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INNOVATIVE MEDICINE FOR ACL REPAIRS IN DOGS

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INTRODUCTION

The acronym ACL, more commonly CCL, stands for the Anterior (Cranial) Cruciate Ligament; the word cruciate means "to cross over" or "form a cross" (cruciate). There are two cruciate ligaments in the knee: the anterior cruciate ligament and the caudal cruciate ligament. These fibrous ligaments located within the knee join the femur and the tibia together allowing the knee to function as a hinged joint. One ligament runs from the inside to the outside of the knee, while the other runs from the outside to the inside of the knee; the ligaments cross over each other in the middle of the knee. The most common orthopedic injury in dogs is a rupture of the anterior cruciate ligament (Christopher, 2011; Hansen, 2011a). This ligament typically ruptures during daily activities due to non-traumatic degeneration of the cranial cruciate ligament over time. Some proposed mechanisms on how this ligament degenerates over time are: immune-mediated joint inflammation, hypoxia of the central part of the ligament, abnormal tibial plateau angle, malformation of the hind-limbs, obesity, and disturbed proprioception (Bogaerts et al, 2018).

For the past two years I have worked as a veterinary technician at Central Hospital for Animals. While working at the clinic, I noticed that Central Hospital for Animals is one of the few clinics that has orthopedic surgeons (they are not board-certified orthopedic surgeons but are specialized in orthopedics) in the surrounding area. Our orthopedic surgeons became specialized by completing training courses for specific orthopedic procedures. We receive referrals from many surrounding states for people to get their pets treated. With this injury being so common, I began to wonder why there are so few orthopedic veterinarian surgeons. A survey performed to measure the economic impact of treating ruptured cranial cruciate ligaments in dogs reported that in 2003, owners spent 1.32 billion dollars in the United States alone on surgical treatment for ruptured cruciate ligaments (Wilke et al, 2005). Cranial cruciate disease has turned the veterinary orthopedic medicine into a billion-dollar business. With a specialty being so profitable and in such high demand, one wonders why is there such a shortage of orthopedic veterinarians?

To become specialized as a veterinarian, additional training beyond veterinary school is required. One can attend educational courses to become specialized to treat specific injuries, or they can become a board-certified surgeon to perform all surgeries within that discipline. To become a board-certified orthopedic surgeon requires "a 1-year internship followed by a 3-year residency program that meets guidelines established by the American College of Veterinary Surgeons" (Anonymous 2019). Once all the requirements are met, the veterinarian must pass a rigorous examination; upon passing, the veterinarian will become a board-certified orthopedic surgeon (Anonymous 2019). Though the demand for orthopedic surgeons is high, the rigor to become certified/specialized may deter many from pursuing this path.

As an undergraduate student pursuing veterinary medicine, I see that there is a great need for orthopedic surgeons that will become problematic once the baby boomer generation retires. According to the United States Department of Labor, "Employment of veterinarians is projected to grow by nineteen percent from 2016 to 2026... Job opportunities will also become available as veterinarians retire" (Anonymous 2018). Therefore, I saw this need as an opportunity to research this multi-billion-dollar injury to identify a potential specialty in line with my vocation. My research on innovative medicine for CCL repairs in dogs may inspire others, who like me, are pursuing a career in veterinary medicine to specialize in orthopedics and alleviate the need for these surgeons.

DIAGNOSIS

Lameness examination

The first step in diagnosing a CCL injury is performing a lameness exam. A lameness examination begins with the doctor observing how the dog stands on its hind limbs. Any observable difference in musculature of the legs, shifting weight, or favoring one leg to stand on can be indicators of a ruptured CCL. Hind limb lameness is typically treated as a torn CCL until proven otherwise through the examination due to how prevalent this issue is in all breeds of dogs. The doctor will also be looking for breed indicators; larger breeds, especially Rottweilers, Labrador Retrievers, Golden Retrievers, American Staffordshire Terriers, Newfoundlands, and St. Bernards, tend to have a higher incidence rate for this disease (Harasen, 2011a).

The next step of the examination is to see if there are any observable differences in the use of the hind legs while walking. Favoring one hind leg can indicate a ruptured CCL of that leg, but a dog with a gait of short, painful steps presenting with an arched back can indicate the presence of a bilateral CCL rupture (Harasen, 2011a). The two most common presentations of CCL ruptures are acute and chronic. In an acute case, the dog typically only becomes lame after mild to moderate activity, but it will go away after rest, which results in it going untreated for several weeks before an owner seeks veterinary help. Chronic cases of intermittent lameness can be present for weeks or months before being diagnosed; this is typically seen in dogs with partial tears and arthritis (Harasen, 2011a). Upon completion of the lameness exam, the veterinarian will begin palpating the stifle joint.

Palpation

Palpating both stifle joints will allow for comparison of the normal limb to the affected limb; in the case of bilateral CCL disease, there will not be a normal leg for reference. By palpating both legs, any thickening of the joint will be very apparent. Palpation is done by taking the thumb and forefinger of each hand and placing them on either side of the patella and moving distally along the patellar tendon. In the case of CCL disease, the borders of the patellar tendon cannot be distinguished due to effusion and fibrous thickening of the joint (Harasen, 2011a). A medial buttress may be detected, typical of chronic CCL disease, which is a fibrous thickening on the proximomedial tibia. The most definitive diagnostic tool for the CCL disease is the cranial drawer test; this tests for the abnormal forward movement of the tibia in front of the femur and indicates laxity in the knee joint (Harasen, 2011a). If the tibia is able to move in front of the femur this results in a positive test for CCL disease, but there is a possibility for a false positive especially in puppies. Therefore, many clinicians will sedate the patient to perform diagnostic x-rays and further palpate the joint without any resistance from the patient.

X-ray radiology

The orthopedic surgeons at Central Hospital for Animals almost always perform x-rays if they suspect there is a torn CCL upon palpation and physical examination. This is a very helpful diagnostic tool that is used to confirm the positive cranial drawer test. On the x-ray, the surgeon is looking for synovial effusion, which is when excess synovial fluid accumulates in and around the knee joint (Sample et al., 2017). Synovial effusion can not only be caused by ligament and meniscus trauma, but it is also caused by arthritis. To make sure that the synovial effusion is a result of a ruptured ligament and not a result of arthritis in the knee, the veterinarian will look for arthritic changes in the knee joint. Arthritic changes are characterized by the wearing down of the cartilage in the knee resulting in a joint that does not look smooth (Sample et al., 2017). If there is a positive cranial drawer test and no sign of pre-existing arthritis (there may be slight arthritic changes in chronic positive cases) then the patient is diagnosed with CCL disease. In addition to x-ray radiology, magnetic resonance imaging radiology can be utilized to obtain diagnostic images of the stifle soft tissue structures.

Magnetic Resonance Imaging radiology

Magnetic resonance imaging (MRI) technology creates diagnostic images of the soft tissues of the body. To utilize this software, the animal needs to be sedated because it must remain still while the scan is in process. As mentioned earlier larger dogs and certain breeds have a predisposition for this injury, which has led to the study of inheritance and gene involvement (Bogaerts et al., 2018). Magnetic resonance technology is being utilized to quantify biomarkers in the stifle to determine CCL fiber damage in dogs with partial tears. The MRI signal reflects the normal CCL structure; when there is a tear, it changes the signal at the ligament attachment sites and displays abnormal looking soft tissue (Sample et al., 2017). Magnetic resonance imaging can also be used to assess macroscopic stifle synovial membrane changes that may influence the risk of ligament damage and future (or current) cranial cruciate ligament ruptures. This technology can be used to assess predisposed breeds for signs of synovial membrane inflammation that would indicate a degenerating CCL ligament; this would allow for early treatment and prevention of rupturing a CCL in these predisposed breeds (Sample et al, 2017). However, magnetic resonance technology is very expensive, and most clinics, especially in rural settings, cannot afford this technology. If there are advancements in preventative medicine for CCL tears in dogs using this technology, many will not be able to utilize the benefit because of the cost.

SURGICAL TREATMENT

Extracapsular lateral suture

The extracapsular lateral suture technique was first described in 1970 as a strong stabilizing suture on the lateral aspect of the stifle joint (DeAngelis and Lau, YEAR). The suture consists of a monofilament nylon leader line of 50–100 lb. breaking strength. The basic concept is that suture material is anchored into drilled holes in the lateral fabella and passed deep to the lateral fascia to the drilled holes in tibia; this will limit cranial drawer movement and rotation of the tibia with respect to the femur (Ledecky et al., 2014). By eliminating cranial tibial subluxation and internal rotation of the stifle joint, the extracapsular lateral suture should mimic the stabilizing functions of the cranial cruciate ligament (Harasen, 2011b). However, studies on operated patients have shown that this method is ineffective because the suture will almost always fail at some point by pulling out at its proximal attachment (Harasen, 2011b). If studies show that this technique will almost always fail eventually, then why is it still being used? I would hypothesize that because it provides stabilization of the joint in most clinical cases, this method does achieve its purpose and needs improvement to develop a permanent fix. Recent developments have been made to improve the extracapsular lateral suture technique. These include using nylon leader line suture material and focusing on the positioning of the suture attachments via bone tunnels and suture anchors. Position focus brought about the development of isometry, which is identifying a location where the suture does not loosen or tighten during joint motion (Harasen, 2011b); this would become the ideal suture attachment location. This technique is still being improved, however, with the development of isometry came the new suture technique: the tightrope cranial cruciate ligament.

Tightrope cranial cruciate ligament

The tightrope procedure is the newest procedure for repairing a ruptured CCL ligament; it is a minimally invasive, cost effective procedure in comparison to the tibial plateau leveling osteotomy (TPLO) or tibial tuberosity advancement (TTA). This technique uses a braided cord that mimics the natural cruciate ligament functions. It has become the preferred method by many veterinarians including the ones at Central Hospital for Animals because it is effective and is the only method that stabilizes the joint in a way that mimics the natural function of the joint. The tightrope ligament is produced by Arthrex Vet Systems, and it is an ultra-high strength (can hold a load up to 225 lbs.), flat, smooth, braided, ribbon-like ligament composed of multi-stranded polyethylene core with a polyester coat (Christopher, Beetem, and Cook, 2011). Due to the strength of this artificial ligament, there is very little chance of the ligament breaking as in the case of the extracapsular technique. The tightrope procedure is a bone to bone technique that utilizes isometric fixation sites (Ledecky et al., 2014). The braided ligament is secured at the isometric points using a surgical button; the tightrope is passed from inside to outside of the femoral tunnel, then from outside to inside the tibial tunnel. A tibial toggle button is rotated and placed on the surface of the tibia, and the tightrope ligament is pulled taut through the tibial tunnel. Then the tightrope ligament is pulled taut through the femoral tunnel and the femoral button is slid down the ligament until it is against the surface of the femur. The ligament is anchored in position by tying it down to the femoral button (Harasen, 2011b). Studies on the long-term outcomes associated with various surgical techniques to repair ruptured CCLs demonstrate that the tightrope procedure is associated with the fewest and least severe complications of all the techniques. The most common major complication reported for the techniques is meniscal pathology; the TTA procedure was associated with the highest rate at 30% of patients followed by the TPLO procedure with 12% of patients, while the tightrope procedure was only recorded to have an incidence rate of 6% (Christopher, Beetem, and Cook, 2011). With the relative ease, shorter total surgery and anesthesia times, better safety profile, and highest success rate of all CCL surgical techniques at 98.7% (Christopher, Beetem, and Cook, 2011), it is expected that veterinarians will develop a preference towards the tightrope procedure.

Tibial plateau leveling osteotomy

The tibial plateau leveling osteotomy (TPLO) procedure changes the geometry of the stifle joint. This procedure does not aim to stabilize the joint, but rather aims to change the biomechanics of the joint so that the animal can walk and bear weight on the limb without a cruciate ligament (Watt, 2000). This is achieved by realigning the tibial plateau perpendicular to the long axis bone. Normally, the tibial plateau slopes caudally at 20-25 degrees. Therefore, a dog will normally walk on the back of the tibial plateau, and the cranial cruciate ligament will prevent the forward cranial tibial thrust during weight-bearing exercises (Watt, 2000). If there is a tear in the CCL, then there is no ligament preventing the forward cranial tibial thrust, and damage to the stifle joint and meniscus will occur. The TPLO procedure begins by taking lateral radiographs of the tibia. The angle of the plateau is made by drawing a line from the most cranial point of the plateau to the most proximal point of the fibular head. Then the first line of the osteotomy is drawn perpendicular to the long axis of the bone at the tibial crest. A second osteotomy line is made parallel to the tibial plateau, and it meets the first line at the caudal cortex of the tibia. These lines cross to form a bone wedge that is removed from the tibia (Watt, 2000). Before removing the bone wedge, the remnants of the CCL are removed, and the menisci are checked and removed if necessary. Doctor Barclay Slocum, the man who created this technique, proposed that a meniscal release should be performed by, "Cutting the caudal intermeniscal ligament or by transecting the entire medial meniscus at the intersection between the middle and caudal thirds" to prevent further meniscal injury after surgery (Harasen, 2011b). Upon closing the wedge, a compression plate that is dependent on the size of the animal is placed on the tibial cortex (Watt, 2000). Dog size greatly influences the method chosen for CCL repair; small dogs are more likely to undergo an extracapsular suture procedure, mini-tightrope procedure, or to be managed conservatively than to have a TPLO. This is primarily due to small dogs having steeper tibial plateau angles than large dogs; this has been associated with increased complications such as patellar tendonitis, tibial tuberosity (TT) fracture and implant failure (Knight, 2018). The increased risk in complications has been linked to surgeon experience level in studies stating, "For TPLO procedures performed by residents were significantly and 2 times more likely to be associated with a major complication than those performed by a board-certified surgeon" (Christopher et al., 2011). Therefore, this procedure may not necessarily have higher risk for small dogs, the risk may just be higher because the surgeons choose other methods of repair in the small breeds, which will increase their complication level for this procedure due to lack of experience.

Tibial tuberosity advancement

The tibial tuberosity advancement (TTA) is similar to the tightrope technique in that its goal is to reconstruct the dynamic stability of the CCL, but the process is more like that of the TPLO because this dynamic stability is accomplished by reducing the patellar tendon angle. The surgical technique is based on the Maquet procedure, which is used to reduce pain related to osteoarthritis of the patellofemoral joint (Zhalniarovich, 2018). During this procedure the tibial crest remains intact, and forks and cages are introduced into the osteotomy line to advance the tibial tuberosity implant. Electrocautery is used to make the skin incision because it allows for control of bleeding; the skin incision is made from the parapatellar region to the proximal tibia on the medial side (Zhalniarovich, 2018). The drill is positioned precisely in both the craniocaudal and proximodistal planes of the tibia. In the proximal hole, K-wire is inserted " perpendicular to the straight patella ligament into the distal infra patellar bursa" into the long leg of the drill guide (Zhalniarovich, 2018). Another K-wire is inserted into the shorter drill guide for the cranial cortical thickness of the tibial crest. The osteotomy line is made perpendicular to the craniocaudal plane, and a bone spreader is used to slightly widen the osteotomy line (the spreader has a scale to prevent the osteotomy line from opening excessively). With the osteotomy line widened, the tibial tuberosity implant is slowly advanced into place; the implant is then fixed in place using titanium screws (Zhalniarovich, 2018). However, this procedure is not associated with full function outcomes of the CCL in studies compared to the tight rope and TPLO procedures where full function of the stifle joint is typically regained (Christopher et al., 2011). The TTA procedure is ten times more likely than the tightrope procedure and four times more likely than the TPLO procedure to be associated with an unacceptable outcome and partial function of the stifle joint (Christopher et al., 2011). The tightrope and TPLO procedures may be superior to the TTA procedure in that they are associated with regaining full function of the ligament, and that the TTA procedure has the highest rate of complications for all procedures. However, client and veterinary medical record assessments concluded that the tibial tuberosity advancement has a high long-term success rate of 90% in dogs (Christopher et al., 2011).

HOSPITALIZATION

Bandage care

A pressure bandage is applied to the wound site for three to five days to reduce swelling and inflammation of the joint and surgical site; a pressure bandage also helps limit the motion in the stifle to aid in healing. The bandage is made by wrapping the leg with a layer of cast padding. Then a roll of stretch gauze is wrapped over the cast padding. CoFlex (vet wrap) is a self-adhesive wrap that compresses the bandage and holds it in place on the leg. Waterproof tape is applied to the top of the bandage around the thigh to prevent the bandage from slipping down. One crucial element of bandage care is ensuring that the bandage remains dry; since the cast padding is made of cotton, if it gets wet it will absorb and retain water. This can result in the necrosis of the tissues in contact with the wet bandage if not changed. The most common place for the bandage to get wet is at the bottom where the patient's foot and toes are. At Central Hospital for Animals, we send clients home with a "boot" we make out of dried fluid bags and gauze wrap; this acts as a waterproof cover for the foot to be used when walking the patient outside. Another important element of bandage care is to ensure that the toes of the animal are not swollen. Swelling of the toes will indicate that the bandage is too tight. If swelling is noticed in the toes, the bandage can be cut slightly near the foot to alleviate pressure. However, if that does not reduce swelling within a few hours, then the bandage will need to be rewrapped. CCL patients are hospitalized for at least one day post procedure to monitor, but before they are sent home their bandage is rewrapped so that the incision site can be checked. The owner is instructed on how to properly care for the bandage and told to return for bandage removal (if they are not comfortable removing it themselves) in two to three days. The bandage can come off sooner if needed because the critical amount of time to reduce inflammation is twenty-four hours, which will be achieved during the hospital stay.

Supportive care

Hypothermia is one of the greatest risks for small animal surgical patients. Due to the lengthy procedures to repair the CCL, there is even greater risk for hypothermia in patients. Therefore, an electric water circulating blanket is placed underneath the patient during the surgery to keep the patient warm. These blankets work by cycling water through a warming pump and into the blanket to keep the blanket at a constant temperature. Throughout the surgery and hospitalization, the vitals of the patient will be constantly monitored. After surgery the patients are placed on heat support until their body temperature is consistently within normal limits for a few readings. Pain relief, such as morphine, is used during and a few hours post-surgery if needed to keep the patient comfortable. The patient will also be sent home with a non-steroidal anti-inflammatory drug to reduce pain and inflammation for about a week post-surgery; one of the most common NSAIDs used for CCL patients is Previcox. Sling support reduces the weight on the patient's good rear leg while walking, since most of the time post-surgery dogs are non-weight bearing on their surgical leg for a few days. Recent studies show that limb function improves significantly faster when the patient is mobile and undergoing post-operative physiotherapy because it prevents atrophy of muscle, stiffness, and unwillingness to use the leg (Wild, 2017). Physiotherapy promotes faster healing in many orthopedic cases including ruptured cruciate ligaments (McCormick et al., 2018).

Restorative therapy

Hydrotherapy and laser therapy are used to reduce pain and promote faster healing in post-operative patients. These therapies will begin while the patient is hospitalized and will continue for a couple weeks or months during the recovery period. Hydrotherapy utilizes pools and water treadmills as a way to provide mobility in a low stress environment for the joints. Research indicates that hydrotherapy experienced superior levels of analgesia in comparison to land based walking, and it was also noted that, "After six weeks the underwater treadmill subjects demonstrated no discernible difference between affected and non-affected limbs" (Wild, 2017). Canine hydrotherapy is also beneficial for neurologic disorders, soft tissue injuries, weight loss, and overall body conditioning (McCormick et al., 2018). Since the majority of dogs' sweat glands are located on their paw pads, during hydrotherapy, sweat is not allowed to evaporate for cooling. Therefore, the animal must rely on panting to cool itself. To prevent dogs from overheating during exertion and cooling during immersion into the pool or water treadmill, the optimum water temperature is kept at a constant thirty degrees Celsius (Wild, 2017). The warm water temperature improves circulation to the soft tissues, thus, promoting healing. One important factor to consider when using the water treadmill is the water level. Small dogs may experience strain on their vertebrae if they must lift their head above the water if the level is too high. The water level must be adapted to suit the patient's size and conformation, and the speed of the treadmill must be monitored to not surpass the physical strengths of the patient (Wild, 2017).

Laser therapy is a new rehabilitation technique utilized for therapeutic purposes. At Central Hospital for Animals, all CCL patients receive laser therapy treatments to promote healing. In a study done on the efficacy of laser therapy for incision healing in dogs, "the surgical incisions in these dogs healed faster and more cosmetically with photobiomodulation (PBM) induced by laser therapy daily for 7 days" (Wardlaw et al., 2019). Beginning at seven days post-operation an improvement in both the healing and cosmetic scores could be seen; there was continued improvement for three weeks post-surgery (Wardlaw et al., 2019). In experimental studies, laser therapy has been used to reduce pain, positively influence inflammatory, proliferative, and maturation phases of wound healing and increase wound tensile strength. However, these studies were performed on laboratory animals, and does not account for the difference in wound healing between species (Wardlaw et al., 2019). Though there are various accounts of the positive benefits of laser therapy for wound healing, there is no set protocol for any condition to be treated. Recent studies have found that, "surgery in combination with PBM decreases the time to ambulation in dogs with T3-L3 myelopathy secondary to intervertebral disk herniation using a wavelength of 810 nm and an energy output of 200 mW" (Wardlaw et al., 2019). Laser therapy is still a very new restorative therapy that needs to be researched more to prove its efficacy and to create treatment protocols for different illnesses.

POST OPERATIVE CARE AND RECOVERY

Recovery time

The recovery time is going to take a couple months. Initial use of the limb with toe-touching occurs within the first four days after surgery. For the first three weeks, postoperative care includes cage confinement and sling-walks only for toilet needs. After the initial three weeks, the level of exercise should slowly be increased from ten minutes daily to thirty minutes daily; this exercise must be leash only to prevent over exertion of the limb (Watt, 2000). Weekly visits for the first month are required to ensure that the patient is healing properly, and a few monthly checkups after. The recovery from this type of injury is very slow; it will take time, patience, and dedication from the owners to ensure their dog heals properly.

Restrictions

Most of the restrictions are activity based since over exertion of the limb can cause injury. Therefore, no running, jumping, or climbing for at least eight weeks. Cage restriction is advised when the owners are not around to ensure that the patient is not over exerting the leg. Sling walking the patient up and down stairs to assist in climbing if necessary, to get outside to avoid pressure on or torsion of the limb. Also, the patient should be strictly leash walked until the leg is deemed fully healed by the veterinarian to prevent re-injury to the leg. The last restriction is diet. Since the animal is not going to be very active for a prolonged period of time, it is essential to adjust the caloric intake to prevent the pet from gaining weight. Obesity puts added weight on all of the joints and has been linked to contribute to CCL disease and the degeneration of the cruciate ligaments (Bogaerts et al, 2018). CCL patients have a one-in-three chance of subsequently suffering CCL injury in the contralateral leg within eight months of the first, which may be due to the weight transfer onto the other limbs (Wild, 2017). Therefore, limiting the amount of extra weight is imperative to the prevention of a CCL injury in the contralateral leg.

Long term treatment

Long term treatment on NSAIDs may be needed for the duration of the animal's life to treat any pre-existing or developing osteoarthritis (Wilke et al., 2005). Osteoarthritis will develop in most patients even with surgical intervention. A gradual increase of exercise over the course of months to strengthen the limb will be required. Close monitoring of the pet is crucial because the risk of rupturing the other CCL is very high. Again, weight management is going to be key in the long-term treatment and success of the operation. A healthy weight puts less stress on the joints, which will help with mobility, developing osteoarthritis, and preventing a contralateral rupture.

CONCLUSION

There are many ways to treat a ruptured CCL, the most effective are through surgery. With all of the benefits of the tightrope procedure, there is no surprise that veterinarians are making this their preferred method of choice. With this injury being the most common orthopedic injury in small animals, there is a need for innovative medicine and orthopedic doctors. Hydrotherapy and magnetic resonance imaging are innovations that will greatly improve the recovery and prevention of the CCL injury. However, these technologies are very expensive, which leaves them inaccessible to most clinics. Laser therapy has very promising benefits from studies on wound healing, but there is still a lot of needed research to create treatment protocols for different illnesses. Great improvements have been made in the treatment of CCL disease, but there is still a great need for innovative techniques to prevent this injury.

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