Case 2706

Salter-Harris classification of epiphyseal fractures
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Clinical History:

Epiphyseal fractures classification

Imaging Findings:

Approximately 10% of long bone injuries in patients under the age of 16 years involve the epiphyseal growth plate (physis). This is important as injuries to the growth plate may result in shortening or deformity of the growing bone.

Anatomy[1]:
Epiphyses consist of the epiphyseal bone plate with the articular surface and the epiphyseal growth plate. Growth of long bones is achieved by division of chondrocytes within the germinal layer of the growth plate, which proliferate towards the metaphyseal side. The cartilaginous matrix hypertrophies, degenerates and mineralises in the zone of transformation after which vascular penetration and osteogenesis begins and this eventually becomes the bony metaphysis. Classification of epiphyseal fractures is based on the degree of involvement of the germinal matrix and allows categorisation according to the radiographic appearances as well as the prognosis. The most commonly used classification is the Salter-Harris classification [2], others have been described (e.g. Aitken classification [3] used in Germany) but are not internationally recognised.

Diagnosis:
Epiphyseal plate injury should be suspected in any child with injuries to joints, be it fracture, dislocation, ligamentous rupture or even simple sprains. Factors affecting the prognosis of epiphyseal plate injuries include the mechanism of this, the age of the child at the time of injury, the blood supply to the epiphysis, the method of reduction and the extent of soft tissue injury (e.g. compound fracture). Significant disturbance of growth occurs in approximately 10% of epiphyseal plate injuries. Minor disturbances, which are not clinically relevant, occur more frequently.

Good quality radiographs are crucial. A minimum of two views obtained at right angles to each other is essential. If doubt exists comparison views of the other limb may be useful. The diagnosis of separation of an epiphysis before its ossification centre has appeared is very difficult, but this may be suspected if there is mal-alignment of the metaphysis and significant soft tissue swelling.

Discussion:

Salter-Harris Type I (Fig. 2)
This amounts to approximately 6% of epiphyseal plate injuries. Type I injuries occur usually below the age of 5 years and may be seen in the context of birth trauma. The epiphysis is completely separated from the metaphysis. This is a result of shearing or avulsion force causing a transverse fracture of the zone of transformation. The germinal matrix is preserved in its entirety on the epiphyseal side. The periosteum is intact and the fracture may reduce immediately and therefore be difficult to spot. If reduction is required, this is usually not difficult due to the continuity of the periost. The prognosis for future growth is excellent unless the epiphysis involved is entirely covered by cartilage (e.g. upper femoral epiphysis). Type I injuries may also be seen in the context of scurvy, rickets, osteomalacia and other endocrine abnormalities.

Salter-Harris Type II (Fig. 3)
This is by far the commonest form of epiphyseal plate injury, amounting to approximately 75%. Peak incidence is at
an age between 10 and 16 years. The fracture line runs across the zone of transformation and extends into the metaphysis removing a triangular metaphyseal fragment (Thurston-Holland’s sign). This is also usually due to shearing or avulsion; however, the periosteum in this case is torn on the convex side of the angulation. Reduction is easy due to the intact ‘periosteal hinge’. The physis itself is again intact remaining attached to the epiphysis with the metaphyseal fragment. Prognosis for growth is therefore excellent assuming that the blood supply remains intact.

**Salter-Harris Type III (Fig. 4)**
Approximately 8% of epiphyseal plate injuries are type III. Peak incidence is between 10 – 15 years. This is an intra-articular fracture running from the joint surface through the germinal matrix and then extending along the metaphyseal side of the growth plate to the periphery of the bone. The periosteum remains intact, however as the fracture traverses the growth plate accurate reduction is essential and open reduction may be required. If good alignment of the fragments is achieved prognosis regarding growth is reasonably good; bearing in mind that the fracture also involves an articular surface. The commonest sites are the distal tibia, proximal tibia and distal femur.

**Salter-Harris Type IV (Fig. 5)**
These are approximately 10% of all epiphyseal plate injuries. An oblique intra-articular fracture extends from the joint surface through the epiphysis across the full thickness of the epiphyseal plate into the metaphysis. Accurate reduction is vital to try to preserve normal growth, as well as reconstructing a smooth joint surface. Open reduction and internal fixation is frequently required. There is a relatively high risk of bony re-union occurring across the growth plate, which will prevent normal symmetrical growth in the future. Type IV injuries are most commonly seen at the lateral condyle of the humerus.

**Salter-Harris Type V (Fig. 6)**
Approximately 1% of epiphyseal plate injuries are type V. Fortunately, this is the rarest of injuries to the growth plate, as it is difficult to diagnose and to treat. It is a consequence of compression trauma to the growth plate resulting in crushing of the germinal matrix and its vascular supply. It usually occurs in joints with a uniplanar range of movement (i.e. knee) submitted to forced ab- or adduction, which squashes the epiphyseal plate. Direct axial trauma may also result in this type of injury. There is no fracture as such and no direct radiographic signs to alert to this type of injury. It is commonest in adolescence and frequently dismissed as sprain. The prognosis of type V injuries is decidedly poor and premature cessation of growth is almost inevitable. There is no specific treatment.

For further reading the excellent chapter in Resnick’s ‘Diagnosis of Bone and Joint Disorders’ is recommended.

**Differential Diagnosis List:** Epiphyseal fracture classification

**Final Diagnosis:** Epiphyseal fracture classification

**References:**


**Normal**

*Description:* Red arrow: Germinal layer of the growth plate. Black arrow: Zone of transformation. The periost is outlined in yellow. *Origin:*
**Description:** There is a transverse fracture through the zone of transformation. The complete epiphysis including the growth plate has been avulsed. The germinal layer remains intact, the periost is not disrupted. **Origin:**
Description: Inversion injury of ankle. The AP view shows soft tissue swelling over the lateral malleolus (arrowheads) and widening of the physis of the distal fibula (arrow). Full recovery with conservative management (plaster). Origin:
Description: The lateral view adds no extra information. Origin:
Description: The fracture extends from the zone of transformation into the metaphysis, removing a triangular fragment. The periost is torn on the convex side (arrow). Origin:
**Description:** Colles type injury after fall on outstretched hand. AP view shows a tilted radial epiphysis with a metaphyseal fragment (arrow). **Origin:**
**Description:** Oblique view: The mal-alignment and the extent of the metaphyseal fragment (arrows) are better appreciated. **Origin:**
Description: Lateral view: There is dorsal angulation and wide separation of the epiphysis (white arrowheads) from the metaphysis (black arrowheads). The mal-alignment between distal radius and ulna also implies disruption of the radio-ulnar joint. Origin:
Description: An intra-articular fracture extends across the growth plate and then along the line of transformation. This results in separation of an epiphyseal fragment. Origin:
Description: Type 3 fracture of the distal tibia. The lateral aspect of the growth plate is widened. This appearance may be mimicked by a cleft epiphysis, however there is a clear break in the articular surface (arrow). Origin:
Description: The lateral view again adds no additional information, emphasising the need for at least two views in orthogonal planes. Origin:
Description: There is an oblique fracture extending from the articular surface across the growth plate into the metaphysis. This injury is at risk of bony fusion across the growth plate, which will impair further growth. Origin:
Description: Type 4 injury of the proximal phalanx. Growth has almost been completed and the focus of treatment needs to be on reconstruction of the articular surface. Origin:
Description: Type 4 injury of the medial malleolus. In this large weight-bearing joint reconstruction of a smooth articular surface is particularly important to prevent premature osteoarthrosis. Origin:
**Description:** Type 5 injuries - either forced angulation or axial compression - result in compression of the germinal layer and its blood supply. X-rays in the acute stage usually show no abnormality. **Origin:**
Figure 7

Description: Comparison view of contra-lateral side. Origin:
**Description:** Previous type 4 injury in a young child. A bony bridge has developed across the medial aspect of the tibial epiphysis resulting in markedly asymmetric growth. **Origin:**