Effect of surgical technique on limb function after surgery for rupture of the cranial cruciate ligament in dogs

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Objective—To determine the outcome and effect of surgical technique on limb function after surgery for rupture of the cranial cruciate ligament (RCCL) and injury to the medial meniscus in Labrador Retrievers.

Study Design—Prospective clinical study.

Animals—131 Labrador Retrievers with unilateral RCCL and injury to the medial meniscus and 17 clinically normal Labrador Retrievers.

Procedure—Affected dogs had partial or complete medial meniscectomy and lateral suture stabilization (LSS), intracapsular stabilization (ICS), or tibial plateau leveling osteotomy (TPLO). Limb function was measured before surgery and 2 and 6 months after surgery. Treated dogs were evaluated to determine the probability that they could be differentiated from clinically normal dogs and tested to determine the likelihood that they achieved improvement.

Results—No difference was found between LSS or TPLO groups, but dogs treated with ICS had significantly lower ground reaction forces at 2 and 6 months. Compared with clinically normal dogs only, 14.9% of LSS-, 15% of ICS-, and 10.9% of TPLO-treated dogs had normal limb function. Improvement was seen in only 15% of dogs treated via ICS, 34% treated via TPLO, and 40% treated via LSS.

Conclusions and Clinical Relevance—Surgical technique can influence limb function after surgery. Labrador Retrievers treated via LSS, ICS, or TPLO for repair for of RCCL and medial meniscal injury managed with partial or complete meniscectomy infrequently achieve normal function. Results of LSS and TPLO are similar and superior to ICS. (*J Am Vet Med Assoc* 2005; 226:232–236)

Rupture of the cranial cruciate ligament (RCCL) is arguably the most common cause for lameness in dogs.[1] Since 1952, when the principals for surgical management of RCCL in dogs were first extensively characterized,[a] numerous surgical techniques have been described, each with theoretical or realized advantages and disadvantages. According to 1 report, diplomates of the American College of Veterinary Surgeons most commonly perform 1 of 3 surgical techniques in large-breed dogs with RCCL: **lateral suture stabilization (LSS)**, **intracapsular over-the-top stabilization (ICS)**, or **tibial plateau leveling osteotomy (TPLO)**.[b] In 1970, DeAngelis and Lau[2] described an LSS technique that incorporated placement of sutures from the lateral femoral fabella to the distal aspect of the patellar ligament. The LSS, or a modification, is a relatively simple technique that remains the most commonly performed surgical treatment for RCCL in dogs, regardless of patient size.[b] Similarly, a number of technical variations have been described for ICS, which has been used for decades. In contrast, ICS is technically more demanding, involving the harvest and placement of an intra-articular autograft through the femoral trochlear notch and over the proximal and caudal aspect of the lateral femoral condyle. The TPLO, first described in a patent[3] in 1987 and later in a review article[4] in 1993, involves osteotomy, rotation, and then stabilization of the proximal portion of the tibia in an effort to provide dynamic stabilization of the stifle joint. Since its conception, the popularity of this technique has increased to the point that at many hospitals, it is now the most commonly performed treatment for RCCL in dogs.

These techniques differ not only in concept but also in technical difficulty, invasiveness, necessary equipment, licensing, and cost to the owner. These differences have led to much controversy about which surgical technique provides the best and most consistent prognosis. In 1986, Fallon and Tomlinson[c] reported that surgical technique had little influence on eventual outcome after evaluating prognostic indicators in 80 consecutive cases of RCCL. In 1996, Chauvet et al[5] reported no difference in lameness scores, stifle joint instability, or results of force platform analysis in dogs treated with LSS or fibular head transposition. In contrast, Timmerman et al[6] evaluated 88 patients 6 months after RCCL surgery and found that dogs treated with LSS had better outcome than dogs treated with an ICS procedure. Similarly, Moore and Read[7] reported that limb function in dogs treated with LSS appeared superior to that in dogs treated with a fibular head transposition. This finding, however, was not supported statistically. Finally, Meterman et al[8] reported that surgical technique influenced the frequency of meniscal injury after stabilization of RCCL. Although each of these reports contributes valuable information, they are lim-

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ited by a lack of prospective objective patient evaluation, a study of various breeds, a large variation in the timing of the postoperative examination, and an absence of the evaluation of the TPLO technique. The purposes of the study reported here were to objectively determine the effect of surgical technique on limb function in dogs (Labrador Retrievers) after surgery for RCCL and injury to the medial meniscus, compare limb function in dogs with RCCL with that of clinically normal Labrador Retrievers, and determine the likelihood that dogs with RCCL had clinically substantial improvement. We hypothesized that surgical technique would not influence outcome.

Materials and Methods

From June 1998 to September 2002, all Labrador Retrievers that were admitted to the Veterinary Teaching Hospital at Iowa State University for RCCL were evaluated for inclusion in the study. Criteria for inclusion included Labrador Retriever breed; diagnosis of unilateral RCCL on orthopedic examination that was confirmed at surgery; partial or complete medial meniscectomy performed at surgery; stabilization of the stifle joint by use of the LSS, ICS, or TPLO procedure; no intraoperative complications; no use of antiinflammatory medication for 7 days prior to gait analysis; and acquisition of preoperative and 2-month and 6-month postoperative gait analysis evaluations. To limit breed variability, only Labrador Retrievers were used. Dogs were allocated into treatment groups on the basis of owner and surgeon preference. The LSS was performed with leader line sutures of various sizes from the lateral femoral fabella to a hole in the proximal tibia tuberosity. The ICS was performed with an autograft (medial patellar tendon graft) that was passed over the top of the lateral femoral condyle. The TPLO was performed as described in the TPLO licensing course. In addition, all dogs had either partial or complete medial meniscectomy after visual inspection of the medial meniscus. Force platform gait analysis[d] was performed prior to surgery as described[9] at a walking velocity (velocity, 1.0 to 1.3 m/s; acceleration, ± 0.5 m/s^2) and was repeated at 2 and 6 months after surgery. Specifically, dogs evaluated between 7 to 9 weeks after surgery were considered for the 2-month evaluation and dogs evaluated between 5.5 and 6.5 months were considered for the 6-month evaluation. In addition, force platform gait analysis was performed on 17 clinically normal Labrador Retrievers. These dogs were owned by faculty, staff, or students at the College of Veterinary Medicine and were determined to be clinically normal on the basis of patient history, physical examination, and radiography of stifle joints.

Statistical analyses—Pairwise tests (*t* tests or χ^2 tests) were used to determine whether the surgeon's experience and patient's weight, age, body condition score, and duration of injury prior to surgery were equal between groups. Age, weight, sex, body condition score, duration of the lameness prior to admission, surgeon, and surgical technique performed were recorded and evaluated to assess their relationships with 6-month limb function by use of Pearson's correlation for continuous outcomes or Kendall's tau for ordinal outcomes. To determine the effect of surgical technique on 2- and 6-month limb function, a repeated-measures ANOVA followed by a cross-sectional analysis was performed with a linear regression model, with 2- and 6-month limb function as the dependent variables and the previously mentioned variables as covariates. All data are reported as mean ± SD. In addition, limb function was determined in all dogs by use of a multivariate statistical method that simultaneously evaluated several ground reaction forces.[d] The ground reaction forces evaluated in this method include mean falling slope, **peak vertical force (PVF)** determined as percentage of body weight, and **vertical impulse (VI)** determined as percentage of body weight. A logistic regression equation was then applied to determine the probability that an individual dog, 6 months after RCCL surgery, could be differentiated from the population of clinically normal dogs. The cutoff used for normal function was the probability that maximized the sensitivity and specificity of the regression equation[c] (80% probability of normal function).

A clinically important improvement was defined as an improvement such that at the time of reevaluation, a dog in the treatment group was more clinically normal than abnormal.[10] Specifically, at the 6-month recheck, limb function as defined by vertical forces was closer to mean limb function of clinically normal dogs or closer to mean limb function of dogs with RCCL before surgery. For all comparisons, $P < 0.05$ was considered significant. The Bonferonni correction was used when needed.

Results

Of 253 Labrador Retrievers evaluated, 131 met all inclusion criteria (LSS [n = 47], ICs [20], and TPLO [64]). The most frequent cause for elimination from the study was a diagnosis of bilateral damage to the CCL (n = 86), followed by failure to gather postoperative data. No significant difference was found between groups when the likelihood of a dog returning for follow-up examinations was evaluated. Overall, 78.4% (n = 131) of dogs that fit the inclusion criteria at the initial time of hospitalization returned for reexamination; the remaining 36 dogs were not included in this study. There was no significant difference between groups in body weight, age, body condition score, duration of injury prior to surgery, or surgeon's experience.

Age (r^2 = 0.06), body weight (r^2 = 0.08), and duration of lameness prior to surgery (r^2 = 0.12) were significantly correlated with 6-month limb function. Body condition score and surgeon experience were not significantly correlated with 6-month limb function.

Dogs treated via LSS had a mean PVF of 26.36 ± 9.84% and VI of 8.69 ± 3.63% before surgery **(Figures 1 and 2)**. Two months after surgery, dogs that had LSS performed had a mean PVF of 31.12 ± 7.27% and VI of 9.97 ± 3.07%, and 6 months after surgery, mean PVF was 40.15 ± 5.0% and VI was 13.59 ± 1.82%. Prior to surgery, dogs that had ICS performed had a mean PVF of 26.47 ± 7.38% and VI of 8.61 ± 2.63%. Two months after surgery, mean PVF was 26.67 ± 5.14% and VI was 8.34 ± 1.74%, and 6 months after surgery, mean PVF was 36.34 ± 5.49% and VI was 12.27 ± 2.12%. Dogs that had TPLO performed had a mean PVF of 26.87 ± 7.42% and VI of 8.77 ± 3.56% before surgery. Two months after surgery, they had a mean PVF of 31.77 ± 5.12% and VI of 10.86 ± 2.57%, and 6 months after surgery, mean PVF was 40.71 ± 4.95% and VI was 13.56 ± 1.82%. There was no significant difference between treatment groups for PVF or VI prior to surgery. Dogs that had LSS or TPLO had significantly increased PVF and VI at 2 and 6 months after surgery. Dogs that had ICS performed had a significant increase in mean PVF and VI only at 6 months after surgery. When mean function was compared among groups, there was no difference between LSS and TPLO groups

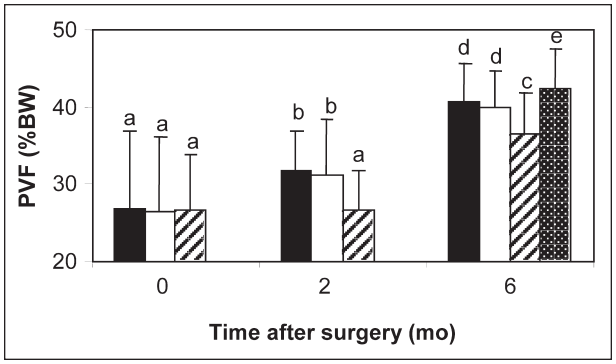

Figure 1—Mean ± SD peak vertical force (PVF) of clinically normal dogs (stippled bar [6 months only]) and dogs with rupture of the cranial cruciate ligament treated via tibial plateau leveling osteotomy (solid bars), lateral suture stabilization (open bars), or intracapsular stabilization (striped bars) prior to surgery and at 2 and 6 months after surgery. [a-e]Different letters indicate significant ($P \leq 0.05$) differences among groups across all 3 time periods. BW = Body weight.

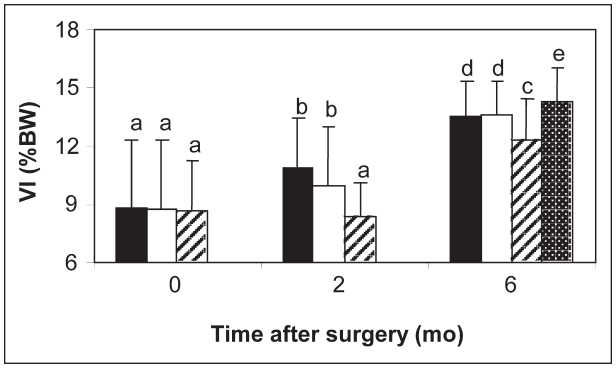

Figure 2—Mean ± SD vertical impulse (VI) of the dogs in Figure 1. *See* Figure 1 for key.

over the duration of the study or at any single time period. Dogs that had ICs performed had a mean PVF and VI that were significantly less than that of the dogs in the LSS and TPLO groups over the duration of the study and at the 2- and 6-month time periods. Clinically normal dogs had a mean PVF of 42.55 ± 5.76 and a VI of 14.09 ± 1.90, which was significantly greater than all treatment groups.

When an 80% probability of normal limb function was used as a cutoff, only 14.9% of dogs that had an LSS, 15% of dogs that had an ICS, and 10.9% of dogs that had TPLO could not be distinguished from clinically normal dogs 6 months after surgery. No significant difference was found among these proportions.

After surgery, most dogs failed to make clinically substantial improvement (as per our definition) toward normal limb function. Improvement was seen in 40% of dogs that had an LSS, 15% of dogs that had an ICS, and 34% of dogs that had a TPLO. There was no significant difference between LSS and TPLO groups, but the likelihood of clinical improvement for dogs in the ICS group was significantly different from the other techniques.

Discussion

We elected to focus this project on Labrador Retrievers because they have been identified as a breed that is substantially predisposed to RCCL and they are common in our geographic region.[11,12] Outcome was determined by use of force platform gait analysis because it is an objective, sensitive test for limb function in dogs. Furthermore, it has been reported to be more sensitive than visual observation of gait for detecting limb function abnormalities in Labrador Retrievers 6 months after RCCL, compared with clinically normal Labrador Retrievers.[e] We performed gait analysis at a walking velocity for several reasons. First, Budsberg et al[13] initially used force platform gait analysis to evaluate outcome in dogs with naturally occurring RCCL, and in that report of dogs that were treated with LSS, gait analysis was performed at a walking velocity. Second, Evans et al[14] reported that vertical forces generated at a walk and a trot in dogs with unilateral lameness are strongly correlated. Third, although one might suggest that the rigor of a trot is advantageous, it is associated with 2 important disadvantages when studying dogs with lameness. In a recent study[14] of 100 Labrador Retrievers with unilateral lameness from RCCL, data were successfully collected from 100% of dogs tested at a walk and from only 67% of dogs tested at a trot. In addition, it was found that dogs with the greatest lameness (smallest vertical forces) were most likely to fail to yield data at a trotting velocity. This is possibly because of limb pain; some dogs are willing to walk on their limb with stifle pain, but as velocity and vertical forces increase, the level of discomfort increases and they cease to use the affected limb. The authors concluded that the consequence of these lost cases, if the dogs were studied at a trotting velocity, was not only reduced power of the study but also, more importantly, that data from dogs with severe lameness would not be collected.[14] This was particularly relevant in our study because by collecting data at a walk, we avoided skewing the results toward only dogs with a more favorable outcome. We also believe that our finding that gait abnormalities were found in the majority (≥ 85%) of dogs 6 months after surgery in any treatment group provides strong evidence that gait analysis at a walk is sufficiently rigorous for clinical studies of dogs with RCCL (when compared with clinically normal Labrador Retrievers and when an 80% probability of normal function is used).

Our data demonstrate that when evaluated at a walk 6 months after surgery, dogs that had LSS and TPLO not only had similar limb function but also had a similar likelihood of achieving normal function and clinically substantial improvement. The typical dog treated with ICS, however, had worse limb function and a reduced chance of achieving a clinically substantial improvement. It is possible that a similar evaluation in a different breed would yield different findings. In addition, it is also possible that if these dogs were evaluated after exercise, a different outcome would have been found. However, dogs treated with ICS consistently had lower mean vertical forces and the 6-month mean VIs of dogs treated with LSS or TPLO were within 0.3% of each other.

One obvious question is how a comparatively straightforward procedure, such as LSS, can provide

the same or better outcome as more technically complex procedures such as TPLO and IC. In addition, why does limb function not return to normal? One explanation is that there could be an upper limit to the amount of healing that is possible for many dogs that have surgery for RCCL. At our referral hospital, most dogs with RCCL have preexisting osteoarthritis. In addition, although there is no predictive relationship between the radiographic severity of osteoarthritis and limb function in dogs,[15] it is has been suggested that osteoarthritis will progress in nearly all dogs with RCCL.[f] Another explanation is that we studied only dogs with an injury to the medial meniscus, and dogs with this injury may have limits on their ability to return to normal limb function. Finally, it is possible that in Labrador Retrievers, beyond the removal of the RCCL and torn medial meniscus, variations in surgical stabilization techniques can be harmful, but no specific procedure provides a unique prognostic advantage. Postoperative management has a role in the outcome in dogs treated with LSS.[16] At our institution, postoperative rehabilitation (including swimming) is frequently encouraged as early as 1 to 2 weeks after surgery. In contrast, dogs treated with ICS or TPLO commonly have exercise restriction for 6 to 8 weeks after surgery. We are not suggesting that swimming soon after TPLO or ICS be instituted, only that this difference in postoperative management may help to explain our findings.

Like most clinical studies, our study was not without weaknesses. First, dogs were not randomly allocated among surgical techniques. Although this would have been optimal, it was not done because some owners requested a specific surgical procedure, there were financial discrepancies in the cost of various surgeries, and some surgeons were more comfortable with 1 technique. Although randomization would have been ideal, the fact that within the TPLO surgery group, we found that the surgeon performing the surgery had no correlation with outcome provides some evidence that this was not a major flaw. Second, we did not segregate our groups on the basis of the type of meniscal surgery performed; some dogs had a complete meniscectomy, and some had a partial meniscectomy. We chose to group them in an effort to maximize the statistical power of the study and because we are not aware of research that documents a difference in the rate or severity of stifle osteoarthritis or in prognosis after partial or complete removal of the medial meniscus in dogs with a naturally occurring RCCL. Third, we did not group dogs on the basis of the severity or duration of lameness or the degree of osteoarthritis prior to surgery. We recognize that independent investigation of these and other potential confounding factors would have been best. However, this fragmentation would have created exceptionally small study groups and we are not aware that any of these factors contribute to outcome. In fact, in this study, we detected a significant correlation between duration of lameness and outcome. However, the correlation was positive (which suggests that the longer the duration, the better the 6-month outcome) and the correlation was small (only 12% of the variation in duration of injury was associated with the variation in outcome). Fourth, we did not study a control group. We did not include a group that was treated with nonsurgical management because it has been well established that large-breed dogs have poor outcome with this treatment. We also did not include a control group with only the RCCL and meniscal injury removed. Given the use of arthroscopy for canine stifle joint diseases[17] and what has been reported about postoperative aquatic therapy for dogs with RCCL,[16] it seems reasonable to establish an outcome with this treatment alone before the development of more surgical techniques.

One explanation for our selected inclusion criteria was that they provided the fairest technical comparison between groups. Some affected dogs in our hospital are treated via release of the medial meniscus. We did not include such a group of dogs because it is a procedure that is essentially unique to the TPLO group and there was variation in the manner that the release was performed. Arthroscopic examination and debridement of the stifle joint as opposed to arthrotomy is another example of a technical variation that we perform but did not include. Variation in the surgical techniques that were used in this report may have contributed to variation in outcome. However, even among the participating surgeons, small variations in technique exist.

We made no attempt to investigate the progression of osteoarthritis, measure the cranial drawer or tibial thrust motion, measure pain-free range of motion or thigh circumference, perform subjective gait analysis, or interview the owners on their evaluation of their dogs' progress. Certainly, gathering and reporting all of that data would have made this clinical study more comprehensive; however, we do not believe it would have changed our conclusions.

Although it would have been ideal, we made no attempt to categorize dogs on the basis of postoperative care. This variable could have influenced outcome if only dogs from 1 group had postoperative rehabilitation or if only dogs in 1 group had exercise restriction. However, postoperative instructions from our institution are relatively uniform and immediate postoperative exercise restriction followed by some form of rehabilitation would have been recommended for nearly all of these dogs.

Historically, measures of outcome in small animal veterinary orthopedics have addressed and compared group means. Although this information is important, we think it is equally important to investigate what might happen to the individual patient. In an effort to address this issue, we compared dogs with RCCL 6 months after treatment with clinically normal dogs and reported the probability that an individual dog's gait could not be differentiated from a normal gait. If one elects to focus on the probability cut off value (80%) that maximizes the diagnostic potential of the force platform, then the unfortunate reality is that surgeons should be quite cautious when predicting return to a normal gait because it infrequently occurs. We also applied a previous definition of a clinically important improvement to the data set. Our finding that the gait of most dogs 6 months after surgery was more abnormal than normal was surprising because although we

did not formally document owners' impressions of outcome, it was our opinion that most owners thought their dogs functioned acceptably as a pets. If this is true, one could conclude that our definition of a clinically important improvement was too rigorous.

There are many justifications for selection of a surgical technique for repair of RCCL in a dog. In this study, dogs that received the ICS procedure had reduced limb function, compared with dogs treated via the other techniques. However, if surgeons are deciding between LSS and TPLO in Labrador Retrievers, postoperative limb function should be cautiously used as one of those justifications.

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