Bone Growth in Foals and Epiphyseal Compression

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SUMMARY
Limb angulation in foals may be due to defects in epiphyseal growth plates. The present state of knowledge concerning rate of growth in foals and differences in growth of different epiphyseal plates is reviewed and the importance of accurate knowledge of these parameters in treatment of angulation by unilateral retardation of an epiphyseal growth plate is stressed.

Retardation of epiphyseal plate growth by compression wiring is described and its advantages in comparison with stapling are suggested. Compression wiring was used in 3 cases in which age, bone width and the degree of angulation were known so that the probable rate of bone growth could be assessed and the necessary unilateral bone increment could be calculated. It is suggested that further measurements of these parameters prior to growth plate retardation would give a more accurate comparison of the benefits of stapling and compression wiring.

INTRODUCTION
DISTORTION of limbs resulting from abnormal growth patterns within growth plates of long bones has been described in humans (Blount and Clarke, 1949; Knight, 1954), sheep (Duff, 1975), dogs (Clayton-Jones and Vaughan, 1970), rabbits (Appleton, 1934; Arkin and Katz, 1956) and horses (Delahanty and Gibbens, 1953; Rooney, 1963; Heinze, 1966; Vaughan, 1976). The probability is that in the absence of specific traumatic damage these deformities occur due to abnormal weight-bearing in the affected limbs, due to poor conformation or unequal distribution of weight as a result of laxity of ligaments in the affected limb, imbalance of muscle activity or lameness in the contra-lateral limb. Some animals may exhibit deformities at birth (Heinze, 1966; Ellis, 1976) perhaps due to abnormal intrauterine position.

The activity of growth cartilage in long bones can be affected by alterations in the compressive forces applied, increase of compression causing retardation (Haas, 1945; Gelbke, 1951), decrease resulting in enhancement (Arkin and Katz, 1956), so that increased weight distribution on one side of the growth plate would retard the growth rate at that side causing increasing distortion. In foals such deformity (fig. 1) resulting from poor conformation or abnormal weight distribution can be easily understood but in many cases the primary factors are not yet clear. Nutritional deficiencies may predispose to primary growth plate abnormalities with secondary distortion and this could be the important aetiological factor in so-called epiphysitis which is said to occur in fast growing heavy foals (Rooney, 1963). In these cases it has been suggested that bone growth outstrips growth of tendon causing abnormal stresses (Owen, 1975). In many, however, the cause of distortion is not clear.

GROWTH PATTERNS IN FOALS
Foals grow most rapidly during the first few months after birth but the rate of growth slows down with increase in age (Green, 1961, 1969). The cartilagenous growth plates in different areas in different bones close at different times. Thus, at birth, there are 6 or 7 growth plates contributing to the length of the limb in Quarterhorses and Thoroughbreds (Adams, 1966). Between 6 and 9 months the phalangeal growth plates ossify, ceasing to contribute to growth and length of the limb. Between 9 and 12 months the growth plate of the distal metacarpal and metatarsal bones disappear so that thereafter only 4 growth areas remain in the forelimb, 3 in the hindlimb. These are, in the forelimb: the proximal radial and distal humeral, which ossify at 15 to 20 months, the distal radial which ossifies at 2 to 2½ years and the proximal humeral which closes at 3 years. In the hindlimb there are the distal tibial, which fuses at 18 to 24 months, and the proximal tibial and distal femoral, which disappear at 2 to 2½ years (Table 1). The proximal femoral epiphysis probably does not
Fig. 1. Thoroughbred foal, 3 months old, showing lateral angulation of the right forelimb from above the carpus.

Contribute much to limb length. Sisson and Grossman (1948) quote slightly later times for fusion for all these epiphyses but this is based on boiled out specimens and the breed of animal is not stated.

The rate of growth at these epiphyses reduces with time. Heinze and Lewis (1968) by radiographing the limbs of Shetland ponies at regular intervals following marking of the bones by stainless steel pins, have shown that growth in both proximal and distal radial growth plates stops at about 18 to 19 months of age, even though the distal plate remains unfused for much longer than the proximal. The proximal cartilage plate causes rapid lengthening in the early months of life, slows down between 4 and 10 months, increases its rate of increment in length of the bone between 10 and 12 months of age then tails off to a very slow rate of growth. The distal epiphysis on the other hand grows at a more regular and faster rate up to the age of 18 months, although there is a similar period between 4 and 7 months when slowing down occurs. It is obvious therefore that variations in rate of growth occur in different growth plates in different stages of development and this will have an important bearing on the rate of increase or decrease in deformity occurring at these growth plates. It is probable that there will also be breed variations in growth rates in particular sites. In general, however, it would appear that there is a gradual slowing down of rate of growth as the animal ages. Thus, according to the figures of Heinze and Lewis, there was an average increment of approximately 9 per cent per month of the total growth of the distal growth plate of the radius over the first 3 months of life. This reduced to an average of approximately 6 per cent per month over the next 8 months and to an average of approximately 4 per cent per month for the following 6 months. The proximal radial growth plate on the other hand showed the following pattern—18 per cent per month for the first 3 months, 4 per cent per month from 4 to 12 months and 2 per cent per month from 12 to 18 months. Other growth plates probably also show slowing with time but accurate information has not yet been produced.

Thus any attempt at correction of deviation by affecting the growth of one side of the epiphyseal plate will take longer and have less likelihood of success the older the animal is.

**SURGICAL LIMITATION OF GROWTH**

Surgical limitation of growth of the cartilaginous epiphyseal plates was described by Phemister (1933) who implanted a bone graft to form a bony bridge across the plate. Haas (1945) used a wire loop in dogs and chickens to produce the retardation of growth while the application of staples was described by Haas (1948) and Blount and Clarke (1949).

Delahanty and Gibbens (1953) reported epiphyseal fixation in a foal by means of a plate and screws, but the most commonly used technique is epiphyseal stapling (Heinze, 1966; Vaughan, 1976). These appliances, although effective in many cases, and easy to apply using the proper tools, appear to have several disadvantages:

1. Compression of the growth plate is not immediate but is produced by continued growth at the epiphyseal line.
2. The effect of compression extends along the arms of the staple and is not concentrated at the outer aspect of the bone curvature.
3. The position and angulation of both arms of the staple have to be considered and controlled simultaneously.
metatarsus when only 3 months old. A 3 inch plate was used and it was fixed to the metaphysis by Fig. 3. Fusion of the growth plate of the distal metatarsus 4 weeks after application of compression plate.

The major disadvantage is the first one since limitation of growth will not occur immediately and if the growth plate’s activity is already slowing down this may negate the effect of the staples. In fact it has been suggested (McGibbon, Deacon and Raisbeck, 1962) that stapling initially stimulates epiphyseal plate growth until compression occurs, and these authors state that their findings are in agreement with other reports that initial arrest is slow.

A compression plate could overcome this difficulty but then the second disadvantage may become important, in that the screws would be unable to deviate significantly from one another due to their fixation in plate and outer cortex so that the compressive force would extend well across the growth plate and may produce rapid ossification. This effect was seen in one thoroughbred foal which was treated by this method for deviation at the distal metatarsus when only 3 months old. A 3 inch plate was used and it was fixed to the metaphysis by two 40 mm AO screws and to the epiphysis by one 40 mm AO and one 1½ inch Sherman screw (fig. 2). Within 4 weeks complete fusion of the epiphysis had occurred (fig. 3).

A technique which avoids these disadvantages is the use of 2 bone screws and a compression wire (Fackelman, 1972) using heavy gauge stainless steel wire. The advantages of this technique are:

1. The screws are only fixed in relation to one another at the surface of the bone and are able to move apart at the tips.
2. Immediate compression is applied at the area of greatest curvature, promoting more rapid return to normal.
3. The screws can be inserted independently at convenient sites after location and direction of the growth plate has been ascertained.

TECHNIQUE OF INSERTING COMPRESSION WIRE

An incision is made through the skin and fascia over the area of greatest curvature. A sharp probe or spring caliper (McGibbon, Deacon and Raisbeck, 1962) is used to identify the epiphyseal growth plate. It is advantageous to take 2 radiographs at right angles to each other with the probe in place to confirm the position of the growth plate and to ascertain the direction in which the epiphyseal screw must be inserted to avoid penetration of the growth plate or joint surface. A stab wound is made through fascia, collateral ligament

Fig. 2. Compression plate applied on distal metatarsus—epiphyseal growth plate is still present.
at the age of one week and had deteriorated since. Compression wire was applied and left for 3 months until the limb was straight. The screws and wire were then removed. Again no problem was encountered with the wound. In this case the bone breadth was 7.6 cm and with the angulation of 16° this meant that lateral growth of 22 mm in excess of medial growth was necessary for straightening to occur.

**Case 3:** a 6 months old Thoroughbred foal with 16° lateral deviation of the distal radius of 2 months duration. Compression wiring was performed, straightening of the limb occurred within the following 5 months after which the fixation was removed. At the time of removal an infected sinus was found to have developed even though the screws and wire were deeply buried in fibrous tissue. After removal of the implant healing of the wound was uneventful. Calculations of bone breadth (9 cm) and angulation showed that correction in this case required an increase of 26 mm on the lateral side to allow straightening of the limb.

**DISCUSSION**

Unilateral fixation of the growth plate to correct limb angulation has been in use for some time and has proved successful in a large number of cases. Following removal of the fixation, growth recurs provided ossification has not occurred across the growth plate (Haas,
the screws are free to move apart except at the points of attachment of the wire loop.

Heinze (1966) states that animals over 10 months of age when treated for radial or tibial deviation are not likely to achieve complete correction. Vaughan (1976) however, considers that 15 months of age is the upper limit at which surgery could be performed. Deviation of the fetlock must be treated by 6 months of age (Vaughan, 1976) and Heinze (1966) states that animals treated by 3 months of age have more chance of complete recovery than an older animal. It can be seen that although the rate of growth of the cartilage plate varies according to the specific site, the age and possibly the breed of the animal, considerable growth does occur up to the age of at least 18 months, and therefore correction of angulation may still be possible within that time. Unfortunately little information is available in the literature as to the speed of correction of angulation related to the degree of angulation and the age of the animal. Following treatment with staples, Heinze (1966) simply states that correction will occur within 8 to 20 weeks.

The 3 cases described here were of different ages and thus probably had different cartilage growth rates and, in addition, the bones were of different diameters. These factors, together with the degree of angulation may account for the difference in rate of correction of the deformity. The tibial deformity was slower in correction than might have been expected, but this could be due to a relatively slow rate of development of the tibial growth plate.

Bisgard and Bisgard (1935) found in goats that the distal tibial plate grew at nearly the same rate as the proximal. However, their findings for growth in other areas in goats were not identical with those found by Heinze and Lewis (1958) in Shetland foals.

Comparison of the effects of compression wiring with a series treated by staples in which age, bone width, degree of angulation, and time to straightening of the limb are recorded may help to indicate the most effective technique. Nevertheless it is suggested that in animals of 6 months or over, compression wiring could be the technique of choice.

REFERENCES


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RESUMÉ

Les angulations des membres chez le foal peuvent être dues à des défauts siégeant au niveau des plaques épiphy-

saires. On résume ici l’essentiel de ce que l’on sait actuellement concernant la croissance des foals et les différences de développement des épiphyse; l’importance d’une connaissance précise de ces paramètres est soulignée pour parvenir au traitement en retardant de façon dissymétrique la croissance épiphysaire.

Ce retard de croissance peut être obtenu par compression à l’aide de fil suivant une méthode décrite dans cet article, et par conséquent différemment de la méthode de fixation par agrafes.

La technique par compression a été utilisée dans trois cas où l’âge, la largeur de l’os et le degré d’angulation étaient connus de telle sorte qu’on pouvait estimer la vitesse probable de croissance de l’os et parant l’importance de la modification qu’il fallait apporter.

Il semble que la prise en considération de ces paramètres puisse permettre d’utiliser avec de meilleurs résultats l’une ou l’autre des méthodes de correction.

ZUSAMMENFASSUNG

Gliedmassenverkrümmungen können bei Fohlen die Folge von Defekten in den Epiphysenplatten sein. Der gegenwärtige Stand des Wissens über die Wachstums geschwindigkeit von Fohlen und die Unterschiede im Wachstum verschiedener Epiphysen wird besprochen; die Wichtigkeit einer genauen Kenntnis dieser Parameter für die Behandlung von Verkrümmungen durch einseitige Hemmung der epiphysären Wachstumsplatte wird hervorgehoben.

Die Hemmung des epiphysären Wachstums durch komprimierenden Draht wird beschrieben; die Vorteile gegenüber dem Einsetzen einer einseitigen Agraffe oder Krampe werden erwähnt. Die Kompressions verdrahtung wurde in drei Fällen eingesetzt, bei denen Alter, Knochenweite und Grad der Verkrümmung bekannt waren und einen Schluss auf die Knochenwachstums geschwindigkeit zuließen, so dass die notwendige, einseitige Knochennahmehernnung berechnet werden konnte. Es wird vermutet, dass weitere Messungen dieser Parameter vor der Operation einen exakteren Vergleich der beiden Operationsverfahren erlauben würden.

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