Growth plate injuries and management

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Abstract

The growth plate, or physis, is the name given to the area of cartilaginous tissue found between the epiphysis and metaphysis of skeletally immature bone. The developing growth plate is weaker than surrounding ossified bone and, therefore, at risk of injury before its closure. Previous studies have shown that fractures account for 10–25% of all paediatric injuries, with growth plate injuries accounting for 15–30% of all paediatric bony injury. The upper limb is most likely to be affected, with the distal radius found to be the most common site of fractures in children.

The Salter–Harris classification describes growth plate injuries based upon location and likelihood of growth arrest. In addition to growth arrest, injury to the growth plate often stimulates bone repair, which can lead to limb length discrepancy, bone bridge formation between the metaphysis and epiphysis, and angulation of the bone. The treatment of growth plate fractures ranges from conservative management to operative fixation and bone grafting. Outcome is varied and dependent upon site and grade of the fracture as well as the age of the patient. Regardless of Salter–Harris classification, an important component of management is counselling the parents about the potential risk of future growth arrest and associated sequelae.

Keywords growth plate; orthopaedic surgery; paediatric; trauma; treatment outcome

Introduction

The growth plate, or physis, is the name given to the area of cartilaginous tissue found between the epiphysis and metaphysis of skeletally immature bone. It is responsible for the longitudinal growth of bone. The growth plate plays a vital role in the prevention of fractures, and there is evidence to suggest young adults failing to reach their optimum bone mass are at risk of osteoporosis in adulthood.[1] However, the developing growth plate is weaker than surrounding ossified bone and, therefore, at risk of injury before its closure. Injuries to the growth plate can result in growth arrest leading to deformity or limb length inequality.

Normal development of bone

Osteogenesis, the new formation of bone, can occur by two means – endochondral and intramembranous ossification. Ossification occurs through the action of osteoblasts, which originate from the osteoprogenitor cells of the bone marrow. These are responsible both for the formation of the underlying bone matrix, and its subsequent mineralisation.

Long bones are laid down in a cartilage model, appearing in the mesenchymal tissue of the limb bud. Intramembranous ossification leads to the formation of primary ossification centres within the diaphysis of bone and is responsible, for example, for the development of the skull and clavicle.[1] Vascular invasion of these primary ossification centres leads to the formation of the endochondral ossification of the primary centre, the growth plate and the perichondrial ring. Further vascular invasion leads to the development of secondary ossification centres within the epiphysis of a bone, surrounded by the growth plate.[1,2] Endochondral ossification, based on this cartilage model within the long bones of the body, is the process by which fractures heal conservatively with the use of casting. Intramembranous ossification is seen in those fractures treated operatively with internal fixation.[1]

Anatomy

The growth plate can be divided into a number of zones that, together, work to achieve the longitudinal growth of the bone. Bone growth here, we have already seen, occurs through endochondral ossification, whereby growth plate chondrocytes are replaced by a calcified cartilage matrix. The invasion of this matrix template with blood vessels results in the formation of either spongy or trabecular bone. The majority of the blood supply to the physis itself is derived from the epiphysis (the epiphyseal artery).[2]

Layers of the growth plate

- Germinal/resting cell zone
- Proliferative zone
- Hypertrophic zone
- Zone of provisional calcification

Cellular layers

Immediately adjacent to the epiphysis is the 'resting cell zone', which is an area of irregularly-arranged cartilage cells that supplies the developing cartilage. Bone length is created by the active cartilage cells found within the 'zone of proliferating cartilage'. These chondrocytes enlarge and enter the 'maturation zone' once no longer active. The longitudinal bars of the cartilage matrix then become calcified – 'the zone of provisional calcification' (Figure 1).[2]

Peripheral zone

Lateral expansion of the physis is facilitated by the Node of Ranvier; a ridge of progenitor cells wrapped around the growth plate. The 'Perichondrial Ring of LaCroix' is a fibrous tissue band, also found in the peripheral zone, which provides the growth plate with its mechanical strength and that acts against compressive forces. This fibrous tissue band merges with the metaphysis periosteum.[3,4]

Matrix

The matrix is formed of collagen (type two predominantly), proteoglycan molecules such as aggrecan, and Cartilage Oligomeric Matrix Protein (COMP).[4]

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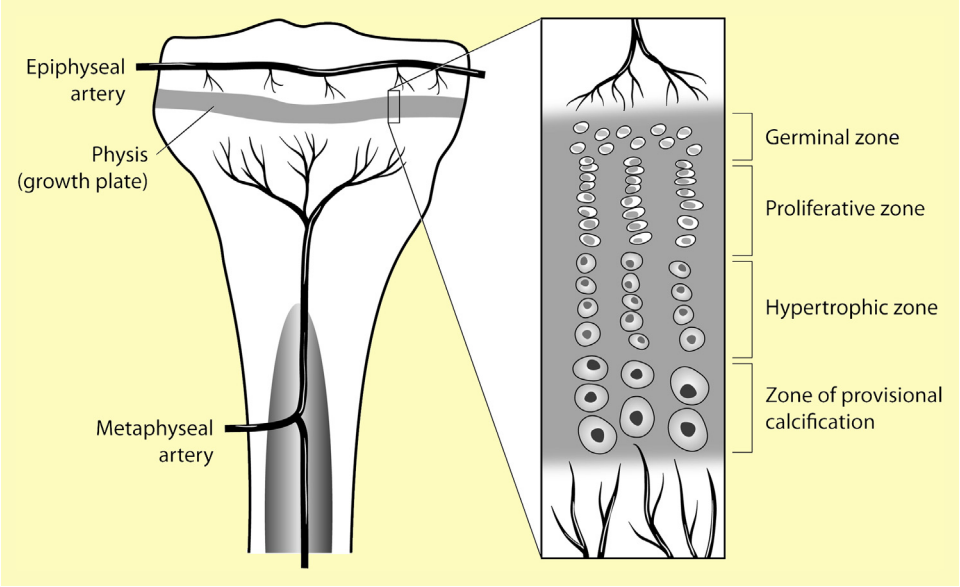

Figure 1 Growth plate anatomy.

The most active physes can be found in the proximal humerus and distal radius, in the upper limb, and distal femur and proximal tibia in the lower limb. The physes have anatomical variations in different locations of the body. In the knee, for example, the physis is locked solidly by the presence of mammillary bodies, designed to resist the high stress and forces passing through the joint. The distal radius, in contrast, has a more linear arrangement and is more likely to displace with minimal trauma.[5]

Damage to the growth plate

Generalised dysfunction of the growth plates can occur through chronic inflammation, cancer, renal failure, hypothyroidism, steroid treatment and chemotherapy. Disorders of the growth plate are also seen in genetic conditions, such as achondroplasia. Direct trauma and infection can affect individual growth plates.

Incidence of growth plate fractures[6,7]

- 30% of all musculoskeletal injury in children
- 10–25% of paediatric fractures
- Boys more commonly than girls
- Peak age 11–14 years

In addition to its comparative weakness to surrounding bone, the growth plate also has a limited regeneration ability. Children have a greater ligament strength in comparison to adults, with resultant added stressing of the physis. Indeed, it has been suggested that injury mechanisms associated with sprains and dislocations in the adult are associated with physeal injury in the child.[8] Growth plate injuries account for up to 30% of musculoskeletal injuries in children,[5] with 80% occurring in children over ten years of age.[9]

Previous studies have shown that fractures account for 10–25% of all paediatric injuries, with boys more likely to sustain a fracture than girls,[6,7] and with growth plate injuries accounting for 15–30% of all paediatric bony injuries.[5] It has been suggested that the peak incidence occurs at an age of 14 years in boys and 11 years in girls.[7] The upper limb is most likely to be affected, with the distal radius found to be the most common site of fractures in children.[6] The ankle is the second most common site of physeal injury, with high complication rates.[10] The ulna, hand and humerus are other common sites of physeal injury. A Scottish study into the epidemiology of paediatric fractures found 15% to be physeal in location, with a fall from "below bed height" being the most common mechanism of injury,[6] and with 50% involving the distal radius. Crush injuries, direct blows and sports accidents were identified as other common causes of paediatric fractures.[6]

Complications of physeal damage

In addition to growth arrest, injury to the growth plate often stimulates bone repair, which can lead to limb length discrepancy, bone bridge formation between the metaphysis and epiphysis, and angulation of the bone. Bone bars can be described as central, peripheral or linear. Whereas central bars are more likely to result in limb length discrepancy, peripherally placed bars can result in angular deformity of the bone.[11] Peripheral bars are the most common presentation, and linear bars involving portions of the central and peripheral physis are the rarest. These are associated with Salter–Harris four fractures.[12,13] Involvement of the articular surface increases the likelihood of arthritis later in life, particularly in Salter–Harris classifications three and four.

The strong physis of the knee is more likely to develop a bony bar and subsequent growth arrest should it fracture and fail, in comparison to the weaker linearly arranged distal radius.[5] A meta-analysis of 564 femoral growth plate fractures found growth arrest in 52% and leg length discrepancy in 22% of cases.[14]