Papillon Club of America Health & Genetics

AN OVERVIEW OF PATELLAR LUXATION

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INTRODUCTION

Patella luxation or femoropatellar instability is a common cause of lameness in dogs. There are varying degrees of the abnormality from a mild instability within the trochlear groove to a complete, irreducible luxation of the patella. Clinical lameness associated with the various degrees may range from intermittent clinical signs to permanent lameness. The direction of the luxation maybe in the medial or the lateral direction. Patella luxation has been reported to be heritable or traumatic in nature. The most common form of the disorder is the heritable or developmental medial patellar luxation in the small breed dogs. Lateral luxation in small dogs is rare and is usually heritable. Lateral patellar luxation in large or giant breed dogs is often a distinct syndrome associated with severe limb deformities and carries a guarded prognosis. The incidence of patella luxation in large breed dogs is increasing.Felines, also, have been reported to be affected by patellar luxation, but not as frequently as the dog. A grading scheme is utilized to standardize the description of the disorder. (Table 1)

Patella luxation is considered to be inherited polygenically. Although, often termed "congenital", in the majority of cases the luxation is not present at birth. The anatomical deformities that cause the luxation are present at birth. Medial luxation is more common than lateral luxations in all of the breeds. Medial luxation accounts for 75-80% of the luxations. Bilateral luxations are seen in 20-25% of the cases.

PATHOPHYSIOLOGY :

The normal anatomy and function as well as the interrelationships of the entire rear limb (hip joint, femur, stifle, and tibia) must be understood before the abnormal state can be appreciated. (FIGURE 1) Normal angulation for the hip joint has been established in three different planes. From the lateral view, the cranial flexor angle of the hip is normally 110 degrees. (FIGURE 2) The flexor angle of the stifle is 130 degrees. From the craniocaudal view, the femoral neck to shaft angle is 130 degrees. (FIGURE 3) An increase in this angle makes the stifle shift outwards into a stance know in lay terms as bow-legged or coxa vara. A decrease in the angle is knock-kneed or coxa valga.

From the stifle joint looking-up from the end through the shaft of the femur, the femoral neck should form an angle of 0 degrees at birth and approximately 27 degrees when mature. (FIGURE 4) The proper anatomic alignment is necessary for stability of the stifle joint and the proper functioning of the extensor mechanism. The extensor mechanism of the stifle is comprised of the quadriceps muscle group (rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis), patella, trochlear groove, straight patellar ligament, and the tibial tuberosity.

The quadriceps muscle group serves to extend and stabilize the stifle. The patella is considered a sesamoid bone. It is embedded in the tendon of the quadriceps muscle. Articulation with the trochlear cartilage is necessary for maintaining the nutritional integrity of the surrounding cartilage. The patella allows for even tension when the stifle is extended and also acts as a lever arm. The human quadriceps requires 15-30% increase in contractile force without the patella.

The patellar ligament is the single confluence of the quadriceps tendon distal from the patella to the tibial tuberosity (tubercle, crest). The tuberosity is located cranial and distal to the condyles. There is a specific alignment of the quadriceps, patella, trochlea, patellar ligament and tibial tuberosity for proper functioning. A deviation in any of the components will result in a tension that predisposes to luxation of the patella.

Anatomic abnormalities can be quite significant with medial patella luxation. The extent of the resulting abnormalities is, in part, dependent on the severity of the disorder and the age of the animal during the severe stage. A significant potential for axial and torsional growth is present in the cartilage columns of the growth plate (physis) of the distal femur. With medial luxation there is a lateral torsion of the distal femur. The origin of the deforming force is still uncertain. Two theories have been proposed; one of a persistence of anteversion at the hip joint (investigated experimentally) and the other of a modifier gene that selectively acts in a specific anatomic region at a critical stage of embryogenesis (speculative).

The persistent anteversion causes a compensatory internal rotation of the pelvic limb. This internal rotation displaces the origin of the quadriceps muscle group medially in relation to the long axis of the femur. The internal rotation displaces the tibial tuberosity medially. These result in a medial displacement of the quadriceps muscle group relative to the long axis of the femur. Contraction of the quadriceps along a straight line from the displaced origin to the tibial tuberosity results in the medial displacement of the patella.

Lateral bowing of the distal third of the femur results from the increased pressure applied parallel to the growth plate, which retards growth. A decrease in pressure applied parallel to the growth plate will accelerate growth. The degree of lateral bowing depends on the grade of patellar luxation and the age of the patient at the onset of luxation. Abnormal growth will continue as long as the patella is luxated medially and the growth plate is active. In the adult dog, existing bone responds to stress by increased bone deposition and realigns according to stress (Wolff's Law). This is remodelling and is much slower that growth plate deformation.

Deformity may occur through remodelling, but this requires a long period of time. More typically, in the mature dog abnormal forces maybe manifested by an increase thickness of the trabecula on the medial aspect of the stifle.

Within the trochlear groove, the articular cartilage is the growth plate for the epiphysis of the distal femur. The response to an increase or decrease of pressure at the metaphyseal growth plate is similar to that of the physis (increase in pressure results in a decrease in growth, the converse also being true). The articulation of the patella within the trochlear groove exerts a physiologic pressure on the articular cartilage that retards cartilage growth. This continued pressure by the patella is responsible for the development of normal depth of the trochlear groove. The degree of deformity depends on the grade of luxation (the amount of time the patella is luxated) and the age of the patient at the onset of luxation. The degree of abnormality varies from nearly normal trochlear depth to the absence of a trochlear groove.

The growth and normal development of the distal femoral condyles depend on the inherent growth potential of the articular cartilage. The same mechanism of presence or absence of pressure will result in a hypoplastic medial condyle when the patella is luxated medially. The increase in pressure can arises from the forces created by medial malalignment of the extensor apparatus or by a shift in the weight-bearing axis toward the medial direction resulting from lateral bowing of the distal femur. Subsequently the lateral condyle is elongated from accelerated growth.

The tibial deformities are the result of abnormal forces on the proximal and distal tibial physis. The deformities associated with a medial patella luxation are medial displacement of the tibial tuberosity, medial bowing of the proximal tibia, and lateral torsion of the distal tibia. The proximal tibial aberrations are from the mechanism previously discussed- the increase or decrease of pressure on the growth plate with a resultant deviation in the longitudinal axis of the bone. The persistent anteversion and internal rotation of the limb causes a compensatory rotation of the foot. In order for the foot to be placed properly, the dog must externally rotate the tarsal joint, which results in external torsion on the distal tibial growth plate.

Rotational stability of the stifle is aided with the normal placement of the quadriceps mechanism on the cranial aspect of the joint with the patella in the trochlear groove. When the patella is displaced medially,the strength and tone of the quadriceps is lost. The lateral joint structures are stretched and the medial structures contract.

TREATMENT AND PROGNOSIS

Surgical treatment of the disorder is directed at correcting the anatomic abnormalities and re-establishing the alignment of the quadriceps mechanism. Arthroplastic techniques utilized for stabilization of patellar luxations can be divided into two classes: soft-tissue reconstruction and bone reconstruction. Considerable judgment and experience are necessary to determine the best combination of procedures for each individual case. Surgical repair must go through the list of procedures until stability is achieved. Assessment of the severity of the abnormalities and the necessary correction are made at the time of surgery. A critical principle is that skeletal deformities like deviation of the tibial tuberosity or shallow trochlear groove must be corrected by bonereconstruction. Such abnormalities cannot be corrected using soft tissue reconstruction techniques.Soft tissue reconstructive procedures are the retinacular overlap, fascia lata overlap, patellar and tibial antirotational suture ligaments, desmotomy, and quadriceps release. The desmotomy and the quadriceps release procedures serve to incise and free the soft tissue structures that have become fibrosed while the patella was in the luxated position. The other procedures serve to utilize the strength of the fascial structures or synthetic materials to anchor the patella in the trochlear groove. These are only performed with obvious Grade 1 luxations or after performing the necessary bone reconstructions to provide for additional support.

The bone reconstructive procedures are to create depth to the trochlear groove, realign the pull of the quadriceps or re-establish the straightness of the femur or tibia. The depth of the trochlear groove should be assessed and the trochlea deepened to the extent that about half the patellar height is above the trochlear margin.

There are several modifications of this procedure that vary in the method of removing the cartilage or bone. The method that deepens the groove while maintaining the hyaline cartilage is the wedge recession. This procedure tends to have the least amount of scarring of the articular cartilage. Other methods are the abrasion trochleoplasty (fibrocartilage in growth) and the trochlear chondroplasty (for dogs less than 6 months of age). The tibial tuberosity should be moved laterally until the quadriceps is realigned with the patella being pulled in a straight line from the proximal femur to the distal tibia. This involves using an osteotome to free the tuberosity and Kirschner wire(s) to maintain fixation in the new position.

The prognosis for a functional joint with the above-mentioned procedures is good. In a study evaluating 52 stifles,no lameness was evident in 92% of the stifles. Although 48% had recurrent patella luxation, the recurrences were always of a lesser grade than the pre-operative grade.

In some cases the deformities are so extreme that drastic procedures must be utilized to normalize the forces. Osteotomies of the distal femur or the proximal tibia maybe necessary to straighten the limb. Because of the technical difficulty of these procedures and the poor prognosis for a functional joint, arthrodesis should be considered. With the arthrodesis the joint is fused in a functional angle of 135 degrees. The function of the leg is affected but should be satisfactory for a pet. The overall function of the limb may not be adequate in some dogs and ambulation with amputation would be less cumbersome.

GENETICS

There are 4 significant modes of inheritance in dogs. These are autosomal (simple) recessive, autosomal dominant, sex-linked recessive, and polygenic. Genes are the physical hereditary link between generations. Unless there are mutations, inheritance is particulate, meaning that a given gene or set of genes is acquired by the progeny in an all or none fashion. Each individual has 2 genes for each trait (simple Mendelian genetics). Each autosome (non-sex chromosome) is present in duplicate since individuals receive one from each parent. In addition to the autosomal or non-sex chromosomes, each animal has two sex chromosomes.

Dogs have thirty-nine pairs of chromosomes,thirty-eight are autosomal chromosomes and one pair of sex chromosomes. Any organism is the product of its genes, or genotype, acting within it's environment.

The phenotype is the external, or physical, manifestations of the animal and is the result of the genotype and theenvironment. Genetic traits cannot be caused by the environment, but modification of the expression can occur. Simple Mendelian traits can be separated into dominant and recessive modes of inheritance. If the trait can be expressed phenotypically by the sole presence of one gene of a gene pair, it is dominant. If both genes in a pair are required to manifest the trait, it is said to be recessive. Not all traits are simple. Some traits are controlled by a number of genes. Each of these genes adds in increments to the total phenotype.These are called complex Mendelian traits. Because multiple genes are involved, distribution of specific phenotypes cannot be predicted. The environment can make these traits more or less detrimental to the phenotype, but the dog will only develop a disorder if it has the complement of genes necessary to produce that trait. Just as the environment can modify polygenic traits, so can the genetic makeup of the individual. The expression of traits may vary as a result of the total number of genes present, by the modification of normal structures, or by the modification of the severity of the trait. Polygenic traits tend to show a continuous variation in the phenotype.The whole dog is composed of about 100,000 genes.

Some general characteristics of polygenic traits are that both the dam and sire contribute one or more of the genes that cause the abnormal phenotype in the progeny. This contribution isn't necessarily equal between the dam and sire. Since these traits are not sex-linked, there is an equal distribution of either sex affected.The trait may skip generations and may appear to be erratic in occurrence.In recent years the progress in mapping the canine genome (chromosomes) has been spectacular. Today the map of the canine genome contains 341 well-spaced markers that provide about 95% coverage. This means that marker tests can and are being developed to help in strategic breeding plans to eliminate undesirable traits. DNA tests for heritable disorders are the best method of evaluation because the genotype of the individual is determined. Most of the current testing methods rely on phenotypic evaluation. The phenotype is the physical expression of individual traits. The phenotype is the product of the environment and the genotype. The phenotypic evaluation is less reliable than the genotypic (DNA) evaluation because carrier individuals can be phenotypically normal.

GENETIC DATABASE

Purebred dog breeders have been challenged by the problem of genetic disease for years. Goals must be established to provide a direction. From a health prospective, breeding animals free from painful, disfiguring or lethal disorders should be paramount. In order to breed these better dogs, breeders need information about the genetic propensities of their dogs. Genetic databases must be the core to control of genetic disorders in our animals. Control of heritable disorders is a complicated problem revolving around the provision of and use of information about the genetic composition of individuals.

A database should provide breeder with the knowledge of all dogs (affected and unaffected) in a given pedigree. To be of value for current breeding decisions, the information should not only be current and up-to-date but also encompass data on the entire family.

Entry into the OFA patella database is by physical examination. This evaluation is phenotypic in nature: it does not reveal the genotype of the individual. Studies have shown that selective breeding using phenotypic evaluations can reduce the frequency of polygenically inherited disorders. There is no charge for entry of affected individuals or up-dating information.

The availability of database information on individual dogs is based on the consent of the owner. Both open and semi-closed databases will be available. The semi-closed database will make only normal results available to the public. The open database will list both normal and abnormal results.

The provision of the normal and abnormal data is a huge step toward informed decisions in the selection of breeding individuals and pets.

It will be necessary for breeders and prospective owners to be educated regarding the nature of the disorder (method of inheritance) as well as the type of test (phenotypic versus genotypic) used for the evaluation.

SUMMARY

Patella luxation affects different breeds of dogs. Luxation is most commonly medial and can be bilateral. It is considered to be a polygenically inherited disorder. The actual luxation is associated with multiple anatomical abnormalities. The severity is categorized by 4 grades of luxation. Surgical procedures are available to provide for a normalization of the physical aberrations. Surgical correction has been shown to produce good clinical results.
Selective breeding of phenotypically normal individuals should be utilized to decrease the frequency of the disorder.

TABLE 1. Grading system for medial patellar luxation

Grade 1	The patella can be luxated medially when the stifle joint is held in full extension. There is no crepitation or bony deformity. Clinical signs are not present or occur very infrequently.
Grade 2	Spontaneous luxation occurs with clinical signs of a nonpainful, "skipping" type of lameness. Mild deformities develop, consisting of internal rotation of the tibia and abduction of the hock. This condition may progress to a Grade 3 luxation with associated cartilage erosion on the patellar and trochlear surfaces.
Grade 3	The patella is permanently luxated but can be manually reduced. More severe bony deformities are present; including marked internal tibial rotation and an S-shaped curve of the distal femur and proximal tibia. A shallow trochlear groove may be palpable. The client often complains of an abnormal, "crouched" gait rather than intermittent lameness, because the dog often uses the leg in a semiflexed, internally rotated position. The condition is often bilateral.
Grade 4	This is a severe condition with permanent, irreducible luxation of the patella. The tibia is rotated from 60 to 90 degrees relative to the sagittal plane. If not corrected early in life, severe bony and ligamentous deformities develop and are often not reparable.

From Singleton WB:
The surgical correction of stifle deformities in the dog.
J Small Anim Pract 10:59, 1969.