Cranial cruciate ligament (CrCL) insufficiency is one of the most common causes of lameness in dogs. Partial or complete CrCL rupture causes stifle joint instability and triggers a cascade of secondary pathological changes including progressive osteoarthritis and subsequent meniscal injury. Numerous surgical techniques have been described to manage CrCL insufficiency, each having potential or proven advantages and disadvantages. In this lecture we will discuss the decision-making progress when presented with a dog or cat with CrCL injury. The best treatment must account for individual mechanical, biological and clinical variations. We will discuss the current best evidence and offer personal opinions and tips based on our own experience of the surgical management of CrCL disease in our practice (which currently treats over 15-20 cases of CrCL disease every week).

The exact aetiopathogenesis of CrCL disease is incompletely defined and controversial. Although acute CrCL rupture does occur secondary to trauma, a number of previous studies have suggested that the majority of CCL ruptures are secondary to CCL disease. Several risk factors have been proposed (breed, body weight, neutering) as well as conformation factors, inactivity and obesity association. More recently, genetic and inflammatory factors and changes in the extracellular matrix of the CrCL have been proposed as contributory factors to the aetiopathogenesis of CrCL disease. There are excellent discussions concerning the putative genetic and environmental influences on CrCL disease published elsewhere.

A consequence of the ongoing uncertainty regarding the etiopathogenesis of canine and feline CrCL disease is a lack of consistency in what is deemed optimal management. This problem has been compounded by the scarcity of high quality prospective randomised controlled studies comparing the most commonly selected surgical techniques. Decision-making in small animal fracture management has been greatly facilitated by the development of a fracture assessment scoring system, which considers the important biological, mechanical, and clinical factors influencing the healing environment. We propose that a similar system can be applied to CrCL disease.

**Biological factors**

**Age:** Presence of significant ongoing growth potential may have an impact on surgical technique. So called “dynamic TPLO” (whereby induced premature closure of the cranial aspect of the tibial plateau) may be an option in young dogs with significant remaining growth potential. To date, there have been no studies comparing the quality of tibial osteotomy healing with animal age. Regardless of animal age, surgical techniques that result in rapid, robust healing, and early return to normal function should be favoured. Techniques with a reputation for rapid healing and recovery may be especially appropriate for older dogs with suboptimal biological healing potential.

**Breed:** There may be an important biological breed effect. For example, Boxer dogs may have a higher risk of an etiopathogenesis involving lymphoplasmacytic synovitis. Giant breed dogs have advantages with respect to the speed of osteotomy healing, although this must be weighed against the negative mechanical impact of increased patient size and weight.

**Body condition:** Recent advances in the understanding of the influence of body fat on the processes involved in osteoarthritis have highlighted the involvement of certain pro-inflammatory cytokines including Leptin. Recent work by Conzemius and others has demonstrated an equivalent short-term effect of weight loss compared to weight loss coupled with TPLO. Whether the improvement is a result of improved biology or improved mechanics is unknown. Although the potential mechanical effects of excessive body condition score are obvious, the biological effects of high body fat on healing after stifle surgery are poorly understood.

**Other biological factors** worthy of discussion include the influence of systemic disease (including the presence of polyarthritides), previous surgery, and the presence of other pathology within the affected joint. An approach to the stifle joint as an organ system is encouraged. The presence of meniscal pathology,
advanced cartilage disease and bacterial infection are examples of biological factors that could exert an important biological effect on this organ system. In a recent study of 1000 dogs operated by TPLO, the author documented incidence of primary meniscal injury at 33.2% and subsequent meniscal injury 2.8%; we found that complete CrCL rupture was a statistically significant risk factor for primary meniscal injury. For TTAs performed by the author the delayed meniscal tear rate was 15.38%.

Mechanical factors

Breed, weight and body condition: In the 1980s Vasseur and others investigated the effects of dog weight on outcome after non-surgical management for CrCL disease. Since then, the dogma has persisted suggesting that dogs weighing less than 15kg perform well when managed non-surgically whilst dogs weighing greater than 15kg have a suboptimal outcome. Further randomised controlled study would be particularly useful to investigate the outcome of non-surgical versus surgical intervention for degenerative CrCL disease in small breed dogs and cats. The author does not concur with this popularly held opinion and will discuss the influence of these important mechanical factors on the decision-making processes.

Conformational/Anatomic factors:

Tibial plateau angle (TPA): There has been widespread debate regarding the relationship between TPA and canine degenerative CrCL disease. Even if an absence of any aetiopathogenic influence of excessive TPA on CrCL disease is accepted, there are important mechanical factors to consider when treating animals with an excessive TPA.

Posture: There are multiple postural variations that have been associated with degenerative CrCL disease in dogs. For example, straight-legged postures in Japanese Akitas and internal torsion of the tibia in dogs with genu varum and concurrent medial patellar luxation have both been implicated in the pathogenesis of CrCL disease. It is especially important to be aware of an individual’s “normal” posture when planning surgical treatment via tibial osteotomy.

Shape of the proximal tibia: The choice of tibial osteotomy may be influenced by individual variations in the morphology of the proximal tibia. In some cases, these variations can be extreme. This pertains to both tuberosity dimensions and plateau angle in the sagittal and transverse planes. In our opinion, this is one reason why no single surgical technique is applicable to all animals.

Abnormalities in the location or fixation of the lateral fabella: It is often recognised that the lateral fabella has a variable anatomy and is even absent in some animals. The femorofabellar ligament also varies in its mechanical properties. Care should be taken when considering this structure as an anchor for an extracapsular prosthesis, as this structure may not be sufficiently strong or durable in some animals.

Presence of tibio-fibular ankylosis: The finding of exuberant osteophytosis surrounding the proximal tibio-fibular articulation might prompt caution when considering TPLO. Rotation of the tibial plateau segment can be challenging under these circumstances.

Previous surgical intervention: The author has successfully revised 58 stifle surgeries in 56 dogs previously operated by extracapsular repair, using TPLO. Some technical modification may be required when considering TPLO in dogs where the tibial bone tunnel is very large at the time of revision surgery.

Traumatic CrCL injury and multiligamentous injury: In our clinic, traumatic CrCL injury is frequently managed using extracapsular techniques (Tightrope™, Arthrex, Naples, FL). We will describe our experience with the surgical management of traumatic CrCL injury with severe shear instability of the tibia relative to the femur, and in animals with multiligamentous injuries affecting the stifle joint. This will include both constrained and unconstrained total stifle replacement prostheses.

Concurrent mechanical orthopedic pathology: Other orthopedic disorders that can influence surgical decision-making include the presence of concurrent patellar luxation, hip dysplasia, or contralateral CrCL disease. For animals affected by simultaneous bilateral CrCL disease, options exist for simultaneous bilateral surgical management. We will share our own experience of simultaneous bilateral TPLO, which occurred in 14.6% of cases and no statistically significant complication incidence was recorded for bilateral surgeries performed simultaneously or staged. The author has described two modified osteotomy procedures
for treating CrCL disease in the presence of concomitant patellar luxation or genu varum respectively with tibial tuberosity transposition advancement (TTTA) and Tibial plateau levelling medial opening crescentic osteotomy (TPLMOCO).

*Partial or complete tear of the CrCL:* This frequently influences surgeon’s choice of technique when deciding whether to employ an osteotomy or a ligament augmentation/replacement procedure. Some reports support leaving partial tears in situ when performing osteotomy procedures, whilst the author has perceived lameness in patients subsequent to TPLO which resolved after subsequent ligament excision.

*Feline CrCL injury:* Feline CrCL disease has a degenerative form, which has been likened to CrCL disease in small breed dogs (affecting older, overweight cats, with a high frequency of bilateral disease), and a traumatic form which is often accompanied by injuries to other (peri)articular structures. Data describing the optimal management of CrCL disease in cats is even more limited than in dogs. Controlled study is warranted to establish any differences in outcome for non-surgical management versus extracapsular repair and tibial osteotomy. We will share our experience with TightRope™ extracapsular repair, TPLO and TTA in cats and will also describe indications and outcomes for total stifle replacement.

**Clinical factors:**

**Patient factors:**

*Activity level:* Anticipated ongoing pet versus working dog function is an important clinical consideration. Techniques that favour rapid return to optimal function should always be favoured in performance dogs. Potential problems with exercise restriction in the early post-operative period must also be discussed thoroughly.

*Animals at higher risk for sedation and general anaesthesia:* In some cases, these considerations preclude surgical intervention, and optimal recovery is dependent on the best available physiotherapy. For high-risk animals treated surgically, the best technique may be the one that can be performed with the shortest possible time under general anaesthesia.

*Other potentially important patient factors* include demeanour, and the presence of concurrent medical or orthopaedic problems.

**Owner factors:**

*Financial constraint:* Careful counselling is required regarding the anticipated costs and the potential for complications. Dealing with complications can incur significant extra costs. A surgical technique that is cheaper at the outset but carries a higher likelihood of postoperative complications may ultimately result in a higher incurred cost. Predicted costs must also consider the possibility or probability of subsequent contralateral CrCL disease.

*Owner preference or preconception:* A large amount of data on canine CrCL disease is available online through multiple common search engines. It is important that owners recognise that, while some of the data is based on good quality evidence, a large part is based on personal opinion and anecdote.

*Other important owner factors* include the likelihood for excellent compliance, and the availability of local facilities for postoperative rehabilitation.

**Surgeon/Facility factors:**

*Skill and Bias:* The surgeon is a vital determinant of the optimal treatment plan for CrCL disease. Factors to consider include personal experience and bias, including how long the surgical time is for a given procedure. For example, the author has reported an overall complication rate of 14.8% for TPLO, which represents the lowest complication rate published to date for any technique described for the treatment of CrCL rupture in dogs (TTA 31%, fibular head transposition 16.5-27%, extracapsular repair 17.4%, previous TPLO 16.5-27%). TTA currently carries an overall complication rate of 18.18% in the author’s hands.

*Available surgical facilities and equipment,* including access to rehabilitation facilities.
Infection rates for different procedures: Perception of protocols or techniques within an individual establishment may vary with regard to certain techniques, especially in reference to infection rates. The author recently reported a 6.6% infection rate following TPLO in a large case series, which is the highest of any technique in the author’s facility. Various strategies have been employed, including patient preparation, aftercare and definitive reasoning for technique choice to reduce this complication. Similarly, surgeons may have experienced increased infections with the TightRope™ technique (75% of all complications seen with this technique when used by the author – overall complication rate 19%). These factors will influence decision making.

In conclusion, whilst presently decision making for treatment of CrCL impairment in dogs is largely subjective, the author proposes that a more structured approach and objective risk-assessment using the assessment scoring system proposed here may help to decide which technique to employ for a given patient, especially as more standardised, controlled cohort studies become available. Whilst the author feels it is important to share experiences and tips based on significant case numbers, it is more important to recognise that the joint is a complex organ system with many biologic and mechanical influences and decision making should be based on best available evidence for that particular animal in those particular circumstances rather than on bias or anecdote.

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