Physeal bar resection for partial growth plate arrest

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Abstract
The results of 21 physeal bar resections for growth plate arrest performed over a 17-year period (1987-2003) were assessed retrospectively.

Five (24%) of the growth plates failed to resume growth. The remaining 16 were followed up for 2 to 8 years (11 to maturity). Eight (38%) growth plates (six to maturity) had an excellent result and growth exceeded the expected normal. Eight (38%) growth plates (five to maturity) had a good result and resumed normal growth.

All five failures occurred in patients with the commonest aetiologies, i.e. distal femoral physeal fractures (three of five) and meningococcal septicaemia (two of five).

We concluded that physeal bar resection was a worthwhile procedure if the size of the bar was ≤ 30%. In growth plate arrest due to distal femoral physeal fractures and meningococcal septicaemia, the prognosis, however, is guarded.

Introduction
Injury to a growth plate can result in physeal arrest. This occurs due to trauma, most commonly a growth plate fracture, or due to decreased blood supply to the germinal cells, e.g., due to vasculitis in meningococcal septicaemia. Langenskiöld1,2 first described the principles of growth plate arrest and resection. He showed that following growth plate injury, the formation of a bony bar between the epiphysis and the metaphysis can be prevented by interposition material. Once a bony bar exists, it can be excised and interposition material allows regeneration of the growth plate from the adjacent physis.

Initial reports of growth plate resection showed good results. Langenskiöld3 used fat as interposition material and had 83% good results in 43 patients. Bright4 using silicone-rubber as interposition material reported 81% good results in 100 patients. Peterson5 used mainly methyl methacrylate (cranioplast) and reported 83% good results in 114 patients. He also showed correction of angular deformity if ≤ 20°.

This initial enthusiasm has been tempered by subsequent reports. Williamson and Staheli6 report poor results if the physeal bar exceeded 30% of the growth plate. Birch7 reported only a 33% success rate and Hasler and Foster8 a 40% success rate. An earlier edition of a standard paediatric orthopaedic textbook9 had a full chapter on partial growth plate arrest. In the most recent edition9 it is limited to only three pages in the chapter on growth plate fractures.
Unpredictable results for physeal bar resection following distal femoral physeal fractures makes completion of the epiphysiodesis and contralateral epiphysiodesis a better option in adolescent patients.

To assess whether physeal bar resection is a worthwhile procedure and still has a role in paediatric orthopaedic practice, we retrospectively reviewed 21 growth plate resections in 19 patients performed in the 17-year period (1987-2003).

**Patients and methods**

Two of the 19 patients had bilateral sites (dysplasia and meningococcal septicaemia). The average age was 8.3 years (range 3 to 12 years).

**Aetiology and sites**

Table I shows the aetiology, site and size of the 21 physeal bars and the results of the physeal bar excisions. The most common cause was growth plate fractures (eight), of which five were at the distal femur.

<table>
<thead>
<tr>
<th>Aetiology</th>
<th>N = 21</th>
<th>Site</th>
<th>Salter Harris type</th>
<th>Size</th>
<th>Follow-up (m = maturity)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth plate fracture</td>
<td>8</td>
<td>Distal femur = 5</td>
<td>I</td>
<td>20%</td>
<td>2 yrs</td>
<td>Excellent</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>II</td>
<td>30%</td>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>II</td>
<td>30%</td>
<td>m</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>III</td>
<td>30%</td>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IV</td>
<td>50%</td>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Proximal tibia = 1</td>
<td>15%</td>
<td>2 yrs</td>
<td>Excellent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Distal tibia = 2</td>
<td>30%</td>
<td>m</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>m</td>
<td>Excellent</td>
</tr>
<tr>
<td>Meningococcal septicaemia</td>
<td>5</td>
<td>Distal femur = 1</td>
<td>40%</td>
<td></td>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proximal tibia = 3</td>
<td>40%</td>
<td></td>
<td></td>
<td>Poor</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>30%</td>
<td>3 yrs</td>
<td>Good</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>3 yrs</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Distal tibia = 1</td>
<td>20%</td>
<td>m</td>
<td>Excellent</td>
</tr>
<tr>
<td>Osteitis</td>
<td>3</td>
<td>Distal femur = 2 (neonatal)</td>
<td>15%</td>
<td>m</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distal tibia = 1</td>
<td>30%</td>
<td>m</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>m</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>Dysplasia</td>
<td>3</td>
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<td>25%</td>
<td>m</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proximal tibia = 1 (Blount’s)</td>
<td>25%</td>
<td>m</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Gunshot</td>
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<td>Distal femur</td>
<td>20%</td>
<td>m</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>Idiopathic</td>
<td>1</td>
<td>Distal femur</td>
<td>20%</td>
<td>4 yrs</td>
<td>Excellent</td>
<td></td>
</tr>
</tbody>
</table>

The second commonest cause (five) was growth plate arrest due to meningococcal septicaemia. The commonest site was the distal femur (12), followed by the proximal tibia (five) and the distal tibia (four).

**Evaluation of the physeal bar**

The physeal bar was evaluated for location and size, initially by biplanar tomography (8), subsequently biplanar tomography and MRI (8) and currently our preference is just MRI (5). Antero-posterior and lateral tomography and/or MRI was done and then synthesised onto a cross-sectional diagrammatic representation or map of the growth plate as described by Carlson and Wenger (1984) (Figure 1).

MRI was performed with a 1.5 Tesla magnet (Siemens, Symphony). The sequences done were T1 (TR 512, TE 13) and Gradient Rephased Echo (GRE) (TR 905, TE 26) in coronal and sagittal planes, perpendicular to the growth plate. The slice thickness used was 3 mm and field of view 200 mm.
The T1 sequence shows the physis (cartilage) as low signal intensity against the high signal intensity marrow (Figures 4-7,9) and the GRE shows the physis as high signal intensity against the low signal intensity marrow and even lower signal intensity bone (Figure 10).

The average size of the physeal bars was 25% (range 15% to 50%). Only three physeal bars exceeded 30% in size.

The majority of the physeal bars were peripheral (15), one was central (meningococcal septicaemia) and five linear (two neonatal osteitis, two Salter Harris type IV growth plate fractures and one idiopathic) (Figure 2).
Technique

The normal physis was defined at the periphery of the bar, and the bar was then removed using a burr and/or gouge until normal physis was visible circumferentially. In the first five cases we used fat as interposition material, but subsequently we used cranioplast as it is more haemostatic and strengthens the defect.

The defect and interposition material was contoured as a collar button into the epiphysis (Figure 3). Parallel Kirschner wires were then inserted as metal markers into the epiphysis and metaphysis in order to measure growth (Figures 4-8).

Follow-up

Five (24%) physeal bar excisions failed to resume growth. They subsequently had completion of the epiphysiodesis. In the contralateral leg an epiphysiodesis or leg lengthening was done, depending on the age of the child.

The remaining 16 physeal bar excisions were followed up from 2 to 8 years, 11 to maturity. At follow-up the leg lengths were assessed clinically with a tape measure and on blocks. An anteroposterior and lateral radiograph of the femur or tibia with a similar distance (100 cm) between the plate and the tube as on the immediate postoperative view was done. The increase in distance between the metal markers and the correction of the angular deformity was measured. A good result implied normal growth, i.e. 10 mm per year for the distal femur, 6 mm for the proximal tibia and 4 mm for the distal tibia. In an excellent result the growth achieved exceeded the expected growth.

Completion of the epiphysiodesis and contralateral epiphysiodesis a better option in adolescent patients
Results

There were eight (38%) excellent results (six followed up to maturity) (Figures 4-8), and eight (38%) good results (five followed up to maturity). Of the 11 patients followed to maturity there was no leg length discrepancy that exceeded 1 cm.

The five growth plate excisions that did not resume growth failed from the start. Up to now there have been no premature arrests. These five failures occurred in the most commonly seen aetiologies. Three of the five failed due to distal femoral growth plate fractures; two were 30% and one was 50% in size. Two of the five failed due to meningococcal septicaemia; both were 40% in size.

Only five physeal bar excisions could be assessed for correction of angular deformities. This excluded two linear bars which were situated in the middle of the joint and had no angular deformity, the five failures, six of whom had concomitant osteotomies and three with too short a follow-up of only 2 to 3 years.

Figure 6a: Anteroposterior radiograph of a 3-year-old girl with an idiopathic physeal bar of the right distal femoral growth plate
Figure 6b: T1 coronal MRI shows sclerotic linear bar
Figure 6c: Immediate postoperative view
Figure 6d: At 4 year follow-up, growth of 60 mm was achieved (150% of expected)

Figure 7a: T1 coronal MRI of a 5-year-old boy with a peripheral bar of the left lateral distal femoral growth plate following a gunshot
Figure 7b: Immediate postoperative view showing a 20º valgus deformity
Figure 7c: At 6-year follow-up, growth of 70 mm was achieved (116% of expected), but angulation was uncorrected

Figure 8a: Postoperative anteroposterior radiograph of a 10-year-old boy with a peripheral bar of the left distal tibial growth plate following osteitis, showing a 20º varus deformity
Figure 8b: At maturity, growth of 37 mm over 6 years (150% of expected) and angular correction of 20º was achieved

Angular correction was not predictable
The remaining five physeal bar excisions corrected angular deformities of 0°-20° over a period of 4 to 6 years. Angular correction was therefore not predictable, although Figure 8 shows a correction of 20° over 6 years.

Discussion
This study shows 76% good and excellent results, which increases to 89% if physeal bars larger than 30% are excluded. We therefore do not share the current pessimism towards physeal bar resection for partial growth plate arrest.9,11 We feel that resection of a physeal bar ≤ 30% in the young child with more than 5 years of growth remaining, is a worthwhile procedure and warrants a place in paediatric orthopaedics.

The five failures occurred in the commonest aetiologies, i.e. distal femoral growth plate fractures and meningococcal septicaemia.
Distal femoral growth plate fractures are notorious for physeal arrest because of the undulating nature of the growth plate which results in damage at the time of injury.12,13 The high incidence of failure following physeal bar resection in these patients is most likely due to secondary tethers which are present at an area separate from the physeal bar.8,14 This small secondary tether may not always be visible on plain radiographs, but can be seen on MRI (Figure 9).

We agree that in the adolescent patient with physeal arrest due to distal femoral growth plate fractures, completion of the arrest with epiphysiodesis is a more predictable option. Since 1998 we have applied this policy in five patients with concomitant epiphysiodesis of the contralateral leg.

In meningococcal septicaemia, which occurs in much younger patients, the growth plate is damaged by ischaemia (vasculitis and disseminated intravascular coagulation) and the inflammatory response (osteoitis) of the surrounding bone.15 Damage to the growth plate may manifest as partial growth plate arrest (Figure 5), or premature physeal closure (probably due to relative avascularity of the physis).
The high failure rate in physeal bar resection in meningooccal septicaemia is most likely due to two factors: secondary tethers, similar to distal femoral growth plate fractures, which may not always be clearly visible on plain radiographs, but may be seen on MRI (Figure 10), or unpredictable premature physeal closure.

Three of the failures had physeal bars > 30%. This may have been a contributing factor, but Peterson (1990) reported good results in bars constituting up to 50% of the growth plate. Since Williamson and Staheli (1990) reported poor results in bars > 30%, we do not attempt to excise bars > 30%.

We found good correlation between the size and location of the bar at surgery and the map drawn pre-operatively from biplanar tomography and MRI. We currently prefer MRI. MRI has no radiation and elegantly demonstrates excellent tissue contrast as well as allowing multi-planar imaging without changing the position of the patient. Any interruption of the physeal plate by a bony or cartilaginous bar or any interruption measuring just a few millimetres affecting the viability of the physeal plate can be well seen on MRI. We have no experience with 3-D MRI reconstruction and helical CT.

At surgery it is important to ensure that normal physeal plate is visible circumferentially and that there are no residual tethers. We attempted to contour the defect as a collar button into the epiphysis in all our patients (Figure 3). In all the patients however, except the patient shown in Figure 6, the defect stayed in the metaphysis. This did not influence the result.

Only five physeal bar resections could be assessed for angular correction. Angular correction was not as predictable as reported by Peterson (1990) and ranged from 0-20° over 4 to 6 years. Our current policy is to do a concomitant ostectomy if the angulation exceeds 20°. If the angulation is ≤ 20° we will await possible correction and perform an ostectomy at maturity if required. Growth plate fractures are followed up at 3 and 6 months post injury, to try and diagnose growth disturbance early before deformity occurs. A growth arrest or Harris line that is oblique (not parallel to the physis) or has a focal tethers suggests early physeal arrest. The physeal bar can then be confirmed with MRI.

We conclude that physeal bar resection for partial growth plate arrest in the younger patient is a worthwhile procedure if the bar does not exceed 30% of the size of the physis. In physeal bars due to distal femoral growth plate fractures and meningooccal septicaemia, the prognosis is guarded.

References