Physeal injuries in children

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Abstract

The paediatric skeleton differs from that of an adult in that the bones are more elastic and they contain growth plates (physes). Physeal injuries affect the growth plates of children and adolescents. A basic understanding of the anatomy and physiology of the physis is mandatory in order that injuries to the growth plate can be managed effectively. Salter and Harris described a classification for physeal injuries based on radiographic findings. The system predicts the prognosis for any given injury and guides treatment choice. The goal of treatment is to achieve and maintain an acceptable reduction of the fracture without compromising the germinal layer of the growth plate. A comprehensive understanding of remodelling potential related to patient age and site of injury is essential and influences treatment. Occasionally, malunion and growth arrest can occur. The management of these complications ranges from simple observation to complex deformity correction. The clinician should know how to avoid such complications but also know how to recognize them should they occur.

Keywords Complications; physeal injuries; Salter–Harris classification; treatment

Introduction

Physeal injuries affect the growth plates of children and adolescents. They commonly occur near the major joints of the limbs (knee, ankle, elbow and wrist) but any physis can be involved. Physeal injuries represent 18% of all fractures in children in the UK.[1] The incidence varies with age and injuries are more common in the adolescent age group. Although complications arising from physeal injury are rare, they are often predictable and preventable.

A child's long bone consists of two epiphyses, two physes (or growth plates), two metaphyses and a diaphysis. The periosteum is the envelope around the bone: it has distinct mechanical and biologic functions. It is very thick in the young child and contributes to the growth in width of the bone. The physis is responsible for longitudinal growth. With the completion of growth at skeletal maturity, the physis disappears and the periosteum becomes a thin fibrous layer. A basic understanding of the anatomy and physiology of the physis is mandatory to manage injuries to the growth plate effectively.

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Physeal anatomy (Figure 1)

The growth plate consists of chondrocytes surrounded by an extracellular matrix: it is intimately connected to the epiphysis which provides its blood supply. The chondrocytes are organized in columns along the longitudinal axis of the bones directed towards the metaphysis where endochondral ossification occurs.

Physeal histology

The physis is divided into four zones: the germinal zone, the proliferative zone, the hypertrophic zone, and the zone of endochondral ossification. The first two zones have an abundant extracellular matrix and can resist shearing forces easily. The hypertrophic zone contains negligible extracellular matrix and is, therefore, weaker. In the last layers of the hypertrophic zone, the chondrocytes are destroyed and a zone of provisional calcification leads into the zone of endochondral ossification. The calcification of the extracellular matrix provides this area with additional resistance to shear stress. Thus, the hypertrophic zone just above the provisional calcification layer is the weakest area of the physis, and it is here that most injuries to the physis occur.

Vascularization

Damage to the growth plate is determined more by the insult to its blood supply than by mechanical stress. The growth plate has three vascular supplies. The main one comes from the epiphyseal side and vascularizes the germinal and the proliferative zones. However, in sites such as the proximal femur and the proximal radius where the epiphysis is essentially entirely covered by articular cartilage the blood supply comes along the metaphysis before entering into the epiphysis. Consequently, the blood supply is vulnerable to damage if the epiphysis is separated from the metaphysis. In such cases, there is a risk of avascular necrosis (AVN) with physeal injury. The second group of vessels come from the medullary canal of the diaphysis to supply the metaphyseal side of the physis. The vessels reach the ossified layer of chondrocytes and play a major role in the process of endochondral ossification. The third blood supply comes from the perichondral ring of LaCroix to vascularize the marginal zone of the physis. The hypertrophic zone, where most injuries occur, remains avascular.[2] Bone growth ends when the physis disappears at which stage the blood supplies all communicate with each other.

The zone of Ranvier and the perichondral ring of LaCroix

The growth plate is connected to the epiphysis and metaphysis by the zone of Ranvier and the perichondral ring of LaCroix. The zone of Ranvier is a wedge-shaped zone at the periphery of the physis. It contains an active group of germinal cells and contributes to the circumferential growth of the physis.[3] The perichondral ring of LaCroix encircles the zone of Ranvier: it is a fibrous continuation of the periosteum. It provides strong mechanical support for the bone–cartilage junction at the growth

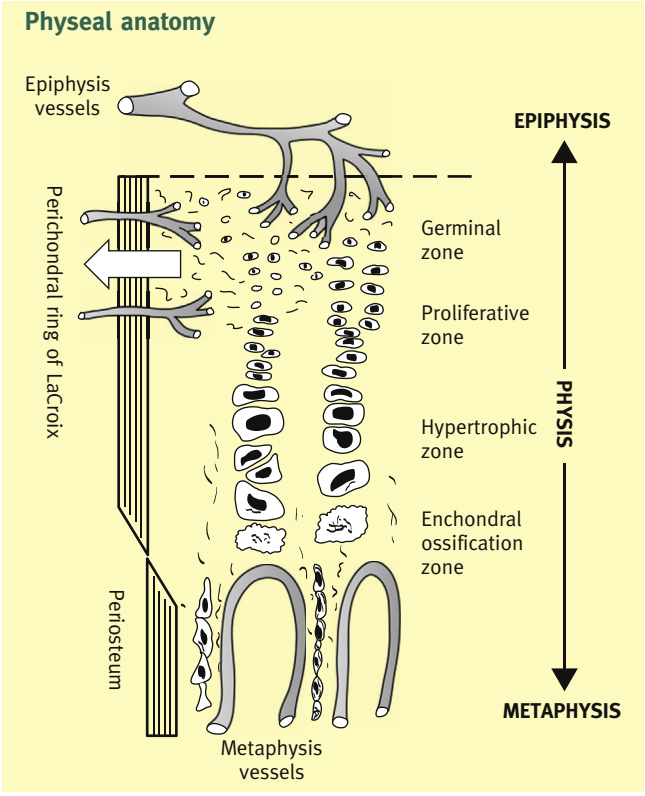

Figure 1

plate. The blood supply comes from peripheral vessels and damage to these must be avoided during open surgery.

Growth factors

The human growth plate contains chondro-progenitor cells (CPCs). It has been shown that these cells can be isolated from the growth plate and expanded in vitro.[4] During the first phase of injury response at the growth plate these cells differentiate towards hypertrophy. As longitudinal growth is obtained by chondrocyte proliferation and volume increase during hypertrophy this maturation might be the first step towards post-traumatic growth disorders such as unwanted premature ossification of the growth plate.

Salter–Harris classification

Physeal injuries are common in children. Most of the time, the prognosis is good. However major complications can arise if they are treated improperly. In 1963, Salter and Harris described a classification for physeal injuries that is still popular today.[5] Based on radiographic findings, the system predicts the prognosis for a given injury and guides the choice of treatment in order to avoid complications (Figure 2).

Type I

A Salter–Harris type I injury is a true separation of the epiphysis from the metaphysis. The germinal layer of the growth plate remains attached to the epiphysis. It is a rare injury, seen most

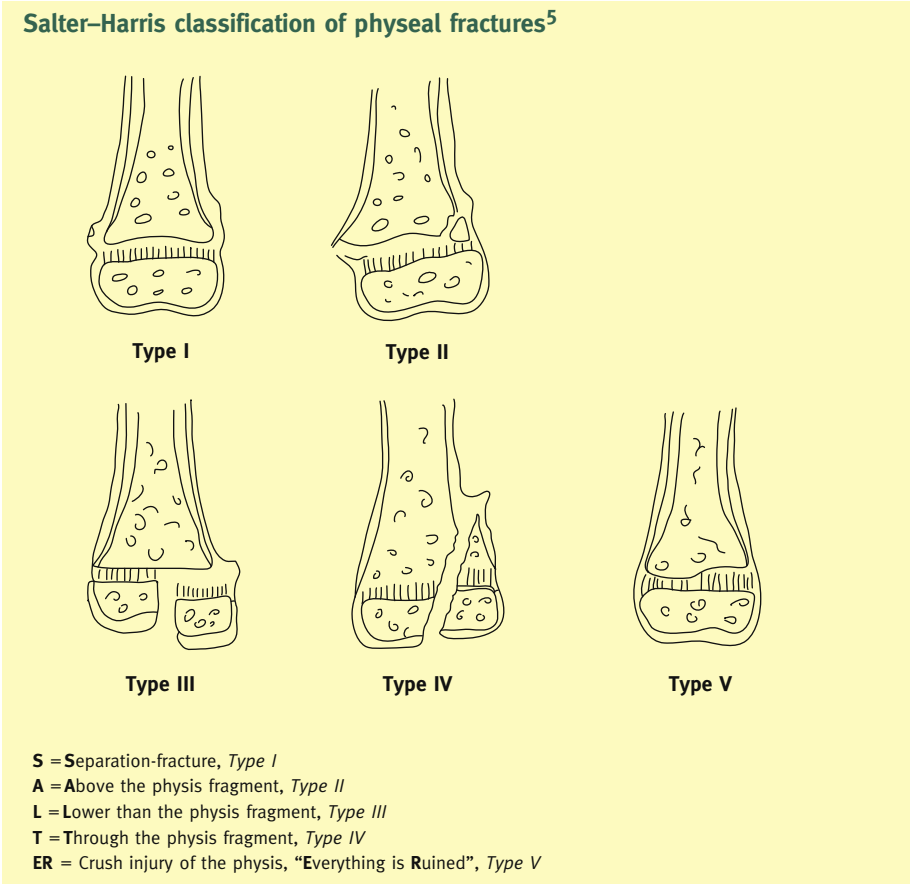

Figure 2