Cranial cruciate ligament (CCL) disease in the canine patient is a common finding in companion animal practice, and the prevalence has doubled over the past 30 years. In humans, the majority of anterior cruciate ligament tears or ruptures are trauma induced. On the other hand, trauma accounts for only approximately 20% of CCL disease in dogs. Bilateral disease occurs in approximately 50% of patients, which can lead to increased dysfunction, pain and chronic degenerative changes in the affected stifles. Although excellent progress has been made over the past 10 years in surgical correction of CCL rupture or injury, complication rates of 14-60% have been reported (depending on the technique).

The best medicine is still prevention but to date, very little research has been focused towards these preventive measures. However, it is clear that CCL disease in dogs is multifactorial and complex, and therefore it is critical to examine the stifle from a whole, functioning unit perspective. Factors influencing the health and maintenance of the canine CCL include genetics, conformation, muscle control, weight, exercise and loading, and joint inflammation.

Anatomy

The stifle joint is stabilized by soft tissues both passively and actively:

- The canine stifle is a complex diarthrodial, condylar joint with 6 degrees of motion about 3 axes: flexion-extension, axial rotation, cranial-caudal translation.
- Passive stability is provided by ligaments (cruciate and collateral), menisci, joint capsule and articular contours.
- Active stability is provided by muscles (primarily the quadriceps, gastrocnemius and biceps femoris) and tendons.
- The cruciate ligaments are the primary passive stabilizers of the stifle joint. The cranial cruciate ligament (CCL) is the more lateral band and is taut in all phases of flexion and extension of the stifle, while the caudal cruciate ligament (CaCL) lies medial to and crosses the CCL, and is taut in extension and relaxed in flexion. Together, these bands limit excessive movement along the 3 axes described above.
- A major difference between dogs and humans is the way in which forces are transmitted through the limbs during weight bearing. When a human is standing, minimal force is placed on the anterior cruciate ligament. However, because dogs are quadrupeds and stand with a flexed stifle, their cruciate ligament is continuously under load.
- The tibia plateau slope is visualized from the lateral view at the top of the tibia:
  - The slope in humans is fairly flat while the slope in dogs varies between 14-60 degrees. When the canine stifle is weight bearing, the tibia is displaced forward as the femur moves down the slope of the tibia. The steeper the angle, the more significant the force, which creates what is known as tibial shear force. In a healthy stifle, the CCL opposes this motion.
  - A meniscus is a crescent-shaped fibrocartilaginous tissue that partially divides the articular surfaces of a joint. There are two menisci within the stifle joint – an inner or medial meniscus and an outer or lateral meniscus. These structures distribute load during weight bearing and provide structural integrity to the stifle as it undergoes tension and torsion. The menisci also play an important role in joint nutrition and lubrication.
- Both menisci are anchored to the tibial plateau. The medial meniscus has a firm attachment to the tibia and medial collateral ligament, and thus has limited mobility. The lateral meniscus has a loose attachment to the tibia and an additional attachment to the femur, allowing a greater range of motion in the joint during translation.
• As a result, the medial meniscus is more vulnerable to injury when cruciate deficiency is present. Approximately 50% of CCL ruptures are accompanied by concurrent meniscal damage.
• Meniscal injury further increases the inflammation, pain, and lameness in an unstable stifle.

Factors influencing stifle disease

Genetics
• Breeds at higher risk of CCL disease: Labradors, Rottweilers, Newfoundlands, Mastiff, Akita, Staffordshire Terrier, St. Bernard
• Newfoundlands – only breed with identified genetic satellite markers; 22% prevalence of CCL disease reported in this breed. Still, only 27% phenotypic expression attributed to genetics, and 73% linked to environmental factors.
• Breeds at lower risk of CCL disease: Greyhounds, Dachshund, Bassett Hound, Old English Sheepdog, German Shepherd Dog

Conformation
• Poor conformation of the pelvic limb leads to misalignment of the joint, abnormal joint forces and may exacerbate the degenerative process leading to CCL disease
• Poor conformation may include medial patellar luxation, genu varum (“bow legged”), and hyperextension of the hock (“post legged”)
• Excessive Tibial Plateau Angle (TPA): excessive tibial slope (> 30 degrees) correlates strongly with cranial angulation of proximal tibia. Increasing the tibial slope decreases the effectiveness of the passive restraint mechanisms and places the CCL under greater abnormal mechanical load.
• Early neutering (<6 months age) may contribute to excessive TPA and cranial tibial translation (CTT).

Muscle control
• Muscle activity has an active role in stabilizing the forces affecting the canine stifle. Proper firing sequence of muscle activity and balanced muscle strength are important in creating normal joint biomechanics.
• In humans, coactivation of the hamstring and quadriceps muscles prevents inappropriate CTT during dynamic movement, thereby stabilizing the knee.
• Greater relative strength of the quadriceps group over the biceps femoris results in failure of active restraints to CTT and places the CCL under abnormal loading forces.
• Finely tuned mechanical and neurologic signaling is required to provide dynamic stifle stability and coordinated, protective movements of surrounding muscles.
• Stifle pain and joint effusion in the early stages of CCL disease lead to inhibition of the quadriceps muscle due to altered neuromuscular interactions (eg, stimulation of joint capsule mechanoreceptors due to joint effusion). This then leads to maladaptive muscle firing and gait patterns that further exacerbate joint instability in both the affected and contralateral hindlimbs.

**Weight**
• The biomechanical load placed on the CCL is influenced not only by active and passive stabilization but also by the total force placed on the limb. Excessive body weight creates increased ground reaction forces, leading to increased loading on joint surfaces.
• Cyclic loading of the CCL under abnormal conditions (as discussed in all of these factors) leads to microscopic failure of the CCL, disease and subsequent partial or complete rupture.
• Excessive joint forces alter microscopic cartilage structure and function, contributing to decreased water content, damage to chondrocytes and release of inflammatory mediators.
• Furthermore, excessive body weight increases the expression of inflammatory cytokines in the body, which may be associated with many pathologic conditions including arthritis, diabetes and heart disease. See below for a discussion on joint inflammation and its role in CCL disease.

**Exercise**
• Exercise is important in developing and maintaining balanced muscle strength and flexibility, and develops fine proprioception and neuromuscular coordination.
• Dogs are “front-end loaded” with 60% of their body weight distributed over the forelimbs. As a general rule, dogs are more aware of their front-end dynamics due to more finely tuned proprioception and coordinated muscle movements. They have less positional awareness of their hind end, but can be trained to improve these abilities.
• Exercise programs should encourage balanced muscle strengthening, proprioceptive conditioning and normalizing joint forces to maximize stifle stability.

**Joint inflammation and osteoarthritis**
• The maintenance of cartilage health is dependent on normal joint stability, joint forces and normal gait patterns. CCL disease results in joint instability, altered joint kinematics and abnormal muscle activation patterns.
• Abnormal joint forces acting on articular surfaces increase contact to regions of thinner cartilage unaccustomed to increased weight bearing. This contributes to structural damage of the articular cartilage, production and release of inflammatory mediators, and the development of osteoarthritis.
• A complex cycle of destructive joint pathology includes abnormalities of tissue composition, upregulation and release of inflammatory mediators and degradative enzymes, proliferation of cells, recruitment of inflammatory and immune cells, and production of anti-collagen antibodies. Careful attention to controlling the factors may aid in slowing the downward spiral and progression of CCL disease.

**Putting it all together**
• As stated in the beginning, canine CCL disease is complex and multifactorial in origin and progression. Although there is a paucity of scientific literature concerning proven preventive measures, certain “best practice” strategies can be extrapolated based on current knowledge.
• The management of (potential) CCL disease in dogs includes the following:
  o Maintaining appropriate growth rates, body weights and body condition scores throughout all life stages.
  o Spaying or neutering canine patients after the age of 6 months or longer after discussing the benefits and risks with the owner.
  o Promoting an active physical fitness program to include conditioning, proprioceptive training and targeted muscle strengthening. Corrective exercises to address conformational risks should be planned with a trained rehabilitation therapist.
  o Early intervention and vigorous management of inflammatory joint/tissue conditions utilizing diet, nutraceuticals, treatment modalities (e.g., therapeutic ultrasound, low level laser, acupuncture, manual tissue therapy) and pharmaceuticals (e.g., NSAIDS and analgesics).
  o Maintaining overall systemic health to decrease chronic states of inflammation, including dental health and infectious disease prevention.
Resources

Physical medicine can make striking difference for you and your patients, especially for managing chronic pain and dysfunction secondary to maladaptive patterns. The sports medicine oriented physical exam focuses on form and function, with the goal of identifying problem areas that can be corrected through targeted exercises, therapies and management. Numerous clinical examples of these techniques will be provided during the lecture.

Getting started
The sports medicine physical exam (SMPE) is intended to supplement rather than replace the routine physical exam. A thorough history should be obtained with an emphasis on functional requirements expected of the dog, abnormalities noted by the owner/handler, owner expectations and goals for the dog, and acute and chronic pain assessment. A minimum database should be obtained for every patient to include weight, TPR and systems exam.

The SMPE then typically begins with an evaluation of overall movement and gait.

Gait cycle - the legs move through a patterned gait cycle that includes a stance phase, during which the foot is on the ground, and a swing phase, during which the foot is moving through the air. Both braking and propulsion are utilized during the stance phase; during the swing phase, the foot and leg first move backwards with propulsion, swing forward, and then backward and downward once again to make contact with the ground.

In the canine, 5 types of gait are typically recognized:

- **Walk** – slow 4-beat gait; one leg is off the ground at a time
- **Trot** – 2-beat gait; legs move in unison in diagonal pairs i.e. two legs off the ground at a time
- **Pace** – 2-beat gait; legs move in unison on one side
- **Canter** – controlled 3-beat gait; faster than a trot but slower than a gallop. Leg movement = 1, 2, 1
- **Gallop** – very rapid 4-beat gait.

The canine patient should be observed in a variety of different gaits at different speeds; dogs are adept at masking lameness and dysfunction at faster gaits (e.g., trotting vs. slow walking). Owners should also lead the patient through movements and tasks related to the dog’s function (e.g., an arthritic dog rising from lying in the down position or an agility dog jumping over obstacles).

Maintaining small items such as traffic cones and PVC pipes in the clinic can readily enable testing such as weaving or stepping over obstacles.

The patient’s postural and skeletal alignment should be carefully observed in static and dynamic postures to evaluate for maladaptive patterns. Evaluate the limbs for abnormal abductions, adductions and rotations, the axial skeleton for curves and rotations, and the pelvis for misalignment. During movement the patient should be assessed for head bobs, guarding postures as a protective measure against pain, and detectable lameness should be graded.

Visual inspection of the gait cycle is important and practitioners have limited ability to detect minute details and subtle alterations just by visually assessing the moving dog. Several technologies are available to analyze movement, including simple video capture, 2-D and 3-D gait analysis, force plate analysis, pressure mats and accelerometers. In the everyday practice setting, simple video capture with a hand held camcorder will allow the practitioner to analyze movements in slow motion and finer detail. Additionally, the patient should be still photographed in a standing position against a neutral backdrop from the side, front and rear.

Palpating and testing tissues
The dog’s overall appearance should be evaluated for the following:

**Body condition score** – this is a measurement of body fat; several scales have been evaluated with the Hill’s 5 point and Purina 9 point scales most commonly used. Assessment of BCS should be made by evaluation of several different points on the dog, including but not limited to palpation of the periscapular region, the last rib and the tail head region. The ideal BCS is 2.5-3.0/5 or 4-5/9, and disease risks may increase with BCS scores above 3.5/5 or 6/9.

**Muscle condition score** – this differs from BCS by evaluating muscle mass. Although not currently as refined as the BCS scoring system, a simple system is illustrated in the 2011 AAHA Nutritional Assessment Guidelines for Dogs and Cats. In addition to tone, muscles should be carefully palpated for symmetry. Muscle loss and asymmetry is an important indicator of dysfunction and compensatory movement, and may predominant early in the process of acute and chronic diseases. Suspected asymmetry can be assessed and tracked by measuring with a Gulick tape. This spring loaded tape measure allows the application of a consistent amount of force when tightening the tape measure around a part of the body. This helps to ensure repeatable measurements and minimizes inter-user variability.
Manual Muscle Testing – this is subjective testing done by the therapist to assess a patient’s muscle strength. This is more difficult in the veterinary patient as the animal cannot be asked to perform voluntary movements such as pushing a leg in abduction against the therapist’s hand. However, the therapist can observe movement patterns to determine muscle firing sequences, and can induce muscle contractions to evaluate strength and tone (e.g., by gently pushing an animal off balance). The muscle strength can be graded as normal, good, fair, poor, trace or zero.

Testing range of motion (ROM) – the practitioner should carefully evaluate the range of motion of the joints, which can be done rapidly in a screening fashion. Range of motion that appears to be limited, painful or asymmetrical should be measured with a goniometer and compared to breed standards. Contralateral measurements in the individual dog can also serve as reference values for that dog. The author highly recommends testing ROM in both a standing position and in recumbency, as dogs (especially large breeds) can often block or override ROM testing from certain positions.

- Range of motion is the full motion through which a joint may be moved.
- Muscle range of motion is the functional excursion of muscles to fully extend or flex a joint.
- Range of motion is affected by joint structure and surrounding soft tissue.
- Evaluate the joint “end feel” - the “feel” or sensation at the limit of ROM of a joint. These can be normal or pathologic, depending on the joint and the type of feel.

Myofascial evaluation – this involves deep palpation of the soft tissues to locate bands of tightness or limitations and painful trigger points. Trigger points are hyperirritable, tender foci in skeletal muscle bands that can be palpated and generally pain is elicited when the points are manipulated. Trigger points can also lead to referred pain at distant sites in the body.

Neurologic evaluation – A thorough neurologic examination should be performed including cranial and spinal nerve reflexes. Proprioception is particularly important in athletic function, and should be carefully evaluated. Proprioception is the sense of the relative position of neighboring parts of the body and strength of effort being employed during movement. It involves a complex interaction of afferent signals from mechanoreceptors found in joints, ligaments, tendons and soft tissues. These signals provide a constant flow of information that allows the CNS to adjust the body’s position in space to maintain appropriate movements. Nerve glide testing should be carefully performed to evaluate for elicited pain that might indicate impingement of the normal movement or “glide” of the long nerve tracts.

Useful technology for the SMPE

Goniometry – measuring the range of motion of a joint provides objective data to assess progression of therapeutic efforts. Goniometry is a rapid, accurate and repeatable technique that has been validated in several studies in a wide variety of breeds. Manual and digital goniometers are available, ranging from a few dollars to several hundred. A reliable digital goniometer is available for around 20.00.

Activity monitors – accelerometers (with or without GPS) have become increasingly popular and widely available in the veterinary market. Simple devices can be attached to collars, and provide basic data to evaluate periods of activity, movement and location (for those with integrated GPS). Most systems integrate directly with phone apps so that the owner (or even the veterinary care provider) can monitor the pet throughout the day. Activity monitors can provide basic objective data to aid in the evaluation of treatment plans and activity levels in pets.

Video capture – simple, subjective motion analysis can be accomplished utilizing video taping of patients as they progress through a range of functional motions. Slow motion mode is especially useful, and increases the ability of the human eye to detect subtle changes in movement patterns. There are also a wide option of video analysis, sport-performance focused programs that can be used to analyze video clips to aid in quantifying motion.

Gait analysis – a variety of gait analysis systems (force plates) have become widely available in the past several years for veterinary use. Force plates utilize the principles of kinetic analysis, and produce numerical values of ground force reactions that reflect foot strikes on a specialized mat or plate. These measurements can be used to assess lameness, weight shifting and therapeutic progression in the canine or feline patient. Currently available systems range from the low $1000s to over $10,000 depending on the size and complexity of the system.

Motion analysis – motion analysis systems utilize the principles of kinematics, and produce data that reflects the velocities, acceleration/deceleration, positions and angles of various anatomic structures in space. These systems generally utilize a combination of markers on the body and video systems; they require significant space and monetary investment, and are most often utilized in academic and referral settings.

Completing the examination

Once the stability of the patient has been assessed, the SMPE can be completed as needed by assessing the level of conditioning and endurance in the patient. This can be accomplished by several means, including tasks such as specific job performance (such as performing a drug detection exercise) or dry treadmill testing.
Maintaining a SMPE template with specific measures can help streamline and simplify the process of recording the results of the physical exam, and all images and videos can be incorporated into the final medical record.

References and recommended reading