ACUTE HAEMATOGENOUS OSTEOMYELITIS

WILLIAM N. GILMOUR, PERTH, WESTERN AUSTRALIA

From the Princess Margaret Hospital for Children, Perth

Few diseases remain unchanged over the years. The influences of environment, of altered treatment, of mutation in the invading forces bring about changes which demand recognition and an adjustment in management. The last seventeen years have seen profound variations in the presentation and course of acute haematogenous osteomyelitis, and a series of 328 cases is presented here to show at first the influence of penicillin and later the effect of resistance of the organisms to this drug.

The patients were children under the age of thirteen years treated in the Orthopaedic Department of the Princess Margaret Hospital for Children, in Perth, Western Australia, and include only those children who were treated at the hospital for an acute illness and with radiological confirmation of bone infection. This latter provision inevitably excluded a considerable number of children in whom the diagnosis had been made on clinical grounds and blood cultures only. On the other hand it established a base line for a general comparison in diagnosis and treatment.

The series is divided into two groups (Fig. 1): seventy-seven children seen from 1944 to 1950, and 251 seen from 1951 to 1960. The year 1944 saw the introduction of penicillin in the treatment of acute osteomyelitis. Published reports (Agerholm and Trueta 1946, Blanche 1952, Altemeier and Wadsworth 1948, McAdam 1945) and the impressions of workers were unanimous in announcing the control of acute osteomyelitis in terms both of mortality and morbidity. In Perth, in the first group of children, very few operations were done in the acute stage, and these amounted only to drainage of an abscess on six occasions and bone drilling once. The results supported this conservative approach because severe sequestration occurred only three times, and joint destruction only twice. Over this period the organism was shown to be sensitive to penicillin both by clinical response and laboratory tests. It was indeed a happy era.
The introduction of penicillin allowed a colossal bacteriological experiment to be undertaken; every staphylococcus, whether it produced the smallest skin lesion or the severest septicaemia, was bathed in penicillin in one of its many forms. It was not an unexpected outcome that the staphylococcus should mutate as its only means of survival. Thus, in 1951, a staphylococcus emerged that was resistant to penicillin, and which, over the next ten years, became so predominant that, on culture, sensitivity to penicillin was found on fifty-four occasions, and resistance on 133 occasions (Fig. 2).

With the appearance of the penicillin-resistant staphylococcus the disease of acute haematogenous osteomyelitis assumed certain new features. 1) It became more frequent.

### TABLE I

The Average Age Incidence of Acute Osteomyelitis in a Children's Hospital and the Incidence of Neonatal Infection

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of cases</th>
<th>Average age of children (years)</th>
<th>Number of infants under three months</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>10</td>
<td>7</td>
<td>—</td>
</tr>
<tr>
<td>1945</td>
<td>7</td>
<td>6</td>
<td>—</td>
</tr>
<tr>
<td>1946</td>
<td>9</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1947</td>
<td>19</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>1948</td>
<td>14</td>
<td>9</td>
<td>—</td>
</tr>
<tr>
<td>1949</td>
<td>8</td>
<td>7</td>
<td>—</td>
</tr>
<tr>
<td>1950</td>
<td>10</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>1951</td>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1952</td>
<td>7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1953</td>
<td>16</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>1954</td>
<td>20</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>1955</td>
<td>33</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>1956</td>
<td>24</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1957</td>
<td>52</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>1958</td>
<td>25</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>1959</td>
<td>40</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>1960</td>
<td>29</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>328</td>
<td>5½</td>
<td>32</td>
</tr>
</tbody>
</table>

Wakeley (1932) noted the lowered incidence in the 'thirties and suggested that osteomyelitis might disappear, because of improved nutrition and resistance to infection. The blame for the resurgence of this disease in recent years must be transferred to the infecting organism, and the increase explained either by altered virulence or altered pathogenesis. 2) Generally the septicaemia was more severe, with several sites affected, and, in particular, staphylococcal pneumonia becoming a common—and destructive—complication. Wallman, Godfrey and Watson reported from this hospital in 1955 a series of fifty-five patients with staphylococcal pneumonia occurring in twenty-nine months in whom the mortality was 23 per cent. 3) Younger children became affected (Table I). In particular this was because of an increased incidence...
in the neonatal period. Twenty-seven of the thirty-two infants in this series with neonatal osteomyelitis were in the era of the penicillin-resistant staphylococcus. 4) Sequestra reappeared. Early surgery was again needed to overcome this and to prevent massive bone destruction. 5) The causative organism was usually the staphylococcus, which was resistant to penicillin in 133 of the 187 children from whom it had been cultured. Unlike the earlier series, other organisms occurred infrequently, streptococci causing seven cases, haemophylyus influenzae three, salmonella three, pneumococci two, and the streptococcus viridans one. 6) The final and optimistic feature was the low mortality. There were only two deaths out of the 328 children, and this can only mean that antibiotic treatment still has a profound influence on this disease; for it represents a considerable contrast to the 15 to 30 per cent mortality recorded by Wade (1929), Wilson and McKeever (1936) and Green and Shannon (1936) in the days before penicillin. It must, however, be remembered that the staphylococcus can still cause a fatal illness, but from pneumonia and not from osteomyelitis.

Fig. 2
Antibiotic sensitivity of the organisms identified in the cases of osteomyelitis from 1951 to 1960.

THE CLINICAL PICTURE

The severity of the illness and the amount of bone destruction was not related to the length of history, which in the early group was four days and in the late group five and a half days. The disease presented in its most severe forms either as an acute fulminating septicaemia, or when there had been a considerable delay in diagnosis. Both forms had a high incidence of visceral involvement, the commonest of which was staphylococcal pneumonia (in eighteen children) and pericarditis (in five).

In this series 62 per cent were boys. This fact, with the frequent history of injury and the frequent involvement of the legs is, perhaps, evidence that osteomyelitis is an infection of bone in an area of impaired nutrition. The high incidence—approximately 70 per cent—of skin lesions, often yielding staphylococci with the same sensitivity as that causing the osteomyelitis, is significant, and it must be accepted that the infection is haematogenous and usually from some superficial lesion. The blood was cultured on admission in 184 children, and it was positive in eighty-eight, or 48 per cent.

Symptoms and signs—The clinical picture naturally varies with the severity of the infection, as well as with age; but there are four constant features: 1) A sick and miserable child who resents and cries with any interference. 2) A fever of about 102 to 104 degrees Fahrenheit. 3) A limp limb which the child will not move. 4) Tenderness localised to one area of a bone. There
on the average. The erythrocyte sedimentation rate is high: it averaged 66 millimetres in the first hour in our children and did not fall until sequestra had been completely absorbed.

Differential diagnosis—There are four principal disorders with which difficulties may arise.

Rheumatic fever—Differentiation can be difficult, particularly when the osteomyelitis involves several bones. The high fever and greater illness of the child, with bone tenderness rather than joint pain, point towards a diagnosis of osteomyelitis. In practice, it is far safer to give antibiotic drugs immediately and observe their effects over the next two days.

Cellulitis—In acute haematogenous osteomyelitis the swelling of the limb is larger and more circumferential than in cellulitis, and there is very little local skin redness or oedema; also the tenderness is localised to the bone. The skin lesion from which the organisms entered is not necessarily on the limb affected by the osteomyelitis, nor are the lymph glands enlarged. Finally, the staphylococcus causes osteomyelitis and the streptococcus cellulitis.

Poliomyelitis and meningitis—The flaccidity of a limb and the complete refusal of the child to move it, associated with a febrile illness, has led to this error of diagnosis on several occasions.

Non-specific or transient arthritis of the hip joint—This common disorder of no
consequence is distinguished by its lower fever, its lower erythrocyte sedimentation rate, and the moderate degree of irritability of the hip which it causes.

For practical consideration, bone and joint tuberculosis does not occur today in the community from which this series was taken.

**Sites of infection**—The various sites are shown diagrammatically in Figure 4. These follow the general pattern of other series, and show that the lower limb is affected six times more often than the upper limb. In certain sites, notably the maxilla and vertebrae, the disease assumes such characteristics as to become an entity warranting separate description, which is beyond the scope of this paper. The infection does not always start in the metaphysis, and it will be noted that the mid-shaft of a long bone was affected five times and the lower femoral epiphysis four times (Figs. 5 and 6).

**Neonatal infection**—With the advent of the penicillin-resistant staphylococcus there was an insurgence of infection in infants in the neonatal period. Among the children affected in the years 1951 to 1960 there were twenty-seven less than three months old (Table I). Most of these infants came from the King Edward Memorial Hospital for Women where, in 1955, there was a high incidence of staphylococci in routine swabs and in the upper respiratory tract of the staff (Table II). The site of entry of the organism was thought to be the umbilicus.

**TABLE II**

**Bacteriological Incidence and Sensitivity of the Staphylococcus at the King Edward Memorial Hospital for Women During 1955**

<table>
<thead>
<tr>
<th>Type of investigation</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine swabs of breast abscesses</td>
<td></td>
</tr>
<tr>
<td>Staphylococci cultured in</td>
<td></td>
</tr>
<tr>
<td>Resistance to penicillin of cultured staphylococci in</td>
<td>73</td>
</tr>
<tr>
<td>Nose and throat swabs of nurses</td>
<td></td>
</tr>
<tr>
<td>Staphylococci cultured in</td>
<td></td>
</tr>
<tr>
<td>Resistance to penicillin of cultured staphylococci in</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Acute osteomyelitis at this age was quite different from that in older children, and it was rarely diagnosed in the early stages. The infant usually presented with a large swelling of the limb and considerable pus formation. The complete refusal to move the limb was the most pronounced sign. In other respects the infant seemed quite well and did not have a high fever. A marked leucocytosis was the usual finding in contrast to the general experience. The eleven infections of the maxilla were in this neonatal group, and these presented with conjunctivitis and profuse nasal discharge.

Surgical procedures other than aspiration of pus were not needed in these infants and, although the radiographs demonstrated tremendous amounts of bone necrosis and new bone formation, the disease was essentially benign (Fig. 7). Sequestration was seen only in the maxillary infections. Only one infant became severely ill and died.

**TREATMENT**

In 1951, with the emergence of a staphylococcus resistant to penicillin, it became evident that the disease caused extreme illness, a high temperature and severe destruction locally. With this realisation, it was decided, in 1953, to combine surgical drainage of the periosteal abscess and the medulla with antibiotic drugs. It was hoped that this would lower the morbidity of the disease to that which had existed during the era of sensitivity to penicillin.
The infection is not always metaphysial. In Figure 5 the area of destruction and new bone formation indicates a primary mid-shaft infection. In Figure 6 the lower femoral epiphysis has osteomyelitis.

Neonatal osteomyelitis is generally characterised by severe bone damage with complete reconstitution of the bone. Sequestration does not occur in the limb bones.
In adopting this policy we were mindful of the experiences of Crossan (1936) and Wilson and McKeever (1936) in the days before antibiotic drugs, and of Nachlas and Markeim (1948)—who had the use of penicillin—that, in attempting to avoid bone destruction by emergency surgery, they had only produced one tangible result—an increase in mortality (Table III). One of the deaths in this series may have been influenced by immediate surgery. It must be stated unequivocally that surgery has no place in treatment during the acute septicemic phase of the illness. The concept that the local bone lesion and the septicemia advance simultaneously gives practical guidance in management, in which the first aim of treatment must be to increase the host’s defence mechanism.

It has been our policy for the surgeon responsible for the care of the child to examine him on admission. An assessment of the site, severity and outlook is made. The blood is cultured; the haemoglobin, leucocyte count, and erythrocyte sedimentation rate are estimated. Splintage, which is painful to apply, is unnecessary at this early stage, because the limb is immobilised by nature and can be rested on a pillow so that further clinical examination is easy and not disturbing to the child. It is important to establish the sensitivity of the causative staphylococcus quickly; swabs are taken of any septic lesions, and subperiosteal aspiration under local anaesthesia may be performed.

Penicillin and tetracycline are given; one of these is usually stopped after twenty-four hours, when the type of the organism is known. Intravenous fluid is given if there is evidence of dehydration, and blood transfusion, in amounts calculated from the haemoglobin and the size of the child, is most valuable.

The child is re-examined after twelve and twenty-four hours. When clinical improvement in the general state is evident it became our policy in 1953 to operate on all cases. The principle underlying the operation is to decompress the periosteal tube and the medulla at the same time, but carefully avoiding any procedure which may cause further devitalisation of bone.

A tourniquet is not used; haemostasis is established, and the bone approached along a fascial plane. For the femur, in particular, the author advocates the approach from behind the lateral intermuscular septum and not through the quadriceps muscle.

When the periosteum is opened pus gushes out under considerable pressure. One-eighth of an inch drill holes are made in the

### TABLE III

**DEATHS IN VARIOUS SERIES OF ACUTE OSTEOMYELITIS TREATED BY DELAYED AND IMMEDIATE SURGERY**

<table>
<thead>
<tr>
<th>Author</th>
<th>Deaths per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delayed surgery</td>
</tr>
<tr>
<td>Wilson and McKeever (1936)</td>
<td>9.7</td>
</tr>
<tr>
<td>Crossan (1936)</td>
<td>.</td>
</tr>
<tr>
<td>Nachlas and Markeim (1948)</td>
<td>3</td>
</tr>
</tbody>
</table>

FIG. 8 Drilling holes in the cortex of the tibia may have determined the sequestration of this area of bone, and the wisdom of interference with the cortex is questioned.
cortex, a small amount of pus usually exudes from one or two holes but it is not under pressure, and rarely does the medulla fail to bleed. Quite frequently no pus is found inside the bone. These findings have caused a certain amount of reflection on the wisdom of drilling, because bleeding, which cannot be controlled, may result, and, on several occasions, subsequent radiographs have shown ring sequestra around the drill holes (Fig. 8). The cortex, although macroscopically a closed tube, is, in fact, porous and allows ready egress of pus, which being under considerable pressure is unquestionably responsible for the lifting of the periosteum.

Primary skin closure is done in the belief that free drainage is a two-way system, and will allow other organisms to enter. At this stage splintage is instituted but again in the form to allow inspection of the area. In forty-eight hours the wound is examined and aspiration is carried out if there is swelling or rise of temperature. The aim of treatment at this time is to encourage the periosteum to fall back into place on the cortex and to assist in revascularisation of the bone, in a fashion comparable to that observed with a free bone graft. In recent cases continuous suction through a small polythene tube has been employed.

![Fig. 9](image1.png)  ![Fig. 10](image2.png)

Figure 9—Bone drilling did not prevent bone sequestration in this case. Sequestrectomy was required in twenty-five of the eighty-one children who underwent operative decompression. Figure 10—The increased growth of the affected left tibia over the fibula has caused a valgus deformity.

RESULTS AND COMPLICATIONS

Results of operation—In analysing our results of early operation we were forced to the conclusion that not only did we not always avoid extensive sequestration (Fig. 9) but that often the bone lesion was slight and surgery did not alter the outcome.

Operative decompression was done eighty-one times, after which a sequestrectomy was needed on twenty-five occasions. The conclusion can only be that early operation did not accomplish its aim, namely to avoid massive bone destruction. We did not achieve the excellent results which Trueta and Morgan (1954) obtained in 100 consecutive patients treated surgically and with penicillin. The results of our earlier series of seventy-seven patients, however, treated over a comparable span of time, and in the period of penicillin sensitivity of the staphylococcus,
do resemble Trueta and Morgan's results: surgery was infrequent in our patients in Perth before 1950 and one is forced to give the credit for the excellent results to penicillin and not to the operation.

Although early surgery failed in one respect, we believe that decompression has a beneficial influence on the course of osteomyelitis: first, because there is a progressive elevation of the periosteum, and interruption of this process will lessen the amount of cortical necrosis, which is determined by the amount of bone that is deprived of its blood supply. Second, the beneficial influence of draining a tense collection of pus on a sick and distressed child is unquestionable. He is changed immediately into a child who is well, and the relief is obvious both on his face and temperature chart. This is no new principle and is as old as surgery itself. It is reason enough for continuation of early operation in the treatment of acute haematogenous osteomyelitis.

**Severity of the illness**—There are great variations in the severity of acute osteomyelitis which, for practical purposes, may be divided into three grades: mild, moderate and severe. Although the etiology and pathogenesis is the same for all three, the treatment at the two extremes is vastly different. Our present management of this condition requires that the subtle distinction between the three grades be recognised within the first twenty-four hours. Mild cases are treated with rest and an antibiotic drug, to give uniformly good results. Severe cases are treated vigorously to control the septicaemia, and a search is made for visceral lesions. In twenty-four to thirty-six hours—and only after improvement in the general state—operation is undertaken.

The group in between, of moderate severity, is observed, but, if there is not a rapid fall of temperature and relief of pain, even earlier surgery is undertaken so as to reduce bone death. It is in this group, in particular, that decompression will influence the amount of bone necrosis and its sequelae.

**Long-term results**—The results of any series can only be of value when analysed in relation to the three grades of severity. This series has illustrated that, over the years, there are natural fluctuations in the severity of the disease, and that changes in both the "seed" and the "soil" may influence this.

**Sequestra**—A sequestrum was removed only on the indication of a persistent sinus and was done in forty-one children.
Subsequently, all sinuses healed and, although the presence of a sequestrum is a distressing feature for a period, the outcome, with rational management, has not incurred any disability beyond the presence of an unattractive scar. Sequestrectomy should be delayed long enough to allow the formation of a firm involucrum, but not so long as to allow the cloaca to constrict and the new bone to become sclerotic. At the operation of sequestrectomy little or no bone cutting should be required, and then only of fresh vascular new bone.

Unequal growth—It is a normal sequela to find the length of the bone increased, on the average, by half an inch. This matters only in the forearm and lower leg, because the increased growth of one bone over the other results in a curved deformity (Fig. 10). Limb shortening occurs only when the disease has involved the joint and has destroyed the epiphysis. It occurred in one child at the upper humeral epiphysis and in fifteen at the upper femoral epiphysis, which caused a difficult problem in young children.

Deaths—There were two deaths in this series, one in a boy aged six and a half years who had multiple bony infections complicated by pneumonia and endocarditis, and the other in an infant boy of three weeks with an infection of the upper femur complicated by pneumonia and a cerebral abscess. Despite these two deaths out of 328 cases, and despite the increased incidence and severity of osteomyelitis, it is our opinion that the outlook regarding life is excellent.

Joint involvement—Those joints in which infection was proven by aspiration and culture or by subsequent radiological changes are shown in Figure 11. The actual incidence may have been higher than this because of the reluctance to insert a needle into the joint without definite signs of an acute arthritis. Knee joint involvement has a good prognosis and it may well be that the repeated daily aspiration of pus was an influential factor in this.

Hip joint infection—This was the cause of our most distressing results in osteomyelitis because, although life can be saved and bone sequestra removed, destruction of the head of the femur is disastrous and crippling.
Of the fifty-four children with osteomyelitis of the upper femur, the hip joint was involved in twenty-seven, and the head of the femur destroyed in fifteen. It is justifiable for the surgeon to dread this all too common complication when the upper femur is affected by osteomyelitis. Neither repeated aspiration of the hip nor drilling of the upper femur affected the outcome. Recently, however, in eight consecutive children, seven obtained complete recovery of the infected hip following surgical drainage. The joint was exposed through Kocher's posterior approach, and the inferior gemellus carefully retracted from the quadratus femoris to avoid damage to vessels (Fig. 12). A window, one centimetre square, is then cut out of the posteroinferior capsule, through which a small polythene drain is inserted, and retained for three days.

The results in eight patients may not be significant, but suggest that the consequences of hip joint infection may be ameliorated by early operative decompression of the joint when there is severe or progressive limitation of movement.

Hip joint infections fall into four types, according to the severity of the destruction of the capital epiphysis. In Type 1 the epiphysis survives but the joint is subluxated (Fig. 13). This is the usual result in infants. The hip is treated in abduction and neutral rotation, and a moderately well formed and mobile joint may result. In Type 2 destruction of the joint cartilage is associated, in some instances, with the death of a small area of the osseous epiphysis (Fig. 14). Treatment is directed towards regaining the movement in the hip, after immobilisation in a plaster spica to allow revascularisation of the necrotic area. In Type 3 the whole epiphysis sequestrates. This is the commonest result. The hips were immobilised in plaster spicas but
usually the capital epiphysis floated free in a cavity full of pus, and had to be removed. After this, in some children, fair movement and stability resulted, enough to serve the demands of active childhood (Fig. 15). In most, however, there is a progressive stiffening of the joint; after repeated attempts to prevent deformity by splintage, and attempts at establishing rapid fusion by bone grafting, we have allowed free activity, and have left the joint to fuse solidly in the position of flexion and adduction, after which it is corrected by a subtrochanteric wedge osteotomy. In Type 4 there is sequestration of the epiphysis together with part of the diaphysis, and, as in Type 3, it is necessary to remove the large sequestrum (Fig. 16). This is followed by a period of traction on a frame to promote fibrous fixation of the joint, and treatment then follows the same principles as in Type 3.

SUMMARY

1. A series of 328 cases of acute haematogenous osteomyelitis in children is analysed.
2. In the first group of seventy-seven cases from 1944 to 1950 penicillin gave excellent results.
3. After 1950 the disease took on new characteristics in terms of frequency, severity and age incidence, with the appearance of a staphylococcus resistant to penicillin; 251 cases are recorded from 1951 to 1960.
4. The importance of the early assessment of the disease into degrees of severity is emphasised as the surgeon's guide in his form of management.
5. The value of operative decompression is discussed.
6. The frequent and dire consequences of hip joint involvement are analysed and drainage of the hip joint is described.

I would like to express my gratitude to Mr R. D. McKellar Hall, Mr A. L. Dawkins, Mr G. M. Bedbrook and Mr G. M. Nunn who were associated with me in the care of these children, and to Mr R. J. Plummer for the photography.

REFERENCES

ACUTE HAEMATOGENOUS OSTEOMYELITIS

ACUTE HAEMATOGENOUS OSTEOMYELITIS


