Cranial cruciate disease is the most common condition of the canine stifle. It is one of the primary causes of lameness in the dog and has a huge financial impact. In 2003 it was estimated that greater than 1 billion dollars is spent annually treating this condition. Despite the common nature of this problem, the frequency of which we see and treat these cases, the number of articles, book chapters and seminars that have been devoted to it, we still do not have “all the answers”.

Review--Stifle Anatomy
The cranial cruciate ligament (CCL) is composed of a large caudolateral band and a smaller craniomedial band. The caudolateral band is taut only in extension, whereas the craniomedial band is taut in extension and flexion. This point becomes very important when dealing with and diagnosing a partial tear. It is imperative that the stifle be evaluated for drawer and thrust in both extension and also slight flexion.

Other important structures of the stifle include:
- Caudal cruciate ligament (CdCL)—deficiency results in caudal drawer (movement of the tibia caudally in relation to the femur).
- Medial and lateral collateral ligaments—deficiency results in lateral to medial instability or vice versa.
- Menisci
  - Lateral meniscus attached to femur
  - Medial meniscus less mobile, more susceptible to damage when instability is present
- Patella/patellar tendon—medial patellar luxation sometimes occurs concurrently with CCL disease.

Pathophysiology of Injury
There are many theories proposed for the pathophysiology of CCL injury. These include: progressive degeneration of the ligament, increased cellular metabolism within the ligament, inflammatory cytokines within the joint, abnormal conformation leading to excessive stress on the CCL, excessive tibial plateau angle, narrowed distal intracondylar notch, genetics, immune mediated disease, obesity, and trauma. We often refer to CCL injury, which might imply to some that it is a result of trauma, however, the vast majority of CCL cases have no history of a specific trauma, accident or injury. CCL injury in the dog is more of a “degenerative process” in which the ligament is weakened and compromised from one or more of the above and ultimately breaks down resulting in lameness. The following are excerpts from studies looking at the pathophysiology or etiopathogenesis of CCL disease:

Abnormal conformation
- Radiographic evaluation of 50 stifles with CCL disease and 50 stifles without revealed no significant difference in distal femur, however development of tibial tuberosity and convexity of tibial condyles were different and may contribute to risk of CCL injury.²³
- Tibial plateau angle has not been found to be predictive for CCL injury in Labradors.⁷

Genetics
- There is a known genetic mode of inheritance for CCL injury in Newfoundlands.¹¹

Risk Factors for CCL Injury
Additional studies have been done in an effort to identify risk factors for CCL disease—very few were found to be statistically significant.

A 1993 JAVMA study by Whitehair et al evaluated 10,769 dogs with CCL injury compared to 591,548 control dogs and found the following:

Breeds with >1000 dogs represented were Rottweilers, Newfoundlands, and Staffordshire Terriers.
Neutered dogs male or female (age at OHE not a factor) were more likely to develop a CCL injury.
Dogs aged 7 to 10 years and also dogs weighing > 22kg were more likely to have CCL disease.

A study in JAVMA 1999 by Duval et al looking at 201 dogs < 2 years of age compared to 804 age-matched controls found breed predisposition for Neapolitan Mastiff, Akita, St. Bernard, Rottweiler, Mastiff, Newfoundland Chesapeake Bay Retriever, Labrador,
and Amer. Staffordshire Terrier. Again, neutered males and females were common and the body weights of CCL dogs were significantly higher than that of control dogs.

Buote, et al. in a 2009 *VetSurg* case series of 94 Labradors found that age, weight at initial rupture, sex and TPA does not affect likelihood or rate of contralateral CCL or presentation with bilateral CCL. There was a trend toward longer time to contralateral injury for older dogs at presentation and female dogs.

~50% of Labs will rupture contralateral CCL within 5.5mo of initial injury and age, weight, sex, and TPA are not predictive.

Mostafa, et al. in a 2009 *Am J Vet Res* and Regetly, et al. in a 2011 *Vet Surg* describe several significant morphometric characteristics in Labrador Retrievers that are significantly associated with the rupture and in some cases the predisposition to rupture of the cranial cruciate ligament. Some of these variables include tibial plateau slope, proximal tibial conformation, and femoral anteversion.

Additional studies that evaluated enzymatic or collagenase activity, prevalence of collagen autoantibodies, association with major histocompatibility complex, and localization of specific inflammatory markers revealed no specific association of these mechanisms in the pathophysiology of CCL degradation or rupture.

**Clinical Signs**

Clinical signs of CCL disease can include one or more of the following:
- Lameness—ranging from intermittent, to toe-touching to non-weight bearing
- Joint effusion
- Crepitus
- Meniscal click
- Stifle instability
- Medial buttress—palpable thickening of the periarticular tissues of the medial aspect of the stifle
- Muscle atrophy

**Diagnosis**

Diagnosis of a CCL injury can be very easy or very challenging and typically includes:
- Observation of gait—watching the dog move at a walk and trot
- Palpation—checking for effusion, crepitus, range of motion, medial buttress and instability. Important to evaluate in varying degrees of flexion and extension. We recommend evaluating for cranial drawer and cranial tibial thrust, as well as ruling in/out caudal drawer and medial to lateral instability
- Radiographs—lateral and AP or PA views

Less common diagnostics include:
- Joint fluid analysis—evaluate quality of joint fluid as well as cytology
- 4Dx, tick titers—rule in/out tick borne arthropathies
- Advanced imaging—MRI, CT

These less frequently used diagnostics can be helpful for cases in which there is very little instability present and other causes of effusion and degenerative changes need to be ruled out (i.e. immune mediated arthritis, arthropathies due to tick borne diseases, septic arthritis, etc.).

**Radiographs**

Desired views for evaluating the stifle radiographically are a *true lateral* and *AP or PA*, including the stifle and tarsus in each view. The lateral is taken such that the femoral condyles are superimposed. The stifle and tarsus are positioned in 90° of flexion for TPLO planning (facilitates identification of the anatomic landmarks for measurement of the tibial plateau angle) and in a more extended position for TTA planning. The AP or PA view is then obtained to further assess the stifle for arthritic changes and to evaluate conformation of the limb. Ideally, the condyles should both be fully visible and the patella centrally located.

We use these view to evaluate the joint for effusion and disruption of the patella fat pad (increased fluid/soft tissue density in the triangle behind the patellar tendon as seen on the lateral view), degenerative changes (commonly seen on femoral condyles, proximal tibia, and patella), and the presence of “static cranial drawer” (displacement of the tibia cranially in regards to the femoral condyles as seen on the lateral), all of which are suggestive of CCL injury and stifle instability. Radiographs are also used to determine if angular and torsional deformities (more easily noted on the AP view) are present and for measurement of the tibial plateau angle. Digital radiographs and the software measuring tools available provide more accurate measurements with less variability and improved repeatability when compared to regular print radiographs and hand measurement.

Once the diagnosis is confirmed, we then have to make our treatment recommendations. This point is where much of the controversy
occurs. There are several different techniques that have been promoted for addressing stifle instability due to CCL injury. Each technique has its proponents and opponents. In medicine of any kind we (the doctors) ideally make recommendations for treatment based on well designed, evidenced based studies and data—rather than opinion and anecdotal information. And…there’s the rub. There are very few prospective, large studies comparing the various techniques such that we can truly say “this technique is superior”. We often will give progression of arthritis and weight bearing function as benchmarks for evaluating the outcome of a particular technique; however, the following studies do not fully support these as good criteria:

- “In reviewing the evidence currently available, there is no single surgical procedure that has enough data to suggest a potential for long-term success in terms of return to normal function, prevention of osteoarthritis or a claim of superiority to other surgical techniques.”
- Elkins, et al. in JAAHA 1991 compared radiographs in dogs undergoing extracapsular vs. intracapsular repair preoperatively and up to 96mo. Postoperatively. All had significant progression of arthritis over time and there was no significance between the two techniques.
- Conzemius, et al. JAVMA 2005 Conducted a prospective study of 131 Labs with unilateral CCL and medial meniscal injury compared to normal Labs. The study dogs underwent intracapsular, extracapsular or TPLO repairs. Limb function (evaluated via force plate analysis) was measured at 2 and 6 mo postop. No significant difference was found between extracapsular suture and TPLO repairs. The Intracapsular group had significantly lower ground reaction forces at both time periods. When compared to normal dogs 14.9% extracap, 15% intracap and 10.9% TPLO dogs were considered normal. Improvement was noted in 40% extracap, 15% intracap and 34% TPLO dogs.
- Au, et al. VetSurg 2010 Reported a comparison of 35 dogs with extracapsular repair vs. 30 with TPLO repair looking at peak vertical force at 3,5,7wk, 6mo and 24mo postop and radiographs preop and 24mo postop. They found that all had significant increase in radiographic osteoarthritic score at 24mo and no significance difference was found between groups. All also had significant increase in peak vertical force preop to 24mo, but no difference was noted between groups at any time period. All dogs showed improvement after surgery, but neither technique was superior.
- Cook, et al. VetSurg 2010 Reported a prospective study of 47 large and giant breed dogs with CCL injury. This study compared the Tightrope CCL technique (24dogs) vs. TPLO (23dogs). The dogs were evaluated immediately postoperatively and up to 6mo. postop. No significant difference was noted in the amount of cranial tibial thrust present at any time period. Tightrope CCL had significantly less cranial drawer present. There was no significant difference seen between groups in radiographic osteoarthritis scores, or any of the owner questionnaire categories.

However a couple recent studies have found differences in outcomes between techniques:

- Nelson, et al. Vet Surg 2013 found TPLO resulted in a quicker recovery and a higher level of recovery at 1 year over extracapsular stabilization.
- Also in Vet Surg 2013, Christopher et al. found that dogs receiving TPLO and Tightrope repair had improved levels of recovery over TTA.
- A blinded study utilizing force gait analysis by Gordan-Evans et al. JAVMA 2013, found improved weight bearing and owner satisfaction scores in patients treated with TPLO vs Extracapsular stabilization.

So, if current scientific literature won’t definitively tell us what to do, how do we decide? Here are some factors to consider when choosing a technique:

- Dog or Cat
- Size of patient
- Age of patient
- Activity level
- Occupation
- Conformation
- Concurrent disease
- Owner Compliance
- Equipment Available
- Surgeon’s Skill
- Familiarity with technique

Treatment

The four most common techniques done today in our geographic region are the extracapsular, tightrope CCL, tibial tuberosity advancement (TTA), and tibial plateau leveling osteotomy (TPLO). There are some commonalities between these techniques. All strive to achieve stability of the stifle joint. Keys to having a successful outcome with any of these techniques are:

- Case selection
- Knowledge of anatomic landmarks used for the technique
- Knowledge and proper application of the technique
- Appropriate postoperative and home care
- Appropriate rehabilitation

Potential complications that can be seen with any of these techniques include:

- Infection (incisional or implant related)
- Failure of repair
- Persistent instability
- Progression of arthritis
- Ongoing lameness

**Extracapsular Repair**

This technique and variations of it may also be referred to as the Flo tech, DeAngelis tech, lateral fabellar tech, and fishing line tech. The goal of this surgery is to eliminate cranial drawer via placement of suture or prosthetic material from the lateral fabella (anchored under the femorofabellar ligament) to the tibial tuberosity. This technique can be used in any size patient, however, many of us are more comfortable reserving it for patients < 20kg that have tibial plateau angles <28°. Other decisions to be made when using the extracapsular repair is what suture material or prosthetic to use (nylon, prolene, fibertape, etc), whether to just hand tie the knots, use a tensioning device, use crimps or clamps, utilize bone anchors rather than the fabella, etc. In vitro studies have found that when using crimps, two crimps are better than one as failure with a crimp usually results from the material slipping through the crimp tube. The crimp/clamp is superior to the slip knot in strength, elongation and load to failure in cycled and noncycled tests. Crimps also have a smaller profile than hand tied knots (particularly with the nylon material and are a bit more aesthetically pleasing. Tests comparing nylon leader line and fiberwire or fibertape have found that nylon has less strength, stiffness, and more elongation than does the braided fibertape products. However, there may be more risk of infection when using a braided material. In addition to the above mentioned complications, patients undergoing extracapsular repair may sustain peroneal nerve damage (with placement of the fabellar suture) and often have decreased range of motion, especially immediately postop, due to the placement of the suture “across” the joint. Later in the course of healing there will be fibrosis and scar tissue that forms around the permanent suture, which can also limit range of motion. Two to 3mm of cranial drawer is expected even after full healing with an extracapsular repair.

**Tightrope CCL**

The tightrope CCL technique was developed as another extracapsular technique to eliminate cranial drawer while maintaining normal range of motion. By placing the fibertape/fiberwire through femoral and tibial bone tunnels, it strives to achieve a more anatomically correct and isometric repair. Placement of the tunnels is key to success in this procedure. The important anatomic landmarks are the femoral origin of the medial collateral ligament and the long digital extensor fossa.

Like other extracapsular repairs, this technique is best suited to patients with a tibial plateau angle less than ≤30°. Also similar to other extracapsular techniques, approximately 2-3mm of cranial drawer can be expected postoperatively. This technique is designed to use the fibertape/fiberwire material and may have a heightened risk of implant infection as noted above. In light of this, strict sterile technique, usage of a betadine impregnated steridrape, and perioperative and postoperative antibiotics are recommended.

**Tibial Tuberosity Advancement--TTA**

The TTA was developed based on studies of a human model in which it was found that the tibial compressive force was the same as the patellar tendon force. A neutral zone where neither cranial nor caudal translation occurs was identified in people with a patellar tendon angle of about 100°. This study was then replicated in dogs and the neutral zone was identified with a 90° patellar tendon angle. When the patellar tendon angle is < 90° there is a caudal shear force. When it is > 90° there is a cranial shear force. This statement assumes that the total joint force is parallel to the direction of the patellar tendon force. Therefore, in advancing the tibial tuberosity to achieve this “neutral zone,” the TTA eliminates cranial tibial thrust. In theory the TTA does this while minimizing stress on the caudal cruciate ligament because the plateau is not altered. Patients with a tibial plateau angle ≥28° are not good candidates for this procedure.

The TTA uses a frontal plane osteotomy of the tibial crest allowing advancement of the patellar tendon to perpendicular with the tibial plateau. This method maintains the patellar tendon angle ≤90° during weight bearing, resulting in a neutral/caudally directed tibiofemoral shear force when walking. Accurate measurements, preoperative planning, and implant selection are key to success of this procedure. Knowledge of plating techniques is also required. Because this technique involves an osteotomy, implant failure can mean more than just an unstable knee. Implant failure or fracture of the tibial tuberosity typically requires additional surgical intervention to resolve.

**Tibial Plateau Leveling Osteotomy--TPLO**

The TPLO is another “osteotomy” technique that strives to achieve stability of the stifle by eliminating cranial tibial thrust. The TPLO assumes that the total joint force is parallel to the functional axis of the tibia. TPLO uses a radial osteotomy of the proximal tibia to “level out” or neutralize the tibial plateau angle such that the cranial shear force is neutralized and the stifle is stable during weight bearing. Accurate measurement of the preoperative tibial plateau angle (TPA), appropriate placement of the radial osteotomy (as high and caudal as possible), excellent reduction, and stabilization of the newly positioned osteotomy with proper application of the bone plate and screws are essential for success of this procedure. The goal for the final postop TPA is 3-8°, with 6° being reported...
as ideal. Overcorrection can put undue stress on the caudal cruciate ligament and may increase risk of damage to the caudal pole of the medial meniscus as well. Like the TTA, failure of the implants or inappropriate placement of the osteotomy and the implants can lead to disruption of the repair and tibial tuberosity fracture, often requiring additional surgical intervention.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantage</th>
<th>Disadvantage</th>
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<tbody>
<tr>
<td><strong>Extracapsular</strong></td>
<td>Least expensive of 4 techniques</td>
<td>Potentially decreases range of motion</td>
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<td></td>
<td>No/minimal special instrumentation needed</td>
<td>Promotes formation of periarticular scar tissue</td>
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<td></td>
<td>Might be considered “Less invasive”</td>
<td>2-3mm cranial drawer expected/accepted even after recovery</td>
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<tr>
<td><strong>Tightrope CCL</strong></td>
<td>Potential to be done as minimally invasive procedure</td>
<td>Requires some specialized equipment</td>
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<td></td>
<td>More Isometric (than extracap)</td>
<td>2-3mm cranial drawer expected/accepted</td>
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<td></td>
<td>Maintains normal range of motion</td>
<td>Not appropriate for dogs with excessive tibial plateau angles (&gt; 30°)</td>
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<tr>
<td><strong>TTA</strong></td>
<td>Eliminates cranial tibial thrust and minimizes drawer</td>
<td>Requires specialized training, equipment, and instrumentation</td>
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<td></td>
<td>Early return to weight bearing</td>
<td>Not appropriate for dogs with excessive tibial plateau angles (&gt; 30°)</td>
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<td></td>
<td>Allows for concurrent MPL correction</td>
<td>Not ideal with tibial angular or torsional deformity</td>
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<td></td>
<td>Some implant limitations for giant breed dogs</td>
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<tr>
<td><strong>TPLO</strong></td>
<td>Eliminates cranial tibial thrust</td>
<td>Causes mild varus and increases medial compartment loading</td>
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<td></td>
<td>Very stable repair early</td>
<td>Requires specialized training, equipment and instrumentation</td>
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<td></td>
<td>Early return to weight bearing</td>
<td>$$$</td>
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<td></td>
<td>Ideal for dogs with tibial slope ≥ 27°</td>
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<td></td>
<td>Allows for correction of concurrent MPL</td>
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**Prognosis After CCL Surgery**
Prognosis for return to function in patients undergoing these techniques is generally good. As we mentioned initially, when really looked at objectively, no particular technique has been identified as superior. It is important to consider what we are using to measure a successful or not successful outcome. The following have been used:

- Degree of stability—does this translate to degree of lameness or function? Not always.
- Use of the limb—this is a subjective assessment
- Range of motion
- Progression of arthritis—all will have some, can we really prove one has more than the other? Not yet.
- Gait analysis—use of a force plate and measurements of peak vertical force do accurately and objectively measure function. Observation of gait is quite subjective and variable.
- Return to function
- Owner’s opinion—biased because they want it to better, possible placebo effect after paying the surgery bill.
- Surgeon’s opinion—biased because we want a successful outcome.

**What do we recommend for our Lakeshore patients?**
Currently at Lakeshore, we offer the extracapsular and TPLO repairs (and very rarely Tightrope). We strongly encourage TPLO for all our CCL patients, particularly the mid to larger sized dogs and those that continue to be quite active. We do offer and discuss all techniques with the owners and do consider the following factors in trying to assist them in their decision:

- Dog or Cat
- Size of patient
- Age of patient
- Concurrent disease
- Conformation
- Activity level
- Occupation
- Owner Compliance
- Previous repair

**Postoperative Care**
Postoperative care is fairly similar for all techniques. We recommend restricted activity for a minimum of 8 weeks—with 4 weeks of strict confinement then controlled leash walks and supervised rehabilitation exercises for an additional 4 weeks. After this period, the patient is assessed and we gradually increase the activities and exercise allowed.

Dogs typically are discharged with a pain reliever (Tramadol), nonsteroidal anti-inflammatory (Carprofen, Meloxicam, Deracoxib, etc.), and possibly antibiotics (Cephalexin). The infusion of longer acting liposomal bupivacaine local anesthetic (Nocita) into the surgical sites during the procedure has seemed to greatly improved patient comfort during the first few days of recovery and has become standard of care in our hospital. We recommend cool compresses in the immediate postoperative period, followed by warm compresses 5-7 days postop (particularly if there is any evidence of seroma formation). Joint supplements such as Dasuquin are
recommended as a life long supplement. “Good” exercise and weight management are also recommended life long. Approximately 30-60% of dogs with one cruciate injury will develop a contralateral injury sometime within their life.

References available upon request.

Special Thanks to Drs. Teunissen, Buback, and Odders for their contributions to this presentation and handout.

We hope to see you at our next event on Thursday, October 26!
“Congestive Heart Failure: When Oxygen Isn’t Enough”
presented by Andrew Linklater, DVM, DACVECC