Physeal injuries in children

Arijit Mallick

Hari Prem

Abstract

Fractures involving the physis account for up to one-third of paediatric fractures. It is also the structure which needs to be preserved to ensure normal growth. The relative strength of the physis changes with age and it becomes weaker as the child grows older, making physeal injuries more common in adolescence. It is important to understand the physeal anatomy and its relevance to different types of physeal injuries. Salter–Harris system is a clinically useful approach to classifying and describing physeal injuries. Each physeal injury should be treated as a distinct entity taking into account the patient's age, location of injury, type of injury, growth potential of the affected part, degree of displacement and time elapsed since injury. Its treatment ranges from conservative management to operative fixation. Manipulation of physeal fractures should be as gentle as possible to prevent growth plate damage leading to growth disturbances. These complications can be difficult and complex to manage. The management involves two phases: the first phase should ensure reduction, maintenance of reduction, and bone healing; the second phase involves monitoring the growth with long-term follow-up, to detect any deformities from growth arrests or disturbances. Counselling parents about the potential risk of future growth arrest and deformity is important.

Keywords Bony bars; growth arrest; paediatric fracture; physis; Salter–Harris

Introduction

The weakest area in a child's bone is the physis or the growth plate. It is also a structure which needs to be preserved to ensure normal growth after the injury. As long as the epiphysis remains more cartilaginous, it acts as a shock absorber and forces are transmitted to metaphysis. Hence there is a higher chance of torus fracture (buckle fracture) in younger children.[1]

The relative strength of the physis changes with age and it becomes weaker as the child grows older, making physeal injuries more common in adolescence.

Relevant anatomy

At around 6 weeks of gestation the long bones are formed from mesenchymal anlage. Then at around 8 weeks of gestation primary ossification centres form in the middle of the bone. This primary ossification centre expands towards the proximal and distal ends of the bone. The peripheral extensions of the primary ossification centre at either ends of the bone gives rise to the growth plate or the physis, a cartilaginous disc separating the epiphysis from the metaphysis. The physis is responsible for the longitudinal growth of long bones. When skeletal maturity is reached, physes are resorbed and replaced by bone.

Physeal structure (Figure 1)

Histologically, a physis is formed with chondrocytes surrounded by extracellular matrix. Chondrocytes are arranged in a columnar fashion along the longitudinal axis of the long bone and grow towards the metaphysis where the endochondral ossification occurs.

A physis is divided from distal to proximal into zones according to the rate of growth, numbers and distribution of chondrocytes. It is important to understand these zones in order to understand various types of physeal injuries.

These are the:

- reserve zone (also known as germinal zone or resting zone)
- proliferative zone
- hypertrophic zone
- zone of endochondral ossification

The hypertrophic zone is further subdivided into:

- zone of maturation
- zone of degeneration
- zone of provisional calcification

There are two important structures on the periphery of the physis[2] (Figures 1 and 2), which are the:

- groove of Ranvier: a circumferential notch described by Ranvier which provides chondrocytes to the periphery for *lateral growth*
- perichondrial ring of LaCroix: a dense fibrous tissue, where the periosteum of the bone is attached to the perichondrium of epiphysis and gives mechanical support to the bone-physis interface.[1]

Blood supply to the physis (Figure 2)

It is important to know the vascular distribution in the various zones to understand it's contribution to the prognosis in physeal injuries.[3,4] Blood supply to the physis comes from three sources:[3]

- epiphyseal circulation
- metaphyseal circulation
- perichondrial circulation.

Epiphyseal circulation: small branches come out from the main epiphyseal artery, enter the epiphysis and pass through small cartilage canals into the reserve zone. None of the branches from the epiphyseal arteries penetrates beyond the proliferative zone to supply the hypertrophic zone.

Dale and Harris[4] mentioned two types of epiphyseal circulation (Figure 2):

- *Type A:* The epiphysis is almost completely covered with articular cartilage and is dependent on blood supply through the perichondrium, making it vulnerable to ischaemia after physeal separation. Examples include the proximal humerus and proximal femur (Figure 2, bottom right).
- *Type B:* The epiphysis is only partly covered with articular cartilage and has blood supply which enters it directly.

Arijit Mallick *FRCS (T&O) is a Senior Foot and Ankle Fellow at the Royal Orthopaedic Hospital, Birmingham, UK. Conflicts of interest: none declared.*

Hari Prem *FRCS (T&O) is a Consultant Foot and Ankle Surgeon at the Royal Orthopaedic Hospital, Birmingham, UK. Conflicts of interest: none declared.*

Please cite this article in press as: Mallick A, Prem H, Physeal injuries in children, Surgery (2016), http://dx.doi.org/10.1016/j.mpsur.2016.10.008

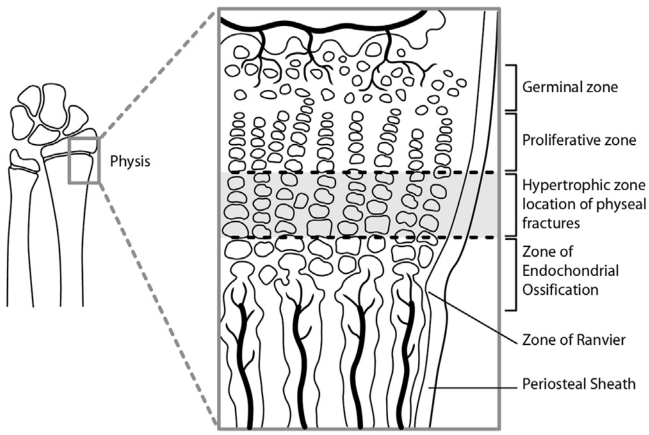

Figure 1 Structure of the physis.

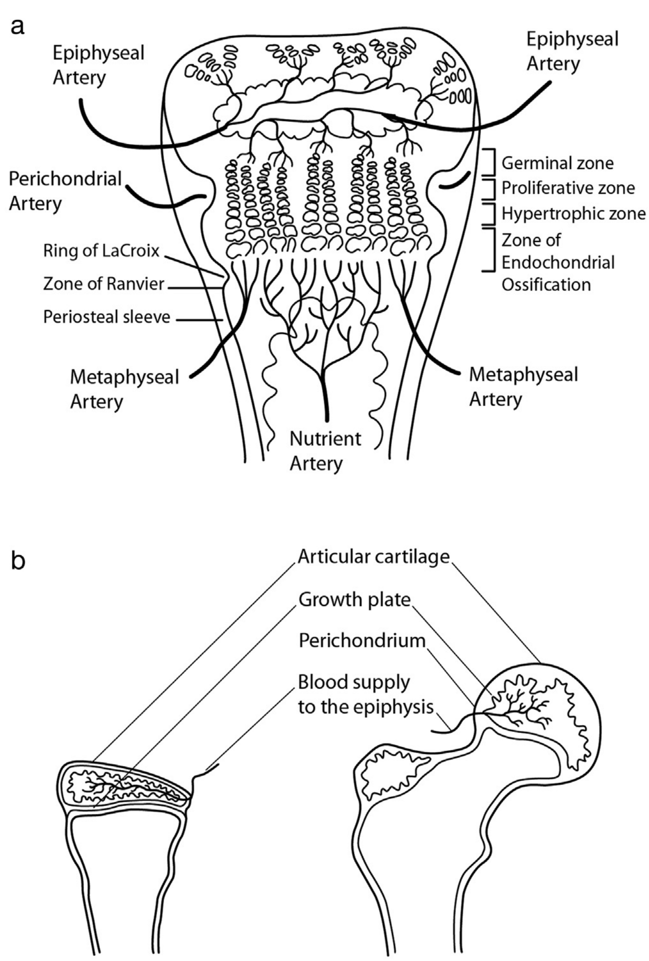

Figure 2 Blood supply of the physis. (a) The three sources of blood supply to physis: epiphyseal, metaphyseal and perichondrial. (b) Two types of epiphyseal blood supply as described by Dale and Harris.

These are at lesser risk of ischaemia following injury. Examples include the distal radius, proximal tibia (Figure 2, Bottom left), distal tibia and distal femur.

Metaphyseal circulation: the metaphysis is richly supplied with blood from the terminal branches of the nutrient artery. These arteries pass vertically towards the bone—cartilage junction of the physis. However, no vessels pass from the metaphysis into the hypertrophic zone.

Perichondrial circulation: the groove of Ranvier and the perichondrial ring of LaCroix, are richly supplied with blood from perichondrial arteries.

Significance of vascularity and zone of physeal injuries[5]

The strength of the physis is related to the morphology of the cells and to the intercellular matrix.

Owing to good vascularity, there is an abundance of extracellular matrix in the reserve and proliferative zones helping them resist shear forces better. On the other hand, extracellular matrix formation is significantly less in the hypertrophic zone due to its avascularity, and it has reduced capacity to withstand shear, bending and tension forces. Hence more physeal injuries occur through the hypertrophic zone. Beyond that, the zone of endochondral ossification is reinforced by calcification and hence is stronger.[4,5]

Incidence of physeal injuries[6–9]

Physeal fractures account for up to 30% of all paediatric fractures. Boys are affected twice as often as girls, probably because their physes remain open longer and they are exposed to more traumas due to athletic activities.[1,6–9] The peak incidence is around 14 years in boys and 11 years in girls. The upper limb is most likely to be affected, with the distal radius being the most common site of fractures in children and ankle the second most common site.[6–9]

Classification

Various radiograph-based classification systems have been described, of which the Salter—Harris system is most widely used.

Salter—Harris (SH) system[10] (Figure 3)

This classification is based on five fracture patterns. It helps guide the treatment as well as the prognosis. There is progressively more chance of growth arrest as you move up through the classification. This classification system also has a good reproducibility.

Types I—V was described by Robert Salter and Robert Harris in 1963:[10]

- Type I: transverse fracture through the physis
- Type II: fracture through the physis and the metaphysis, sparing the epiphysis
- Type III: fracture through physis and epiphysis, sparing the metaphysis
- Type IV: fracture through the physis, metaphysis, and epiphysis
- Type V: compression fracture of the growth plate (resulting in a decrease in the perceived space between the epiphysis and metaphysis on X-ray)

Please cite this article in press as: Mallick A, Prem H, Physeal injuries in children, Surgery (2016), http://dx.doi.org/10.1016/j.mpsur.2016.10.008