CHILDREN’S ORTHOPAEDICS

Distal tibial physeal arrest after meningococcal septicaemia

MANAGEMENT AND OUTCOME IN SEVEN ANKLES

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Survivors of infantile meningococcal septicaemia often develop progressive skeletal deformity as a result of physeal damage, particularly in the lower limb. Distal tibial physeal arrest typically occurs with sparing of the distal fibular physeal leading to a rapidly progressive varus deformity. There have been reports of isolated cases of this deformity, but to our knowledge there have been no papers which specifically describe the development of the deformity and the options for treatment.

Surgery to correct this deformity is complex because of the patient's age, previous scarring and the multiplanar nature of the deformity. The surgical goal is to restore length equality and the mechanical axis at the end of growth. Surgery should be planned and staged throughout growth in order to achieve the best functional results.

We report our experience in six patients (seven ankles) with this deformity, who were managed by corrective osteotomy using a programmable circular fixator.

Patients and Methods

Between March 2005 and June 2007 we treated six patients (seven ankles) with distal tibial physeal arrest by corrective osteotomy using a circular fixator. There were four boys and two girls with a mean age of 9.3 years (4.0 to 14.0). On presentation six ankles had a varus and one a valgus deformity of the distal tibia.

The deformities were measured on anteroposterior (AP) and lateral radiographs. Because of the bilateral involvement in patients with this condition we were unable to compare the affected side with the contralateral limb. We therefore used normal ranges as described by Chao et al.5

In the coronal plane we measured the lateral distal tibial angle with respect to the mechanical axis. We took the normal value to be 89.0º (SD 3.0º). In the sagittal plane we measured the anterior distal tibial angle with respect to the mechanical axis and took the normal value to be 80.0º (SD 2.0º) (Table I). The morphology of the distal tibial physis was also classified according to Shapiro, Simon and Glimcher6 (Table II).

Two patients (cases 1 and 3, Table III) had previously undergone distal tibial osteotomy, plate fixation and distal fibular epiphysiodesis elsewhere. Four of the seven ankles also had scarring after plastic surgery in the acute phase of purpura fulminans (cases 1, 2, 6 and 7; Table III). The mean time between the onset of meningococcal sepsis and definitive treatment was 7.8 years (3.0 to 12.0).

We managed all the deformities using a Taylor Spatial Frame (Smith & Nephew, Memphis, Tennessee).

Operative technique and post-operative regimen. A two-level construct was used in all cases. This was assembled with a complete tibial diaphyseal Taylor Spatial ring and a composite distal tibial Taylor Spatial ring and a composite 5/8 calcaneal Ilizarov ring (Fig. 1). The distal construct crossed the ankle to provide stability to the fixator. This was a working compromise, given that the level of deformity was physeal and a more proximally placed...
Intra-operative arthrography was carried out to define the position and alignment of the talus and its relation to the distal tibia (Fig. 2). Two 1.8 mm Ilizarov wires were inserted into the distal tibial metaphysis parallel to the ankle, with two further parallel wires placed in the calcaneum. These were attached to a full and 5/8 ring, respectively. The proximal construct involved a full ring, secured by three 4.5 mm hydroxyapatite (HA)-coated pins. This was used as the reference point from which corrections were made. It is conventional to use the ring closest to the origin of the deformity which in this case would be the distal Taylor Spatial Frame ring. This gives a shorter distance between the ring and origin which enhances accuracy. Our policy is to use a proximal reference point as a default since this simplifies programming. We have not found any clinically important errors of measurement associated with this strategy.

The tibial osteotomy was performed through an anterior incision using multiple drill holes and completed with an osteotome. The fibular osteotomy was performed through a lateral incision, using an oscillating saw to resect 1 cm of the distal fibula. Once the osteotomy was complete a percutaneous distal fibular epiphysiodesis was performed with multiple passes of a 2.7 mm drill.

No attempt was made to correct the deformity acutely. Lateral and AP radiographs of the tibia, centred on the proximal ring, were used to define the deformity and to plan the correction using the web-based programming software for the Taylor Spatial Frame (Smith and Nephew). Angular and axial correction began on the fifth post-operative day. An individualised programme was given to each patient and their family. The aim was to correct the

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**Table I.** Values of the lateral distal tibial (LDT) and anterior distal tibial (ADT) angles pre- and post-operatively

<table>
<thead>
<tr>
<th>Case</th>
<th>LDT (°)</th>
<th>ADT (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-operative</td>
<td>Post-operative</td>
</tr>
<tr>
<td>1</td>
<td>107.0</td>
<td>89.5</td>
</tr>
<tr>
<td>2</td>
<td>127.2</td>
<td>100.9</td>
</tr>
<tr>
<td>3</td>
<td>107.0</td>
<td>87.0</td>
</tr>
<tr>
<td>4</td>
<td>120.0</td>
<td>89.3</td>
</tr>
<tr>
<td>5</td>
<td>79.0</td>
<td>88.0</td>
</tr>
<tr>
<td>6 (L)</td>
<td>105.9</td>
<td>100.2</td>
</tr>
<tr>
<td>7 (R)</td>
<td>112.0</td>
<td>102.6</td>
</tr>
<tr>
<td>Mean</td>
<td>108.4</td>
<td>93.9</td>
</tr>
</tbody>
</table>

**Table II.** Classification of the morphology of the distal tibial physis according to Shapiro et al.

<table>
<thead>
<tr>
<th>Shapiro type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Normal</td>
<td>The subchondral bone ends laterally well within the epiphyseal mass, but with minimal obliquity</td>
</tr>
<tr>
<td>I Mild abnormality</td>
<td>Considerable obliquity of the distal tibial epiphyseal surface</td>
</tr>
<tr>
<td>II Moderate abnormality</td>
<td>The obliquity of the distal tibial epiphyseal surface is such that the subchondral bone passes into the epiphyseal growth plate itself</td>
</tr>
</tbody>
</table>

**Table III.** Details of the six patients (seven ankles) and their treatment programmes

<table>
<thead>
<tr>
<th>Case</th>
<th>Gender</th>
<th>Age at sepsis</th>
<th>Side affected</th>
<th>Shape of epiphysis (Shapiro classification type)</th>
<th>Age at surgery</th>
<th>Length of corrective programme (days)</th>
<th>Time to removal of TSF* (days)</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>13 m</td>
<td>Left</td>
<td>3</td>
<td>8 y/10 m</td>
<td>57</td>
<td>153</td>
<td>2 y/4 m</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>1 y/3 m</td>
<td>Left</td>
<td>3</td>
<td>9 y/7 m</td>
<td>21</td>
<td>127</td>
<td>1 y/8 m</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>3 y</td>
<td>Left</td>
<td>3</td>
<td>10 y/7 m</td>
<td>63</td>
<td>210</td>
<td>3 y/1 m</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>6 m</td>
<td>Left</td>
<td>3</td>
<td>8 y/3 m</td>
<td>38</td>
<td>98</td>
<td>1 y/7 m</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>2 y</td>
<td>Left</td>
<td>2</td>
<td>14 y/8 m</td>
<td>38</td>
<td>132</td>
<td>4 y/1 m</td>
</tr>
<tr>
<td>6 (L)</td>
<td>F</td>
<td>1 y/1 m</td>
<td>Left</td>
<td>3</td>
<td>4 y/3 m</td>
<td>84</td>
<td>208</td>
<td>1 y/10 m</td>
</tr>
<tr>
<td>7 (R)</td>
<td></td>
<td></td>
<td>Right</td>
<td>3</td>
<td>4 y/3 m</td>
<td>88</td>
<td>201</td>
<td>1 y/10 m</td>
</tr>
</tbody>
</table>

*TSF, Taylor Spatial Frame
deformity gradually, at a rate no greater than 1° of angular correction or 1 mm of translation per day.

Post-operatively, the patients were assessed clinically and radiologically in order to determine the residual deformity, overall correction, gait and satisfaction. Radiological evaluation included standing AP and lateral radiographs of the tibia taken both before and after surgery, to determine the coronal and sagittal alignment and leg-length discrepancy (Tables I and IV). All operations were performed by the senior author (FPM) and the follow-up by the other authors.

### Results

The mean time of correction was 55 days (21 to 88) and the mean time in a circular frame was 161 days (98 to 208). After removal of the frame, all the patients were treated in plaster for two weeks. The mean follow-up was 29.1 months (20.0 to 49.0). At the time of the last follow-up, all but one patient was mobilising independently and six ankles had a pain-free full range of movement.

Restoration of the mechanical axis was achieved in all ankles. The mean residual varus deformity was 4.8° (0.3° to 13.6°). We achieved correction to within 2° of the normal anatomical alignment in four ankles, but three had a residual varus deformity of more than 10° (maximum 13.6°; Table I).

The mean relative pre-operative shortening of the tibia when compared with the fibula was 16 mm (-6 to +26). The correction of leg-length inequality are shown in Table IV. Because of the concomitant injury to other limbs, we were unable to compare measurements with those on the contralateral side.

Figures 3 and 4 show an illustrative case.

### Complications

Three patients had a superficial pin-site infection. Two were treated successfully by a single course of oral antibiotics, but one who had previously undergone a splenectomy, required two separate courses of antibiotics. The decision was taken to remove their construct two weeks earlier than planned (during the consolidation phase) in order to prevent deep infection. One patient had a neuropraxia of the peroneal nerve which resolved completely within two months. Three developed an equinus deformity after removal of the frame, due to underlying muscle ischaemia and skin tethering secondary to scarring.
which required further surgery. One was corrected subsequently by Taylor Spatial Frame alone and the other two by both calcaneal osteotomy and Taylor Spatial Frame.

Discussion
Meningococcal septicaemia has previously been fatal in most patients, but with the recent advances in paediatric intensive care, survival is increasingly common. The combination of onset at a young age and involvement of several physes may cause major limb deformity in survivors.\(^1\)\(^2\)

At the ankle, we have found that the distal tibial physis is usually incompletely damaged leading to partial growth arrest and asymmetrical development. The medial tibial physis was most often involved leading to a varus deformity. It is of interest that one of our patients developed a progressive valgus deformity of the ankle. This was mild in comparison to those with a varus deformity. This patient presented with hindfoot pain after sporting activity, but without the functional problems of gait usually associated with a varus deformity. The valgus deformity occurred secondary to scar tissue over the lateral malleolus and hindfoot which tethered the ankle on the lateral side. The patient was offered many treatment options, including conservative management, but because of limb shortening elected to have the deformity corrected using a circulator fixator and has now resumed full sporting activity.

Surgery to correct this deformity is complex because of the age of these patients, previous scarring and the multiplanar nature of the deformity. It should be planned and staged throughout growth in order to achieve the best functional results. Often there is associated intra-articular damage and realignment is important to prevent further deterioration of the articular surface. The surgical goal is to restore leg-length equality and the mechanical axis at the end of growth. Because of growth arrest at such an early stage in development, the affected limb will often be short, or equal but disproportionate. The challenge is to decide whether to correct the deformity and perform epiphysiodesis at the expense of longitudinal growth, or to allow further longitudinal growth and to address the deformity later. This decision is made on an individual basis and considers the rate of deterioration, the age and therefore remaining growth potential and the pattern of physeal involvement.

In a case of isolated, unilateral ankle involvement, it is rational to perform a distal tibial and fibular epiphysiodesis at the time of correction of the deformity. Limb-length equalisation can be achieved either by concurrent overlengthening or with subsequent contralateral epiphysiodesis. The condition of the soft tissues surrounding the involved ankle will influence the strategy, and epiphysiodesis provides a satisfactory solution with acceptable loss of standing height.

The decision is substantially more difficult in the more severely affected limb with multiple physeal arrest and considerable soft-tissue involvement. If the rate of angular deformity is slow, and ankle correction is part of a strategy that involves several staged surgical procedures, particularly further lengthening, the physis is not ablated since the additional longitudinal growth simplifies subsequent lengthening and further angular correction can be achieved at the time of lengthening. This is a matter of philosophy, not science, and reflects the authors’ opinion that angular correction is more predictable than lengthening in the presence of considerable soft-tissue injury.

In our series four of seven ankles had skin scarring around the deformity. This is in keeping with the findings of Buysse et al,\(^1\) who reported an incidence of long-term skin scarring of 48% after meningococcal sepsis. The importance of the soft-tissue problems in these patients cannot be emphasised strongly enough. Meningococcal septicaemia does not just affect the physis. Muscle ischaemia and scarring as a result of the initial vascular insult can cause soft-tissue tethering. Even after bony correction these soft-tissue tethers result in further deformities which evolve with further growth. In our series three of the seven ankles needed further correction using a circulator fixator because of an
evolving deformity secondary to soft-tissue tethering, despite all the ankles being neutral at the time of removal of the frame.

An acute closing lateral-wedge osteotomy of the distal tibia had previously been performed in two ankles, resulting in further shortening of the tibia and subsequent recurrence of deformity due to ongoing growth of the unaffected fibula. Performing an acute correction of this deformity has a potential risk of compartment syndrome or neuapraxia because of the minimal soft-tissue envelope surrounding the distal tibia. It also does not allow for ‘fine tuning’ of the correction post-operatively.

Excision of a bony bar for partial growth arrest can be effective for small bars, or those affecting only the central area of the plate. However, in our series this would not have provided any benefit since six of the seven ankles had an irregular physis and the growth plate itself was not perpendicular to the long axis of the tibia (Fig. 1). Supramalleolar osteotomy, transphyseal osteotomy, distal tibial wave osteotomy, progressive opening-wedge osteotomy and stapling of the physes, have all been described to correct distal tibial deformity.

Supramalleolar osteotomy is known to cause secondary step-off over the medial cortex because the osteotomy is further away from the apex of the deformity and stapling of the distal unaffected physis is a slow process and often requires additional procedures to correct leg length and rotational deformities.

Our technique allows controlled and progressive correction of the deformity with limited surgical exposure. The ability to control six degrees of freedom (three rotations and three translations) allows continuous correction until the desired position is achieved. In addition to accurate correction of the deformity, another advantage of this technique is the ability to overlengthen in order to accommodate for lost growth and therefore maintain body proportion.

The fixator was left in situ until there was radiological evidence of stable union. This took twice as long as correction of the deformity. Patients were allowed to bear weight on their frame by the third post-operative week. Epiphysiodesis of the remaining growth plate of the tibia was performed at the time of removal of the frame to prevent recurrence of deformity. Physiotherapists were involved early to assist mobilisation of the knee and quadriceps strengthening and all patients received orthotic support.

Patients and families were seen at length by the frame team (surgeon, frame nurse specialist, physiotherapist) before surgery and consequently the frames were generally well tolerated by the children. Each received a print-out of their correction programme and strut adjustments were easily carried out by either child or parent.

In conclusion, varus deformity of the ankle secondary to meningococcal septicaemia is a very difficult problem to treat using conventional methods because of the position of osteotomy, progressive deformity, skin scarring and multiple joints/limb involvement. We feel that the Taylor Spatial Frame facilities progressive correction of multiplanar deformities, including lengthening, and is well tolerated by children. Despite this, it is important to state that managing this deformity in this group of patients is complex. Patients are required to be reviewed on many occasions both pre- and post-operatively and should be followed until skeletal maturity, since the deformity can recur and may need further realignment/lengthening procedures. Surgery should be undertaken only after precise planning, ideally by a multi-disciplinary team familiar with correction of limb deformity.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References