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Large Animal VETERINARY Rounds™

JANUARY 2006
Volume 6, Issue 1

AS PRESENTED IN THE ROUNDS OF THE DEPARTMENT OF LARGE ANIMAL CLINICAL SCIENCES OF THE WESTERN COLLEGE OF VETERINARY MEDICINE, UNIVERSITY OF SASKATCHEWAN

Angular Limb Deformities in Foals: Management and Implications of Angulation on Athletic Performance

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Angular limb deformities are an important problem in foals and young horses. Deformities at the carpus, fetlock, and tarsus lead to abnormal stress on the affected limbs and can limit athletic performance. This issue of *Large Animal Veterinary Rounds* discusses the etiology, pathogenesis, and treatment of angular limb deformities.

Developmental orthopedic disease has become the "catch phrase" that encompasses a number of orthopedic conditions affecting the growing horse. Conditions included under this umbrella are angular limb deformities, flexural deformities, and osteochondrosis. While the predisposing factors and underlying pathophysiologic mechanisms for each of these conditions may be inter-related, the management techniques are specific for each condition. Angular limb deformities represent a deviation of the limb in a sagittal plane (viewed from the front or from behind); however, there has also been recent interest in limb rotation.[1,2] Although most foals have a less than ideal conformation at birth, the majority of angular deformities resolve spontaneously and relatively few foals require surgical management. Recently, interest has focused on identifying and managing this latter group of foals, particularly with regard to the implications of limb angulation on racing performance.[2] The following article discusses the mechanisms responsible for angulation, the treatment modalities that can be employed, and the impact of abnormal angulation on racing performance.

Etiopathogenesis

Angular limb deformities may be congenital or acquired. Three basic mechanisms are responsible for the presence or development of an angular limb deformity in the foal.

- The most common deformities are those resulting from a greater than normal degree of laxity in the ligaments supporting the medial and lateral aspects of the joints.
- Inadequate development in the cuboidal bones of the carpus and/or the tarsus is potentially the most devastating manifestation of angular deformity.
- Deformities that arise due to a medial-to-lateral disparity in long-bone growth commonly resolve spontaneously, though surgical management is required in some foals.

History and physical examination

The assessment of foals with angular limb deformities should always begin by collecting a complete patient description and history. The foal should be observed standing at rest and at a walk to establish whether the angulation displayed is consistent or variable. The affected limb(s) should be palpated to

*This issue of Large Animal Veterinary Rounds marks the first for the new Editor, **David G. Wilson, DVM**. Dr. Wilson is a large animal surgeon in the Department of Large Animal Clinical Sciences at the Western College of Veterinary Medicine. His research interests include developmental orthopedic diseases in horses and the biomechanics of orthopedic fixation. As it happens, Dr. Wilson, is also the author of this issue, reporting on his research into angular limb deformities in foals. On behalf of the Department of Large Animal Clinical Sciences at the Western College of Veterinary Medicine, Dr. Wilson would like to thank past-Editor, Dr. Jonathan Naylor, for his work as founding Editor of Large Animal Veterinary Rounds and his editorial guidance over the past 5 years.*

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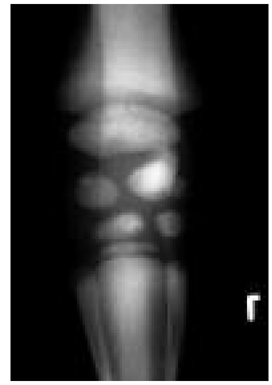
Figure 1: Geometric assessment of angular deformity at the carpus

Figure 2: Severe hypoplasia of the cuboidal bones of the carpus, the proximal physis of the metacarpus is visible



evaluate the degree of ligamentous laxity present and the presence of pain or swelling. When visually assessing the affected limb, the observer must view each limb in a dorsopalmar/plantar plane. Simply assessing limb conformation directly from in front or behind the foal will not result in an accurate assessment of limb angulation. Radiographs should be taken to evaluate the cuboidal bones. Geometric assessment is performed by drawing lines that bisect the long bones immediately above and below the joint (Figure 1).

Angular limb deformities: ligamentous laxity

Angular limb deformities due to ligamentous laxity are typically present and most pronounced at birth. The carpal and tarsal joints are most commonly involved and, in severe cases, the stifle joints can be angled as well. Examination of the foal at rest reveals excessive medial to lateral mobility of the involved joints. At a walk, the deformity may be consistent or variable in direction and severity. Manipulation will not elicit a painful response. Radiographs are morphologically normal and the geometric pivot point is located within the joint.

The majority of angular deformities due to ligamentous laxity resolve spontaneously over the first few days of life. The conservative clinician may recommend a short period of stall confinement. There are rare cases where mechanical support in the form of a stiff bandage or a splint may be indicated (eg, the foal's carpi are rubbing against each other). The clinician should be aware that the provision of mechanical support might slow the resolution of the laxity.

Angular limb deformities: cuboidal bone hypoplasia

Angular limb deformities caused by cuboidal bone hypoplasia potentially have the poorest prognosis. Under normal circumstances, the small bones of the carpus and the tarsus achieve their adult shape within 30 days of birth. Foals with underdeveloped cuboidal bones are clearly skeletally immature; however, skeletal immaturity does not correlate well with gestational age. This condition can occur in otherwise healthy foals, but in Western Canada these foals often suffer from the well known, but incompletely understood "hypothyroid foal syndrome."[3,4] Although the cause of this condition remains unproven, triiodothyronine (T_3) is essential for the normal endochondral ossification process and this process is disrupted in these hypothyroid foals.[5] Initially, the deformity observed in foals with immature cuboidal bones is secondary to elastic deformation of the bones and ossification may result in a completely normal joint. If the deformation proceeds past the plastic limit of the cartilage template, a crush injury results in permanent deformity (dysplasia) with angulation. Foals with dysplasia are destined to suffer from degeneration of the affected joint(s). With the exception of foals with hypothyroid syndrome, foals with underdeveloped cuboidal bones have a good prognosis if therapeutic intervention is undertaken before permanent deformity occurs.

Foals with hypoplastic cuboidal bones generally have a mild to moderately severe angular limb deformity. Manipulation of the affected limbs reveals an impression of ligamentous laxity, although the force needed to create deformity is greater than in foals with ligamentous laxity. Radiographic assessment confirms the presence of inadequately ossified cuboidal bones (Figure 2) and a geometric pivot point within the joint. In severe cases, the proximal growth plate of the metacarpus and metatarsus may still be present (it should close before birth; Figure 2). Deviation in the front limbs usually occurs in a medial-to-lateral direction but, in the rear limbs, the angulation typically occurs in a dorsoplantar direction (Figure 3).

Foals with underdeveloped cuboidal bones should be confined to a box stall. If the foal is especially active, a splint or tube cast should be used to provide mechanical support to the essentially cartilaginous cuboidal bones. In otherwise normal foals, the ossification process proceeds rapidly and most affected foals need only be confined for a period of 14 to 21 days. Hypothyroid foals seem to respond more slowly and their condition is often complicated by other abnormalities (eg, congenital flexural deformities, extensor tendon rupture, and generalized weakness). Radiographic evaluations should be repeated at 7- to 10-day intervals.

Unfortunately, cuboidal bone hypoplasia may go undetected. In these foals, the presenting complaint is often the sudden

Figure 3: Tarsal collapse due to cuboidal bone hypoplasia

appearance of a moderate-to-severe angulation, 2 to 4 weeks postpartum. Affected foals frequently have swelling over the carpus or tarsus and object to manipulation of the affected joints. Radiographs reveal misshapen, but completely ossified cuboidal bones with a geometric pivot point located within the joint. Although the angulation may be resolved following the use of one of the techniques described for the management of growth disparities, regrettably, the involved joints will become arthritic. Foals with permanent cuboidal bone deformity in the carpi are candidates for euthanasia unless they have value as breeding animals. Foals with tarsal involvement will have a period of lameness, but they may be able to perform athletically if the affected joints undergo fusion.

Angular limb deformities: disparity in long bone growth

Angular limb deformities caused by a disparity between medial and lateral long bone growth may be present at birth or the deformity may be an acquired developmental condition. In either case, there is an imbalance between growth occurring at the medial and lateral aspects of the physis in the affected bone. The most common deformity is a lateral (valgus) deformity originating at the distal radius. Other affected areas can include the distal metacarpus/metatarsus and the distal tibia.

Uterine positioning is believed to be the major cause of congenital deformities. The foal is restricted to cramped quarters and medial-to-lateral compressive stress over a period of time promotes overgrowth on one side of the physis allowing the development of angulation.[6] Foals born with straight limbs that later develop angulation are believed to have undergone some degree of growth plate injury.

Physical examination reveals a constant angulation. Palpation and manipulation does not elicit a painful response and there is no swelling or laxity of the involved joint. Radiographic evaluation confirms the presence of normally shaped cuboidal bones and the geometric pivot point is located proximal to the joint (Figure 1). A complete and accurate history will elucidate 1 of 6 possible scenarios:

- a congenital deformity that is improving, static, or worsening
- an acquired deformity that is improving, static, or worsening.

The collection of the above information will allow the clinician to develop a logical approach to managing the condition. The window of opportunity for dealing with deformities arising from the distal radius is large (duration of growth exceeds one year). However, there is a degree of urgency when the deformity is at the distal metacarpus or metatarsus because there is little growth potential in these bones after the foal is 100 days old.[7]

The majority of foals with angular limb deformities caused by a growth disparity of the long bones will have spontaneous deformity correction.[8-10] The challenge for the veterinarian is to identify which foals are likely to require more aggressive intervention and to implement measures while there is still sufficient growth potential to allow correction. Exercise restriction and corrective hoof care (maintenance of medial-to-lateral hoof balance) are routinely used to reduce biomechanical stress on the concave side of the angled limb and avoid exceeding the compressive physiologic limit of the physis.[6] In many cases, this conservative approach will result in resolution of the deformity. Severely affected foals or foals failing to respond to confinement and corrective hoof trimming are candidates for surgical treatment.

Surgical management of angular deformities due to growth disparities

Prior to 1980, the preferred surgical approach was placement of a temporary transphyseal bridge to delay growth on the overgrown (too rapid growth) side of the physis. Initially, transphyseal stapling was practiced,[11] but that technique fell out of favour owing to the perceived advantages of a screw and wire technique, specifically, a reduced incidence of cosmetic blemishes at the implant site.[12] The author has used both approaches successfully and finds the blemish associated with the staple technique can be avoided by ensuring that the skin incision is not directly over the staple. The transphyseal bridge compresses the growth plate, restricting growth while allowing the slow-growing side to catch up, thereby resolving the angulation.

Beginning in 1980, a periosteal stripping procedure was described.[13] The procedure was performed on the side of the growth plate that was growing too slowly. The proponents of the technique thought that manipulation of the periosteum stimulated growth and the subsequent resolution of the deformity occurred either through a vascular effect or a periosteal release effect. Since the introduction of this procedure, there have been numerous reports detailing its use, although none of those reports critically evaluated the technique's utility.[14-16] Twenty years later, the efficacy of the periosteal stripping procedure has come into question. Foals undergoing periosteal stripping procedures are exercise restricted and corrective hoof care is routinely applied. This begs the question, "is the observed correction due to exercise restriction, corrective hoof care, periosteal stripping, or a combination?" The author of one study suggests that foals correcting after periosteal manipulation would have corrected spontaneously.[8] The original work by Auer reported creating angular deformities in ponies by performing periosteal manipulation in normal foals;[17] the results are in direct conflict with recent experimental work from 2 research groups.[8,18]

In their original paper, Auer and Martens reported the creation of angular deformities with periosteal stripping, followed by a correction of these deformities with a second periosteal stripping procedure.[17] They were unable to detect any difference between medial and lateral bone growth at the distal radial growth plate and they thought they had created and corrected a deformity. They attributed the correction to growth at the proximal radial growth plate.[17] Slone was not able to produce an angular limb deformity by performing a periosteal stripping procedure and detected no change in medial-to-lateral growth at either the proximal or distal growth plates.[8]

Researchers at the Western College of Veterinary Medicine have developed an angular limb deformity model for assessing the utility of periosteal stripping. Temporary transphyseal bridges were placed across the lateral aspect of both distal radial physes in 10 normal foals at 30 days of age. By approximately 90 days of age, all of the foals had developed lateral deviations of ≥15°. The transphyseal bridges were removed and periosteal stripping was performed on 1 limb. The contralateral limb served as a control. Exercise was restricted and medial-to-lateral hoof balance was maintained by rasping the hooves bi-weekly. Over the ensuing 10 to 12 weeks, the deformities in the treated and control limbs corrected at the same rate, demonstrating that periosteal stripping was no more effective than exercise restriction and corrective hoof trimming alone.[18] The efficacy of periosteal manipulation was further called into question by a controlled trial involving clinically-affected foals where periosteal stripping was no more effective than conservative management.[19]

Our research group is currently conducting an interventional criteria study specifically evaluating congenital valgus deformities at the carpus. To be eligible to enter this study, foals must be between 2 and 4 weeks of age with deformities of < 15°. Management involves maintenance of medial-lateral hoof balance and 4 to 6 weeks of exercise restriction. To date, 15 foals have been entered into the study and one foal has required transphyseal bridging. Until recently, periosteal stripping would have been performed in all of these foals and credited for this apparent spontaneous correction. At this time, there is no clear, published evidence supporting the use of periosteal stripping as an effective treatment for angular limb deformities in foals.

Detailed reports of surgical techniques for the correction of angular limb deformities due to medial-to-lateral growth disparities abound in the literature. Unfortunately, nearly 40 years after the earliest report of surgical treatment, there is no published clinical algorithm available to aid the clinician in the development of optimal treatment strategies. Until that information is available, the clinician must rely on currently available intervention considerations, including, age of the foal, anatomic site involved, severity of the deformity, and status of the deformity (congenital or acquired, improving, static, or worsening).

Table 1: Interventional criteria

Site	Angle	Age	Status of Deformity	Treatment Recommendation
Distal Radius	< 15°	< 4 – 6 wks	Not worsening	Confine, Hoof Balance
	> 15°	< 4 – 6 wks	Static, worsening	Transphyseal Bridge
Metacarpus/ Metatarsus	< 4°	< 2 wks		Confine, Hoof Balance
	> 4°	< 2 wks		Transphyseal Bridge

In general, a less-aggressive approach can be taken to correct deformities arising from the distal radius because the window of opportunity for correction is large. This author's current intervention criteria are found in Table 1. With this approach, there is little risk in giving the foal with a deformity at the carpus an opportunity to self-correct. The more aggressive tactic for dealing with deformities at the fetlock avoids missing the smaller window of growth opportunity. Older foals with deformities at the fetlock can be corrected by performing an osteotomy of the cannon bone.[20] The procedure is a major one and effective; however, economic constraints often limit its application.

Transphyseal stapling technique

Although purpose-specific staples are commercially available, we often manufacture a variety of staple sizes from 5/32 inch Steinman pins. After aseptic preparation of the surgical site, the skin in the area of the proposed staple placement is displaced dorsally. A size-matched skin incision is made and the physis is identified with a 20-gauge needle. The articular surface is identified by palpation and the staple is placed spanning the physis (Figure 4). To facilitate later removal, the proximal corner of the staple is left slightly elevated off the bone. When the skin tension is released, the skin slides in a caudal direction

Figure 4: Transphyseal staple

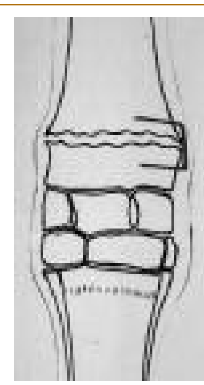


Figure 5: Transphyseal screws and wires

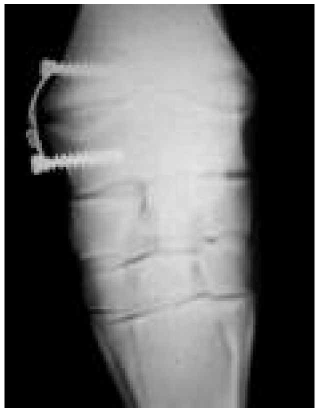


Figure 6: Transphyseal screw

leaving the staple under intact skin. Closure is routine and the incision is supported with a bandage for 2 weeks after surgery. Foals are exercise restricted and medial-to-lateral hoof balance is maintained by rasping the hooves bi-weekly. When the limb is straight, the staple is removed under a short-acting injected anesthetic.

Screw and wire technique

The screw and wire technique is undoubtedly the most popular temporary transphyseal bridging technique. Using either a straight, displaced skin incision or a curvilinear skin incision, the area over the physis is exposed. The physis is identified with a 20-gauge needle before a 3.2 mm hole is drilled 1.5 cm proximal to the physis. The hole is tapped and a 4.5 mm cortical screw is inserted (30 mm in length for radius). A second screw is placed midway between the physis and the articular surface. Two strands of 18-gauge stainless steel wire are placed around the screws in a figure eight configuration (Figure 5). Inexperienced surgeons are encouraged to utilize intra-operative radiography. Care must be taken to ensure that the cut ends of the wires are bent over and directed toward the bone before the incision is closed. The incision is supported with a bandage for 2 weeks after surgery. Possible complications include incisional dehiscence and rarely, implant failure. Exercise is restricted and medial-to-lateral hoof balance is maintained by rasping the hooves bi-weekly.

The implants are generally removed with the foal under a short-acting injected anesthetic. In foals with bilateral transphyseal bridges, limbs often correct at different rates. In these cases, the author frequently removes the proximal screw from the limb that corrects first with the foal standing. Removal of the wire and the distal screw is carried out when the second limb is straight.

Transphyseal screw technique

The most recent development in the surgical management of angular limb deformities has been the use of a single transphyseal screw.[21] After identifying the physis with a needle, a stab incision is made approximately 1.5 cm proximal to the physis, a 4.5 mm drill bit is seated perpendicular to the long axis of the bone and then angled to about 20 degrees. A glide hole is drilled to the level of the physis and a 3.2 mm drill bit is used to drill into the epiphysis. The hole is tapped to accept a 4.5 mm cortical bone screw in lag fashion. Alternatively, a 4.5 mm self-tapping screw can be inserted (Figure 6). To facilitate screw removal, the screw head is not countersunk. Intra-operative radiography is essential to avoid inadvertent entry into the joint. The incision is supported with a bandage for 14 days after surgery. Exercise is restricted and medial-to-lateral hoof balance is maintained by rasping the hooves bi-weekly.

This transphyseal screw technique was recently used to effect a correction in 350 foals. Interestingly, unlike other reports where valgus deformities predominate, over 70% of the deviations at the carpus were medial deviations.[21] Reported complications of this technique include incision infection and screw breakage at the time of removal. Clinicians opting to use this technique are encouraged to purchase broken screw removal equipment available from Synthes, USA.

Effect of angular deformity on performance

While this author and others were evaluating the utility of periosteal manipulation, other investigators were reporting that Thoroughbred race horses with some degree of valgus deformity at the carpus (up to 8^{o}) were less likely to develop articular chip fractures in the carpus, suggesting for the first time that a horse with perfectly straight forelimbs may be disadvantaged.[22] Subsequent to this report, researchers followed a group of Thoroughbred foals from birth to 18 months of age. Their findings confirmed that angular deformities are common in newborn foals and many resolve as the foals mature.[1] Finally, 2 to 4-year-old Thoroughbreds with straight forelimb conformation appear to have no advantage on the racetrack over peers with less than ideal conformation at either the carpus or the fetlock.[2]

Summary

Angular limb deformities are common in foals. Most deformities are due to ligamentous laxity and resolve spontaneously. Deformities resulting from cuboidal bone hypoplasia can be devastating if the condition progresses to dysplasia. Medial-to-lateral growth disparity is most often congenital; however, these can also be acquired. The majority of angular deformities due to growth disparities also self-correct. The principal challenge for the clinician is to identify those foals needing a temporary transphyseal bridging technique to achieve correction. Finally, recent investigations suggest ideal limb conformation (perfectly straight limbs) may not be directly associated with racing success.

*Guest editor, **Dr. Hugh G.G. Townsend** is a Professor in the Department of Large Animal Clinical Sciences at the Western College of Veterinary Medicine. Dr. Townsend's research interests include infectious disease epidemiology; public health; vaccine formulation, delivery and efficacy; and the immune response to infection.*

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This publication is made possible by an educational grant from

Schering-Plough Animal Health

117-048R

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