale findings, the presence of a fistulous tract yielded the highest specificity and PPV (100%), whereas periosteal thickening was the most sensitive (92%), though not specific, finding (specificity 50%) (20).

Up to our search we could not find any published work about the sensitivity and specificity values of each individual sign in acute osteomyelitis.

Along the course of our work we faced two main disadvantages of ultrason; the first is the underestimation of the actual amount of pus and extent of the disease. The second is: unfamiliarity with musculoskeletal sonography.

Overall, high resolution and power Doppler sonography were found to be very sensitive (100%) and highly specific (100%) in diagnosis of acute osteomyelitis in pediatrics with clinical suspicion of the disease. High positive and negative predictive values of high resolution sonography were noted reaching 100%.

The high values of sensitivity and specificity in our work might be explained by the strict inclusion and exclusion criteria of our patients which narrowed the scope of our selection to those with clinical suspicion of osteomyelitis together with negative radiographs for any other bony lesions.

Also the presence of only one sonographic criterion of acute osteomyelitis was considered by the authors to be sufficient to reach the final diagnosis.

5. Conclusion

A constellation of gray-scale and CDUS findings can be highly indicative of reactivated bone infection in patients with longstanding chronic post-traumatic/post-operative osteomyelitis.

We concluded that sonography is not only helpful tool for establishing the diagnosis in acute osteomyelitis, but also for determining its complications. Power Doppler sonography allowed detection of advanced osteomyelitis and revealed the progression or regression of inflammation during antibiotic therapy. It should be used as initial routine examination beside conventional radiograph, to facilitate early diagnosis of acute osteomyelitis and to limit further imaging work up.

References


