Kentucky Equine Research®
World Leaders In Equine Nutrition

Advances in Equine Nutrition

Volume III

Edited by

J.D. Pagan

OVERVIEW OF BONE DISEASE

C. WAYNE MCILWRAITH
Colorado State University, Fort Collins, Colorado, USA

Introduction

Bone is a critical component of the equine musculoskeletal system. It not only provides strength to the legs, but also acts as the foundation for cartilage in the moveable joints. Much of the clinical disease in the horse associated with bone involves the subchondral bone immediately under the articular cartilage leading to problems in the joint. These conditions can be divided into developmental problems of bone and traumatic problems of bone. They will be considered separately.

Developmental Problems of Bone

The term developmental orthopaedic disease (DOD) was coined in 1986 to encompass all orthopaedic problems seen in the growing foal (McIlwraith 1986) and is a term that encompasses all general growth disturbances of horses and is therefore nonspecific. The term should not be used synonymously with osteochondrosis, and it is inappropriate for subchondral cystic lesions, physitis, angular limb deformities, and cervical vertebral malformations all to be presumed as manifestations of osteochondrosis. When the term developmental orthopaedic disease was first coined, it was categorized to include the following:

- Osteochondrosis—Osteochondrosis is a defect in endochondral ossification that can result in a number of different manifestations depending on the site of the endochondral ossification defect. These manifestations include osteochondritis dissecans (OCD) and *some* subchondral cystic lesions—not all subchondral cystic lesions or osseous cyst-like lesions are necessarily manifestations of osteochondrosis. Another manifestation is some physitis (but we now recognize that most clinical swelling associated with the physis has no pathologic change involving the physis itself).
- Acquired angular limb deformities.
- Physitis.

- Subchondral cystic lesions.
- Flexural deformities.
- Cuboidal bone malformation.

Osteochondrosis

Osteochondrosis (dyschondroplasia) was initially defined as a disturbance of cellular differentiation in the growing cartilage (Olsson, 1978). Osteochondrosis is considered to be the result of a failure of endochondral ossification and, therefore, may affect either the articular epiphyseal cartilage complex or the metaphyseal growth cartilage. It is usually in the articular epiphyseal cartilage. It can have three consequences:

1. These areas of retained cartilage, due to a lack of endochondral ossification, can heal.
2. They can break out and form flaps of cartilage and bone or fragments of cartilage and bone (called osteochondritis dissecans or OCD).
3. The retained cartilage can undergo necrosis and form a subchondral cystic lesion (subchondral bone cyst).

The majority of cases of OCD and subchondral bone cysts are considered to be the result of necrosis occurring in the basal layers of the thickened retained cartilage with subsequent pressure and strain within the joint giving rise to fissures in the damaged cartilage.

Osteochondritis Dissecans

There is a general agreement that this condition involves a dissecting lesion with the formation of a chondral or osteochondral flap. Flaps may become detached and form joint mice. In some instances, lesions have been found at arthroscopy that consist of cartilage separated from bone, and the cartilage does not appear to be thickened (McIlwraith, 1993). Based on these observations, the author questions whether persistence of hypertrophied cartilage is a necessary event prior to the development of an OCD lesion. This question is based on instances seen at arthroscopic examination or in follow-up histologic examination where dissection or separation occurs close to the cartilage-bone interface, rather than in the underlying cancellous bone between normal cartilage and a normal bone-cartilage junction, as it commonly does in humans. The clinical manifestations and treatment of the common entities of OCD are discussed in a separate lecture.

Subchondral Cystic Lesions

Subchondral bone cysts were first reported as a clinical entity in 1968 (Pettersson and Sevelius, 1968). Subchondral cystic lesions have also been proposed as manifestations of osteochondrosis by a number of authors (Stromberg, 1979; Rooney, 1975), and there is some pathologic support for this (Rejno and Stromberg, 1978). However, more recent work has demonstrated that subchondral cystic lesions can be produced from a small defect in the bone (Ray et al., 1997), and other work has shown that the lining of clinical subchondral cystic lesions contained increased quantities of neutral metalloproteinases, PGE-2 and interleukin-1, and also are capable of osteoclastic resorption of bone.

The Cause of OCD

Despite the instances where there is no evidence of thickened cartilage, it is generally accepted that most OCD lesions are manifestations of osteochondrosis. In the one- to two-year-old horse, most cases of subchondral cystic lesions are also related to osteochondrosis. For that reason, the following discussion is on various etiologic factors associated with osteochondrosis.

GENETIC PREDISPOSITION

There have been a number of genetic studies on the heredity of OCD in the hock in Standardbreds and Scandinavian cold-blooded horses. A radiographic survey by Hoppe and Phillipson (1985) in Standardbred trotters and Swedish Warmbloods showed that one stallion of each breed had a significantly higher frequency of OCD among its progeny, compared with the progeny groups of the other stallions ($p<0.001$). In another study, Shougaard et al. (1990) showed radiographic evidence of a significantly higher proportion of OCD in the progeny of one of eight stallions, even though the stallion itself did not show radiographic signs of OCD. Since that time, there have been two additional studies (Grondahl and Dolvik, 1992; Phillipson et al., 1993) on the heritability of osteochondrosis in the tibiotarsal joint. Both of these studies were in Standardbred trotters, but did show significant heritability with OCD. Studies in other breeds are markedly lacking. In the Dutch Warmblood, there has been a protocol preventing breeding of stallions with any OCD for ten years, but whether this has lowered the incidence of the disease is questionable.

GROWTH AND BODY SIZE

An association has been made between body weight and OCD by Pagan and Jackson. Foals in Kentucky that had to have arthroscopic surgery for OCD were significantly heavier than foals that did not have OCD.

MECHANICAL STRESS AND TRAUMA

It has long been recognized clinically that mechanical stresses precipitate the onset of clinical signs, presumably by avulsing an OCD flap or fragment (McIlwraith, 1987). The role of trauma as a primary initiator of a lesion is more controversial. Pool pointed out that there are no unique histologic features that will consistently distinguish the lesion of osteochondrosis from that of trauma at a developing osteochondral junction, and that the radial vessels supplying the chondrocytes in the epiphyseal physis may be sheared and cause a primary osteochondrosis lesion (Pool, 1986). He felt that biomechanical forces are an important factor and are superimposed upon an idiopathic lesion to produce defective cartilage. Reflection back to the classic paper by Konig in 1887 is appropriate in considering the potential role of trauma in the pathogenesis. He claimed that loose bodies in the knee joints of young people had three causes: a) very severe trauma, b) lesser trauma causing contusion and necrosis and c) minimal trauma acting on an underlying lesion—for which he suggested the name "osteochondritis dissecans" (and for which he is considered the originator) (Barrie, 1987). I feel that these three different syndromes can be seen in the horse.

DEFECTS IN VASCULARIZATION

OCD was initially described as being caused by a vascular or ischemic necrosis of the subchondral bone (Adams, 1974; Schevitz, 1966). Although recent work in the pig suggested that the viability of epiphyseal cartilage and the articular epiphyseal cartilage complex is highly dependent on adequate blood supply from cartilage canal vessels and implicates a defect in blood supply in the pathogenesis of osteochondrosis (Carlson et al., 1991), there is no evidence yet documented in the horse.

NUTRITION

Osteochondrosis-like lesions have been induced in horses by feeding 130% of National Research Council (NRC) carbohydrate and protein (Glade and Belling, 1986). More recently, further work has defined that 130% of NRC digestible energy will certainly significantly increase the incidence of osteochondrosis lesions, but increasing the protein content does not (Savage et al., 1993).

MINERAL IMBALANCES

Various mineral imbalances have been implicated in the pathogenesis, including high calcium, high phosphorus, low copper and high zinc. There is no good equine-specific support for high calcium causing problems, but three times the

NRC levels of phosphorus significantly increased the number of OCD lesions (Savage et al., 1993).

Low copper has been implicated as a cause. In experimental studies, it has been reported that a marked copper deficiency (1.7 ppm) produced both flexural deformities and osteochondrosis-like lesions (Bridges and Harris, 1988). Bridges and Harris also noticed a softening of articular cartilage and suggested that the low copper status may lead to reduced cross-linking of collagen by lysyl oxidase, predisposing to physeal and articular fractures. Hurtig et al. conducted a controlled experiment with high (30 ppm) and low (7 ppm) copper diets (1990). A much higher incidence of lesions of osteochondrosis was seen in the foals fed the low copper diet. Many of the changes were present in the cervical spine. Hurtig considered the lesions as one of reduced structural strength rather than arrested or abnormal endochondral ossification. Further work has been done in copper by Pearce et al. in New Zealand. The absolute levels of copper at which OCD can be produced have been questioned, or at least it appears clear that there are differences between different countries. Professor Elwyn Firth's group failed to produce significant clinical OCD with low copper diets. They also showed that, while oral supplementation of mares could enhance the foals' copper status, parental administration could not.

Excessive zinc intake has been related to equine osteochondrosis (Messer, 1981). The effects of environmental exposure to zinc and cadmium were studied in pregnant pony mares, following observations of lameness, swollen joints, and unthriftiness, particularly in foals (Gunson et al., 1982).

ENDOCRINE FACTORS

It has been postulated by Glade that the production of osteochondrosis lesions in association with overfeeding is mediated by the endocrine system (Glade and Belling, 1986). Glade has proposed that feeding initiates increased concentrations of insulin and T_4, and high concentrations of insulin could inhibit growth hormone, although the exact mechanism is not known (Glade, 1986). A long-term administration of dexamethasone has been associated with the production of osteochondrosis-like lesions (Glade and Krook, 1983). More recent work showing an association between high-glycemic feed, insulin secretion, and osteochondrosis has been made by Ralston and Pagan.

SITE VULNERABILITY

Because the lesions of equine osteochondrosis occur at specific anatomic sites, this does suggest vulnerability that could be related back to trauma or excessive stress and interference with blood supply as originally suggested by Pool (1986). Lesions are frequently bilateral in the femoropatellar and tarsocrural joints and

quadrilateral in the fetlock joint, although they infrequently involve different joints in the same animal. This observation could perhaps suggest a "window of vulnerability" in the endochondral ossification of that specific joint at that specific location.

Natural History of Osteochondrosis Lesions

Recent work done by the workers at Utrecht (van Weeran and Barneveld, 1999) has shown that many lesions in the stifle and the hock will heal. In this study, foals were radiographed every month, and lesions developed (defects developed, signifying a lack of endochondral ossification) and then the lesions healed. Relatively few of them became clinical, but the times at which they were going to persist were established. This study emphasized that we need to be careful of radiographic surveys in deciding that we have a problem with OCD. This author feels that only when we have clinical signs associated with it should we be intervening. This study also clarified the age at which surgical treatment was appropriate. If surgical intervention is carried out at a very young age, it is likely that it is unnecessary in many instances.

Further work by McIntosh and McIlwraith (1993) showed that it was certainly possible to have lesions heal beyond this time if foals were confined. Definition of what lesions can heal with conservative management has greatly progressed treatment, and this is discussed elsewhere.

Traumatic Lesions of the Subchondral Bone

In recent years, good evidence has been provided that intra-articular fractures are preceded by subchondral bone disease. This subchondral bone disease consists of a spectrum of microcracks, diffuse microdamage, cell loss (apoptosis or necrosis) and accompanying subchondral bone sclerosis (Kawcak et al., 2000; Kawcak et al., 2001).

Cause of Subchondral Bone Disease

The development of microdamage is presumed to be associated as a consequence of cyclic trauma. The repeated wear and tear has been noted with radiographic study and, more recently, CT to contribute to subchondral bone sclerosis. However, the direct association between sclerosis leading to the necrosis of bone has not been totally demonstrated. The development of lytic lesions in the subchondral bone, however, is presumed to be associated with microdamage. Factors involved in the predisposition of horses to damage based on the cyclic trauma of an athletic career include racetrack or arena surface, conformation, genetic predisposition, as well as a destabilizing traumatic injury.

Consequences of Traumatic Subchondral Bone Disease

Subchondral bone disease creates an environment for pathologic fractures. The most common manifestation are osteochondral chip fractures, which can be career-ending if not treated successfully. However, the overall success with arthroscopic surgery is high. Slab fractures represent a more severe injury requiring internal fixation. Some of these cases can return to athletic activities. However, in other instances, such as collapsing slab fractures in the carpus, the failure to treat adequately can lead to loss of life. The third level of fracture injury in terms of severity are the catastrophic injuries that can be life-threatening. Surgical treatments of such conditions are salvage procedures.

Diagnosis

Early diagnosis is critical. The recognition that early disease in the subchondral bone can lead to fractures has resulted in research efforts to diagnose bone disease early.

References

Adams OR. Lameness in horses. 3rd ed. Philadelphia: Lea and Febiger, 1974.

Barrie HJ. Osteochondritis dissecans. 1887-1987. A centennial look at Konig's memorable phrase. J Bone Jt Surg 1987;69-B:693-695.

Bridges CH, Harris ED. Experimentally induced cartilaginous fractures (osteochondritis dissecans) in foals fed low-copper diets. J Am Vet Med Assoc 1988;193:215-221.

Carlson CS, Meuten DJ, Richardson DC. Ischemic necrosis of cartilage in spontaneous and experimental lesions of osteochondrosis. J Orthop Res 1991;9:317-329.

Glade MJ, Belling TH. A dietary etiology for osteochondrotic cartilage. J Equine Vet Sci 1986;6:151-155.

Glade MJ, Krook L, Schryver HF, et al. Morphologic and biochemical changes in cartilage of foals treated with dexamethasone. Cornell Vet 1983;73:170-192.

Glade MJ. Control of cartilage growth in osteochondrosis: a review. J Equine Vet Sci 1986;6:175-187.

Gunson DE, Kowalczyk DF, Shoop CR et al. Environmental zinc and cadmium pollution associated with generalized osteochondrosis, osteoporosis and nephrocalcinosis in horses. J Am Vet Med Assoc 1982;180:295-299.

Hintz HF, Hintz RL, Van Vleck LD. Growth rate of Thoroughbreds, effect of age of dam, year and month of birth and sex of foal. J Anim Sci 1979;48:480-487.

Hoppe F, Phillipsson J. A genetic study of osteochondrosis in Swedish horses. Equine Pract 1985;7:7-15.

Hurtig MB, Green SL, Dobson H et al. Defective bone and cartilage in foals fed a low copper diet, in Proc 35th Annual Conv Am Assoc Equine Practnr 1990;637-643.

Kawcak CE, McIlwraith CW, Norrdin RW, Park RD, James SP. The role of subchondral bone and joint disease: a review. Equine Vet J 2001;33:120-126.

Kawcak CE, McIlwraith CW, Norrdin RW, Park RD, Steyn PS. Clinical effects of exercise on subchondral bone of carpal and metacarpophalangeal joints in horses. Am J Vet Res 2000;61:1252-1258.

Kawcak CE, Norrdin RW, Frisbie DD, McIlwraith CW, Trotter GW. Effects of osteochondral fragmentation and intra-articular triamcinalone acetonide treatment on subchondral bone in the equine carpus. Equine Vet J 1997;30:66-71.

McIlwraith CW, ed. AQHA Developmental Orthopedic Disease Symposium. Amarillo, TX: American Quarter Horse Association 1986;1-77.

McIlwraith CW. Inferences from referred clinical cases of osteochondritis dissecans. Equine Vet J Supplement 1993;16:27-30.

McIlwraith CW. Osteochondrosis. In: Stashak TS, ed. Adams' Lameness in Horses, 4th ed. Philadelphia: Lea and Febriger, 1987;396-410.

McIlwraith CW. What is developmental orthopaedic disease, osteochondrosis, osteochondritis, metabolic bone disease? Proc 39th Annual Convention AAEP 1993;35-44.

Messer NT. Tibiotarsal effusion associated with chronic zinc intoxication in three horses. J Am Vet Med Assoc 1981;178:294.

Norrdin RW, Kawcak CE, Capwell BA, McIlwraith CW. Subchondral bone failure in an equine model of overload arthrosis. Bone 1998;22:133-139.

Olsson SE. Introduction. Acta Radiol Supp 1978;358:9-14.

Pettersson H, Sevelius F. Subchondral bone cysts in the horse: a clinical study. Equine Vet J 1968;1:75.

Pool RR. Pathologic manifestations of osteochondrosis. In: McIlwraith CW, ed. AQHA Developmental Orthopedic Disease Symposium. Amarillo, TX: American Quarter Horse Association, 1986;3-7.

Rejno S, Stromberg B. Osteochondrosis in the horse. II. Pathology. Acta Radiol Suppl 1978;358:153-178.

Rooney JR. Osteochondrosis in the horse. Mod Vet Pract 1975;56:41-43 and 113-116.

Schougaard H, Falk-Ronne J, Phillipsson J. A radiographic survey of tibiotarsal osteochondrosis in a selected population of trotting horses in Denmark and its possible genetic significance. Equine Vet J 1990;22:288-289.

Stromberg J. A review of the salient features of osteochondrosis in the horses. Equine Vet J 1979;11:211-214.