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ORIGINAL STUDY

Ultrasound and colour Doppler sonography in acute osteomyelitis in children

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Early diagnosis of osteomyelitis is of paramount importance to avoid irreversible sequelae. This often requires a multimodal approach. The purpose of the present study was primarily to evaluate how ultrasound might be useful in early diagnosis of osteomyelitis in the paediatric age group. The evolution of ultrasound findings with progression and resolution of disease was also analysed.

In this prospective study, 55 children with osteomyelitis of limbs were subjected to sonographic examination including colour Doppler study. The sonographic machine used was a LOGIC-500, using a linear multifrequency transducer (7-9 MHz). Ultrasound guided aspiration was performed in all cases showing sub-periosteal accumulation of fluid, and the aspirate was sent for culture and sensitivity report. Surgical drainage was undertaken in all patients in which a sub-periosteal abscess was demonstrated.

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 abscess with periosteal reaction was demonstrated in 35 children (63.63%). Colour Doppler study revealed increased vascular flow within or around the affected periosteum in all cases. Concurrent involvement of a joint was noted in 13 cases.

Ultrasound is a rapid, cheap, easily available, non-ionising and reasonably accurate diagnostic modality. It also helps in localising the lesion for diagnostic aspiration. Serial ultrasound and technical innovations such as colour Doppler sonography further help in monitoring the progression and resolution of the disease.

Key words : osteomyelitis ; children ; ultrasound ; colour Doppler.

INTRODUCTION

Osteomyelitis is a significant cause of morbidity in childhood with a reported incidence of 1 in 5000 children less than 13 years of age. Early diagnosis of osteomyelitis is of paramount importance (*14*), so that definitive and adequate treatment is not delayed, an important step to avoid irreversible damage and morbidity.

The clinical diagnosis of osteomyelitis especially in the early stage still remains a challenge. A

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multimodal approach is often needed to establish the diagnosis (*1*). This involves routine laboratory tests such as white blood cell count (WBC), erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP), bacteriological tests such as blood and bone culture and radiological examination.

Markers of the acute phase reactants are non-specific, and plain radiographs are unable to pick up early changes in osteomyelitis. In such circumstances, bone scan (*10*) and magnetic resonance imaging (MRI) (*13, 15*) remain sensitive tests. Unfortunately, these modalities of investigations are not available in all centers, especially so in developing countries like ours. Furthermore, expenses incurred and radiation associated with CT and bone scan make repeated use of these tests undesirable and also beyond reach of most people.

Well-controlled trials have already established the value of ultrasound imaging in areas like developmental dysplasia of the hip in infants, pathology of the rotator cuff, tendon and ligament abnormalities, monitoring of limb lengthening etc. Careful review of literature (*3, 4, 7-9, 17*) further revealed that ultrasound is emerging as a new imaging modality for the early diagnosis of osteomyelitis. This allows early detection of an occult collection and provides guidance for diagnostic aspiration (for bacteriological culture and sensitivity). Ultrasound also detects concurrent adjacent joint involvement.

The purpose of the present study was primarily to evaluate how ultrasound might be useful in early diagnosis of osteomyelitis and also to analyse the evolution of sonographic findings with the progression or resolution of the disease.

MATERIALS AND METHODS

Over a period of one and a half year from June 2002 to December 2003, 55 patients in the age group of 7 months to 12 years were diagnosed to have osteomyelitis. The clinical diagnosis of osteomyelitis was based on the diagnostic criteria established by Petola and Vahvanen (*11*). They considered that in the presence of two of the following four criteria, the diagnosis of osteomyelitis was firm :

1. Pus aspirated from bone,
2. Positive bone or blood culture,
3. Classic symptoms of localised pain, swelling, warmth and limited range of motion (ROM) of the adjacent joint,
4. Radiographic changes typical of osteomyelitis.

Operative findings in 42 cases and MR imaging in nine cases further confirmed the diagnosis of osteomyelitis.

Haematological examination including pus culture, radiographs of the part (anteroposterior and lateral views) and sonographic examination including colour Doppler study were performed in all patients at the time of admission. Haematological and sonographic examinations were repeated as and when required to reaffirm the diagnosis and also to obtain a correlation between these and clinical progression.

The sonographic machine used was LOGIC-500 by GE (General Electrical) using a linear multifrequency transducer (7-9 MHz). Scans (longitudinal and transverse) covering the full thickness of the relevant areas were obtained. Both proximal and distal joints were always scanned as part of the ultrasonographic examination. Vascular images were evaluated by colour Doppler ultrasonography using low velocity and filter setting. Dynamic colour adjustment was done during the examination to maximise the visualisation of the blood flow. The unaffected contralateral side was also examined for comparison when required. This allowed detection of subtle changes.

Sonography demonstrated normal muscle layers to be hypoechoic with linear echogenic striations separating the layers. The cortex of normal bone appeared as a dense echogenic line with a smooth surface. Vascular structures were clearly visualised with colour Doppler flow analysis.

Ultrasonography-guided aspiration of pus was performed under local anaesthesia or sedation (depending on age and co-operation of the patient) in cases where subperiosteal fluid was demonstrated, and the pus thus obtained was sent for Gram staining, culture and sensitivity. A large bore, shallow, tapered needle was used for the aspiration. Care was taken to insert the needle till it came in contact with the bone. If aspiration at this point failed to withdraw pus, the needle was twisted till it was felt to penetrate the bone.

All cases which demonstrated an abnormal collection of fluid adjacent to the bone without intervening soft tissue, underwent surgery. Intravenous (IV) antibiotic was started in the remaining 13 cases that showed only deep soft tissue swelling adjacent to the affected bone. Repeat

Table I. — Anatomical Distribution

Site	No. of patients
Proximal Femur	12
Distal Femur	25
Proximal Tibia	8
Distal Tibia	3
Proximal Humerus	4
Distal Humerus	3

sonographic examination was performed on the third day after initiation of therapy.

RESULTS

Fifty-five children, 38 boys and 17 girls ranging in age from 7 months to 15 years were included in the study. They had systemic features of acute infection and the duration of symptoms varied from 2 to 15 days, with a mean duration of symptoms of 4.6 days at the time of admission. High fever, inability to use the extremity, along with local swelling and redness were the most common symptoms, while local tenderness and painful restriction of movement were the signs most commonly elicited. In our series the femur was the bone most commonly involved, followed by the tibia ; the hip was the joint most commonly involved, followed by the knee. The anatomical sites involved are shown in table I. Concurrent involvement of a joint was noted in 13 cases.

No radiographic findings were appreciated in patients symptomatic for up to seven days at the time of admission. Soft tissue swelling with blurring of muscle planes could be seen in eight cases which presented after seven days. Periosteal reaction, rarification and cortical erosion were visible only in four patients with symptoms of at least 10 days duration.

Sonographic examination in patients with symptoms of less than three days duration demonstrated increased soft tissue swelling adjacent to bone in ten children, while in the remaining three patients no abnormality was detected. In nine of the 13 cases, the diagnosis was confirmed by MR imaging, however the diagnosis in the other four cases was based on the clinical criteria of Pettola

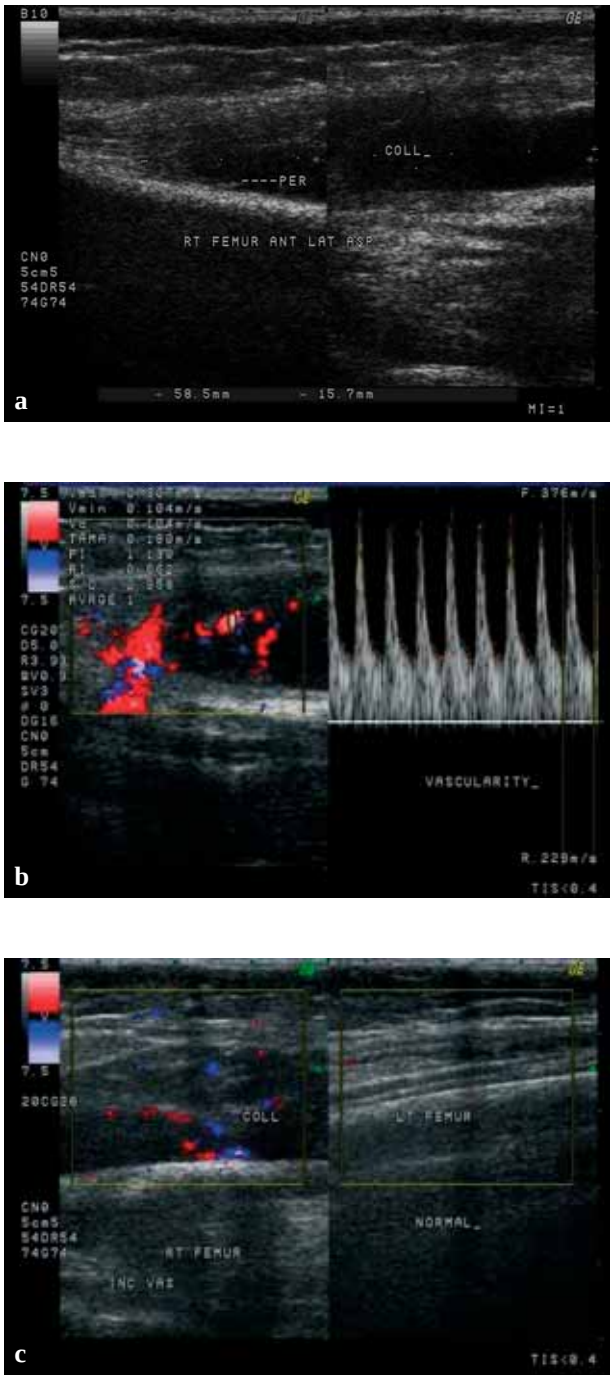


Fig. 1. — a) Longitudinal sonogram of right femur (anterolateral aspect) showing elevated periosteum with hypoechoic collection adjacent to bone ; b) Colour and spectral Doppler of the same patient showing increased vascularity around the involved periosteum ; c) Colour Doppler and grey scale image of the same patient, showing hypoechoic subperiosteal collection with increased vascularity. Scan of normal right femur is shown for comparison.

and Vahvanen (*11*). All but two of these children showed clinical improvement following conservative treatment (IV antibiotic). Repeat sonographic examination performed in these two cases revealed a subperiosteal collection. Surgical drainage was immediately performed in both of them.

Subperiosteal fluid collection was demonstrated in 42 patients (figs 1, 2) who presented after three days. Pus was aspirated in all of them under real time sonographic guidance. These children underwent surgical drainage and had remarkable improvement.

A positive culture was reported in 81.8% (36 cases) of the aspirates. Positive blood culture

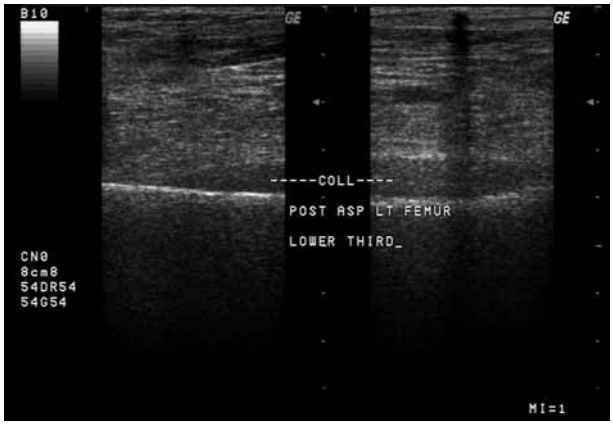
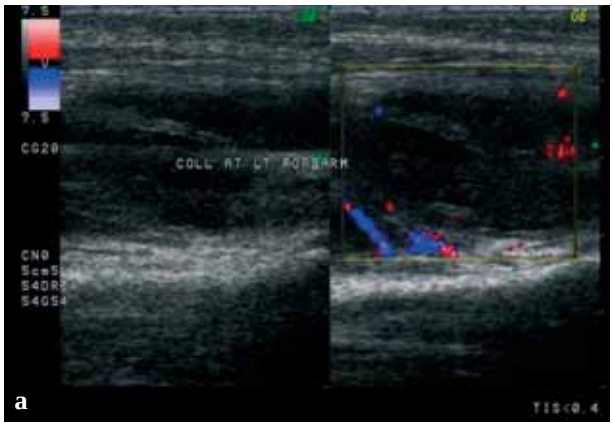


Fig. 2. — Sonogram of left femur (posterior aspect) demonstrating periosteal elevation and subperiosteal collection.



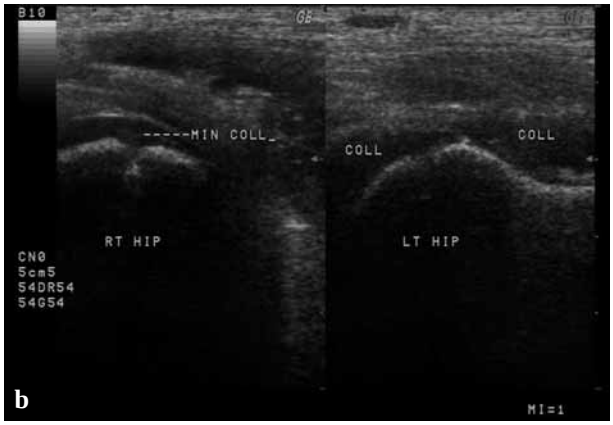


Fig. 3. — a) Grey scale and colour Doppler scan showing large hypoechoic collection adjacent to left radius. The bone cortex is irregular and vascularity around it is increased ; b) Sagittal sonogram of both hips of the same patient showing effusion in both hips with hypoechoic collection at the neck of left femur with elevated periosteum.

Table II. — Relevant details of radiographic and sonographic features according to duration of symptoms

Duration of symptoms	Number of cases	Radiographic findings	Sonographic features (number)
1-3 days	13	• No abnormality	• No abnormality (3) • Soft tissue swelling adjacent to bone (10)
4-7 days	30	• No abnormality	• Soft tissue swelling adjacent to bone • Subperiosteal abscess • Increased vascularity in/around periosteum • Periosteal reaction
8-15 days	12	• Blurring of muscle planes adjacent to bone • Rarification • Periosteal reaction	• Subperiosteal abscess • Periosteal reaction • Cortical erosion, irregularity and cloacae

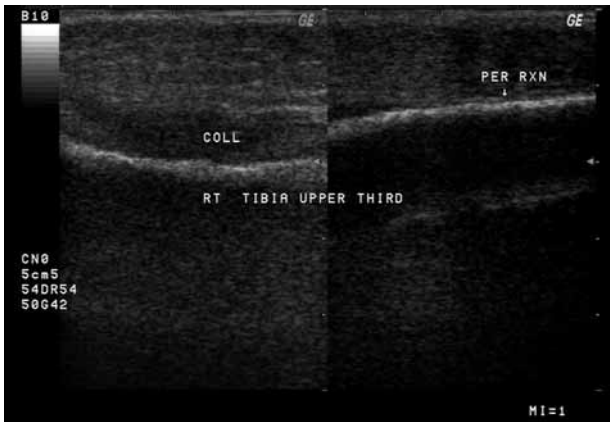


Fig. 4. — Ultrasonographic scan of right upper tibia showing periosteal reaction and subperiosteal collection.

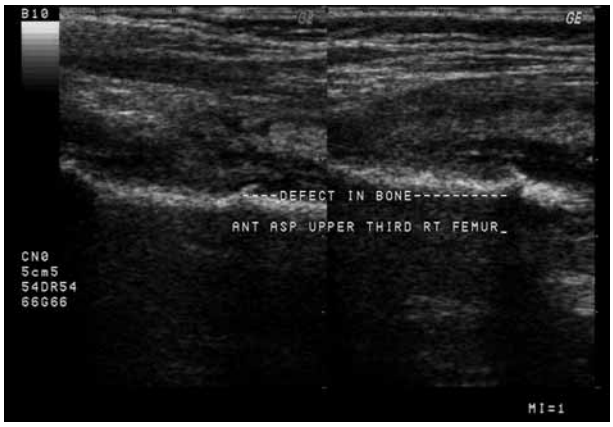


Fig. 5. — Longitudinal scan of the anterior aspect of the right upper third of the femur demonstrating small cortical defects (cloacae) with a hypoechoic collection.

was obtained in 24 patients (43.63%). Common organisms isolated in our series were *Staphylococcus aureus* (58.18%), Gr-A *Streptococcus* (9.09%), *S. pneumoniae* (7.27%), *H. influenzae* (18.18%) and others (7.27%).

Figure 3 shows scans of a child diagnosed to have multifocal osteomyelitis. Other important sonographic features such as periosteal reaction (fig 4), cortical erosions, cortical thickening and cloacae (fig 5), appeared only after the seventh day with symptoms (table II). Concurrent septic arthritis was noted in 13 cases (fig 6).

The location of fluid in relation to bone was a very valuable finding in discriminating between osteomyelitis and soft tissue collections. Fluid collection contiguous with bone was highly suggestive of osteomyelitis, whereas presence of any soft tissue between the bone and the fluid tilted the diagnosis in favour of a non- osseous origin of the fluid.

Interestingly, three of the 42 children who did quite well after surgical debridement and had no clinical signs of infection, demonstrated a substantial collection of pus when routine sonographic examination was performed at the time of discharge as a part of our study. Surgical drainage was performed in all these cases and they were advised antibiotics for a longer duration.

Patients who responded satisfactorily showed no abscess on ultrasound examination at the time of discharge, and vascularity in and around the affected periosteum was decreased. Serum CRP and ESR were elevated in all the cases at the time of admission. The CRP value decreased significantly or became normal at the fifth day of treatment in all such cases. However, the ESR either decreased minimally or remained elevated at that moment.

DISCUSSION

Early diagnosis of acute osteomyelitis and timely institution of appropriate therapy is of paramount importance in osteomyelitis of children to achieve good outcome. Better imaging technology and improved antibiotic therapy have improved diagnostic accuracy and decreased morbidity. Nevertheless, overlapping clinical symptoms and signs, non-specificity of haematological parameters, positive blood culture in only 25-50% cases, inability of plain radiographs to pick up early changes, may make the diagnosis of osteomyelitis in children (especially in the early stage) a formidable challenge. A multimodal approach involving plain radiographs, bone scintigraphy (*10*), CT and MRI (*13, 15*) has been used for diagnosis of infection of the musculo-skeletal system.

Diagnostic modalities like bone scan, CT and MRI are sensitive but are not commonly available, especially in developing countries like ours. In addition, the expenses incurred are beyond reach of common people. Ionisation hazards further make

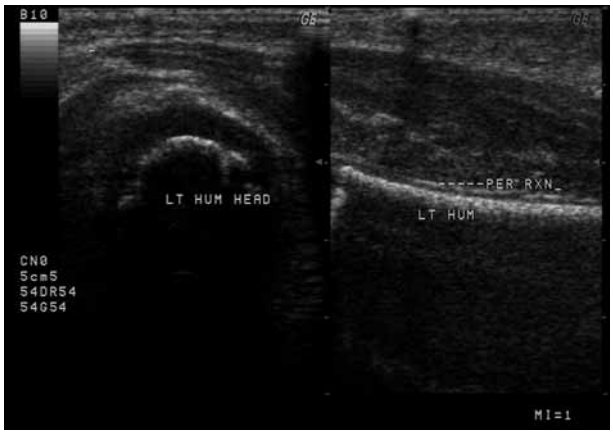


Fig. 6. — Sonogram of left humerus with shoulder joint showing periosteal reaction with linear hypoechoic subperiosteal fluid accumulation with effusion in the joint.

repetition of these tests to monitor the clinical course of the disease undesirable and unacceptable.

In such circumstances, ultrasound facilitates an early diagnosis of osteomyelitis, permits real time guided aspiration for bacteriological examination and helps in monitoring success of therapy.

Capitanio and Kirpatrick (*2*) described that soft tissue swelling and loss of muscle planes are discernible in plain radiograph as early as 48 hours. However, in our study, these features could not be seen before 7 days. Destructive changes in the bone strongly suggestive of osteomyelitis were seen on plain radiographs no earlier than 10 days after the onset of osteomyelitis.

We experienced that an anechoic fluid collection, when seen in direct contact with bone, was highly suggestive of osteomyelitis. Serial ultrasound examination revealed that the spectrum of findings changes with the duration of the disease. Deep soft tissue swelling adjacent to bone was the earliest finding, noted as early as the second day of symptoms, followed by a thin layer of subperiosteal fluid, subperiosteal abscess and periosteal reaction in patients with symptoms duration of more than three days. In patients who presented late after 7-10 days, cortical erosion and cloacae were noted. Demonstration of intervening soft tissue between the fluid and bone suggests a non-osseous origin of the fluid. These findings corroborated with similar findings noted by authors like Sarti (*12*), Abiri *et al* (*1*) and Mah *et al* (*8*).

Subperiosteal fluid accumulation was seen in 42 cases (76.36%). Subperiosteal abscess and periosteal reaction together was seen in 35 children (63.63%). Howard and Einhorn (*5*) reported periosteal reaction in 100% of cases. Kaiser and Rosenberg (*6*) showed subperiosteal fluid in 41% of cases and Mah *et al* (*8*) demonstrated periosteal reaction and subperiosteal accumulation in 50% of cases.

We compared serial sonographic findings following treatment with clinical status and haematological parameters (CRP and ESR) in an attempt to draw a correlation among them. ESR proved to be neither a reliable indicator of disease nor a valuable tool for following the resolution of infection as it lags behind the improvement seen clinically. Serum CRP and ultrasound findings correlated well with clinical improvement. Our study indicated that sonographic findings and increased vascularity (on colour Doppler sonography) are sufficiently accurate in monitoring the disease. Previous literature (*11, 16*) has also emphasised the importance of serum CRP as a valuable indicator to monitor the disease.

Authors of the present study are of the view that pus should be drained as quickly as possible and early demonstration of subperiosteal abscess by ultrasound helped in diagnostic aspiration, early surgical intervention and in deciding the approach of surgery. Howard and Einhorn (*5*) and Harris (*4*) also feel that all cases of subperiosteal abscess must be drained. This is in contrast with Mah *et al* (*8*), who observed that subperiosteal abscesses of 3 mm or even more resolved completely with antibiotic treatment alone.

CONCLUSION

Ultrasound is a rapid, easily available, portable, non-invasive, non-ionising, cheap and reasonably accurate diagnostic modality, for screening and early diagnosis of osteomyelitis and concurrent septic arthritis in all patients who are clinically suspected of having osteomyelitis.

Ultrasound helps in differentiating conditions with overlapping clinical symptoms and signs such

as soft tissue abscess, pyomyositis and cellulitis. Furthermore, by localising the lesion it guides for diagnostic aspiration. Ultrasonography is quantifiable and reproducible, and we recommend its use as a first line of investigation in such situations. Serial ultrasound and technical innovations such as colour Doppler examination reasonably help in monitoring the progression or resolution of disease process.

However in the absence of localising features (i.e. when survey of a large area is required) and in suspected multifocal osteomyelitis, scintigraphy and MR imaging are better suited diagnostic modalities.

REFERENCES

1. **Abiri MM, Kirpekar M, Ablow RC.** Osteomyelitis : detection with ultrasonography. *Radiology* 1989 ; 172 : 509-511.
2. **Capitanio M, Kirpatrick J.** Early roentgen observations in acute osteomyelitis. *Am J Roentgenol* 1970 ; 108 : 488-496.
3. **Chao HC, Lin SJ, Huang YC, Lin TY.** Color Doppler ultrasonographic evaluation of osteomyelitis in children. *J Ultrasound Med* 1999 ; 18 : 729-734.
4. **Harris NH.** Some problems in the diagnosis and treatment of acute osteomyelitis. *J Bone Joint Surg* 1960 ; 42-B : 535-541.
5. **Howard CB, Einhorn MS.** Ultrasound in the detection of subperiosteal abscess. *J Bone Joint Surg* 1991 ; 73-B : 175-176.
6. **Kaiser S, Rosenberg M.** Early detection of subperiosteal abscess by ultrasonography : a means for further successful treatment in pediatric osteomyelitis. *Pediatr Radiol* 1994 ; 24 : 336-339.
7. **Loyer EM, DuBrow RA, David CL *et al.*** Imaging of superficial soft tissue infection : sonographic findings in cases of cellulitis and abscess. *Am J Roentgenol* 1996 ; 166 : 149-152.
8. **Mah ET, Le Quesne GW, Gent RJ, Patersson DC.** Acute osteomyelitis in children. *J Bone Joint Surg* 1994 ; 76-B : 969-974.
9. **Nath AK, Sethu AU.** Use of ultrasonography in osteomyelitis. *Br J Radiol* 1992 ; 65 : 649-652.
10. **Paterson DC, Foster BK & Savage JP.** The present status of bone scanning in clinical orthopaedic diagnosis. *Recent Advances in Orthopaedics*. 1987 ; 5 : 19-41.
11. **Pettola H, Vahvanen V, Aalto K.** Fever, C-reactive protein and ESR in monitoring recovery from septic arthritis : A preliminary study. *J Pediatr Orthop* 1984 ; 4 : 170-174.
12. **Sarti DA.** Ultrasonography of the lower extremity. In : Sarti DA and Sample WF (eds). *Diagnostic Ultrasound.* 1st ed, G.K. Hall &Co., Boston, pp 486-501.
13. **Schlesinger AE, Hernandez RJ**. Diseases of the musculoskeletal system in children : Imaging with CT, Sonography and MR. *Am J Roentgenol* 1992 ; 158 : 729-741.
14. **Trueta J, Morgan JD.** Late results in the treatment of one hundred cases of acute hematogenous osteomyelitis. *Br J Surg* 1954 ; 41 : 449-457.
15. **Unger E, Moldofsky P, Gatenby R.** Diagnosis of osteomyelitis by MR imaging. *Am J Roentgenol* 1988 ; 150 : 605-610.
16. **Unkila-Kallio L, Kallio MJT, Eskola J, Pettola H.** Serum C-reactive protein, erythrocyte sedimentation rate and white blood cell count in acute hematogenous osteomyelitis of children. *Pediatrics* 1994 ; 4 : 170-174.
17. **Wright NB, Abbott GT, Carty HML.** Ultrasonography in children with osteomyelitis. *Clin Radiol* 1995 ; 50 : 623-627.