Rate of return to agility competition for dogs with cranial cruciate ligament tears treated with tibial plateau leveling osteotomy

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OBJECTIVE
To determine rate of and factors associated with return to agility competition for dogs with cranial cruciate ligament (CrCL) rupture treated with tibial plateau leveling osteotomy (TPLO).

DESIGN
Retrospective case series with nested case-control study.

ANIMALS
31 dogs involved in agility competition with CrCL tears treated by TPLO at a private veterinary clinic from 2007 through 2013.

PROCEDURES
Medical records were reviewed to collect information on dog signalment, lesion characteristics, and surgical data. Owners completed a survey regarding whether and when their dog returned to agility competition after TPLO and, if so, how the dog performed. Performance data before and after TPLO were compared.

RESULTS
20 of 31 (65%) dogs returned to agility competition after TPLO, 16 (80%) of which returned within 9 months after TPLO. The mean convalescent period for returning dogs was 7.5 months (range, 3 to 12 months). No dog that returned to competition sustained an injury to the affected limb during the follow-up period. No significant difference was identified between dogs that returned or did not return to agility competition regarding severity of osteoarthritis or proportions with meniscal injury or partial (vs complete) CrCL tears.

CONCLUSIONS AND CLINICAL RELEVANCE
These data suggested that the prognosis for returning to agility competition was good for dogs undergoing TPLO. None of the evaluated lesion characteristics were associated with return to competition. Rate of return to competition and duration of the convalescent period may be useful outcome variables for future investigations involving orthopedic procedures in dogs. (*J Am Vet Med Assoc* 2018;253:1439–1444)

Several techniques have been reported for the surgical correction of CrCL tears in dogs, including intracapsular, extracapsular, and osteotomy-based procedures.[1–9] No single procedure has been established as optimal for this purpose on the basis of scientific evidence. Rather, selection of a specific corrective procedure is often based on surgeon preference, which differs with training and experience, as well as on the available evidence.[7]

Several studies[1–9] have shown that dogs treated by TPLO recover faster and have better function and slower progression of osteoarthritis than those treated by other stabilization procedures. In some studies,[7–10] outcomes have been assessed with kinetic and kinematic computer-based gait analysis systems involving force plates and electronic pressure walkways. Such systems have the potential to provide important information regarding locomotion but are expensive and require a considerable learning curve for operation, data collection, and data analysis.[11] Consequently, the use of gait analysis systems has been generally limited to highly specialized practices and research facilities.

Successful surgical outcomes in human and equine orthopedic and sports medicine are often defined by return-to-sport rates and postoperative athletic performance. For horses, athletic performance is measured in track times, duration of the convalescent period (interval from surgery to first start), generation of racing revenue, and career longevity.[12,13] For humans, commonly published outcome data of the National Basketball Association, Fédération Internationale de Football Association, and National Football League include mean time to return to sport and

ABBREVIATIONS

AKC	American Kennel Club
CrCL	Cranial cruciate ligament
MYPS	Mean yards per second
TPLO	Tibial plateau leveling osteotomy

sport-specific statistics.[14–24] Convalescent periods and return times are inexpensive and simple to measure and provide consistent quantitative measurements of clinical success after surgical correction for orthopedic disease.

Canine agility competition is an international sport in which human handlers direct dogs through obstacle courses designed by an agility judge. Dogs run the course off leash, while receiving visual and auditory commands from their handler, who guides them through the course sequence in a race for both time and accuracy.[11,25] Agility competition is becoming increasingly popular, with > 1 million active canine participants in events hosted in 2011 by the AKC alone.[11] More than 12 organizations host canine agility events internationally.[11,25,26]

Agility competition involves speed, sharp turns, and jumps that can cause canine participants to sustain various injuries, including CrCL tears.[25,26] In a previous study,[25] 1,627 dogs were followed during a season of agility training and competition. Overall, 33% of those dogs sustained an injury, and 12% (n = 169) of injuries involved the stifle joint.[25] To the authors' knowledge, the rate of return to agility competition for dogs after surgical correction of orthopedic disease has not been reported, and this rate could provide a simple, objective measurement of postsurgical outcome.

The purpose of the study reported here was to determine whether dogs involved in agility competitions could return to competition after CrCL tear stabilization with TPLO. Specifically, we aimed to determine the rate of return to competition for affected dogs, mean duration of the convalescent period, factors associated with an inability to return to sport, and any complications that developed after return to competition. A secondary objective was to characterize specific factors that could be used to evaluate agility performance before and after surgery. We surmised that dogs would be able to return to agility competition within 10 months after TPLO and that they would safely compete without recurrence of injury to the affected limb.[1]

Materials and Methods

Case selection criteria

Medical records of dogs undergoing TPLO at a private veterinary practice from January 1, 2007, to December 31, 2013, were evaluated to identify dogs for inclusion in the study. Dogs were included if they had been actively participating in agility competitions (not just training) within the year prior to CrCL injury and surgery and their owners completed a prospectively administered follow-up questionnaire. A diagnosis of CrCL tear had been made on the basis of physical examination findings, including positive results of cranial drawer and tibial thrust tests, detection of stifle joint effusion on radiographs, and direct visual confirmation at the time of surgery.

Medical records review

Medical records included physical examination findings and radiographs obtained at the time of TPLO and 30 to 90 days after surgery. Information obtained from the medical records included dog age, reproductive status, and body weight at the time of TPLO; whether clinical signs were unilateral or bilateral; meniscal integrity at surgery; whether the CrCL tear was partial or complete; severity of osteoarthritis as assessed via radiography at the time of surgery; postoperative complications; whether reinjury occurred after return to competition; and identity of the surgeon who had performed the procedure.

Severity of osteoarthritis in the affected limb had been recorded at the time of surgery, and the investigators (SNH, SOC, and CSL) used data from these recordings and associated radiographs to classify the grade of severity. Grading was based on a modified version of a previously reported scoring system[27] for arthritis formation as detected on preoperative radiographs as follows: none = no evidence of osteophyte formation or joint space narrowing, mild = possible osteophyte formation and joint space narrowing, moderate = definitive osteophyte formation and possible joint space narrowing, and severe = multiple osteophytes or large osteophytes and definitive joint space narrowing.

Postsurgical complications as identified through medical record review were classified as minor or major. Major complications were defined as those that required corrective surgery. Minor complications were defined as those that resolved without surgical intervention.

Surgical procedure

All dogs underwent TPLO for stabilization of the affected stifle joint. All procedures were performed by 1 of 3 surgeons. Hydromorphone (0.1 mg/kg [0.45 mg/lb], IM) and midazolam hydrochloride (0.2 mg/kg [0.09 mg/lb], IM) were administered as premedications. Anesthesia was induced with propofol (3 mg/kg [1.4 mg/lb], IV) and midazolam (0.2 mg/kg, IV). Anesthesia was maintained with isoflurane in oxygen and a constant rate infusion of fentanyl (10 to 15 µg/kg/h [4.5 to 6.8 µg/lb/h], IV). Cefazolin (22 mg/kg [10 mg/lb], IV) was administered at the time of anesthetic induction and every 90 minutes thereafter.

After the affected limb was aseptically prepared for surgery, a craniomedial incision was made over the distal portion of the femur and proximal portion of the tibia. The cruciate ligaments and menisci were inspected and treated via miniarthrotomy or arthroscopy. If a partial CrCL tear was found, the torn portion of the ligament was debrided and the remaining portion was left in place. So-called bucket-handle meniscal tears were treated by caudal pole hemimeniscectomy. No meniscal release was performed. Routine TPLO was performed with and without a TPLO jig,[3] depending on surgeon preference. The joint and surrounding tissues were copiously lavaged

and closed in layers. Postoperative radiography was performed to confirm appropriate implant placement and the tibial plateau angle.

Following surgery, dogs received hydromorphone (0.05 mg/kg [0.02 mg/lb], IV, q 6 h) and cefazolin (22 mg/kg, IV, q 8 h) for 24 hours. They were then transitioned to tramadol (2 to 4 mg/kg [0.9 to 1.8 mg/lb], PO, q 8 h), cefpodoxime (7 to 10 mg/kg [3.2 to 4.5 mg/lb], PO, q 24 h), and an NSAID (carprofen, deracoxib, firocoxib, or meloxicam). All dogs were discharged from the hospital 24 hours after surgery. Activity was subsequently restricted to leash walks and passive range of motion exercises for 6 to 10 weeks. Recheck examination and radiography were performed monthly until radiographic union of the osteotomy was achieved.

Questionnaire

Follow-up information regarding return to and performance in agility competition was prospectively obtained through an online questionnaire[a] sent to owners of included dogs via email on September 15, 2014, and closed for responses on September 15, 2015 (**Supplementary Appendix S1**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.253.11.1439). In development of this questionnaire, a list of variables for gauging performance in AKC agility competitions was derived on the basis of variables used in human and equine medicine and the structure of AKC agility competitions. These variables included MYPS in which the course was run, jump height of hurdle bars, and mean number of dropped bars per run. Owners were first asked whether their dog had returned to agility training. For those who answered yes, owners were then asked to report their dog's MYPS and jump heights before and after TPLO. They were also asked to report whether the mean number of dropped bars per run increased, decreased, or remained the same, compared with before surgery. Owners were not asked to report the method of data collection (memory vs written record). Owners who reported that their dogs had not returned to competition were contacted via a second email and asked to list the specific reason for the decision not to return their dog to agility competition.

Statistical analysis

Analyses were performed with statistical software.[b] The rate of return to agility competition was calculated as the percentage of all included dogs that returned to agility competition. Dogs were classified by whether they had or had not returned to agility competition. Distributions of perioperative data (sex, meniscal injury, unilateral vs bilateral clinical signs, postoperative complications, complete vs partial CrCL tear, surgeon, and grade of osteoarthritis severity) were compared between the return and nonreturn groups by means of the χ^2 test. Values of $P < 0.05$ were considered significant.

For dogs in the return group, jump height and MYPS were determined before and after TPLO and are reported as mean ± SD. Data for these variables were examined for normality with the Komogorov-Smirnov test; no statistical comparisons were performed.

Results

Animals

A total of 2,310 TPLO procedures were performed on 1,918 dogs during the 7-year study period. Seventy-three of those dogs were involved in agility competition and met all inclusion criteria, except for questionnaire completion. Questionnaires were completed for 31 of the 73 (42%) dogs, and those 31 dogs were included in the study.

Overall, 21 (68%) dogs were female (19 spayed and 2 sexually intact) and 10 (32%) were male (8 castrated and 2 sexually intact). Dogs included 4 Pembroke Welsh Corgis, 3 Labrador Retrievers, 3 Golden Retrievers, 2 Border Collies, 2 German Shepherd Dogs, 2 Brittany Spaniels, and 1 each of various other breeds or breed types (Rottweiler, Staffordshire Bull Terrier, Giant Schnauzer, Australian Cattle Dog, Schipperke, Doberman Pinscher, Portuguese Water Dog, Belgian Sheep Dog, Toy Poodle, Standard Schnauzer, Pointer mix, Bernese Mountain Dog, Cocker Spaniel, Fox Terrier, and Mastiff). Age at the time of TPLO ranged from 2.2 to 10.1 years. Body weight at this same point ranged from 4.5 to 84.1 kg (9.2 to 185.0 lb).

Mean and median interval from TPLO to questionnaire completion was 4.6 and 4 years, respectively (range, 1 to 8 years). Twenty (65%) dogs returned to competition (return group), and 11 (35%) did not return (nonreturn group). Mean follow-up period for the return group was 5.1 years (range, 2 to 8 years) and for the nonreturn group was 3.7 years (range, 1 to 7 years).

Perioperative comparisons

No difference was identified between the return and nonreturn groups with respect to age (mean ± SD, 6.2 ± 2.4 and 5.45 ± 2.0 years, respectively; $P = 0.50$) and body weight (mean ± SD, 21.0 ± 12.9 and 25.0 ± 8.0 kg [46.2 ± 28.4 and 55.0 ± 17.6 lb], respectively; $P = 0.50$). Groups did not differ significantly ($P = 0.57$) with respect to proportions of females (12/20 [60%] vs 9/11 [82%], respectively) and males (8/20 [40%] vs 2/11 [18%], respectively).

Ten (50%) dogs in the return group had a partial CrCL tear, and the other 10 (50%) had a complete tear. For dogs in the nonreturn group, these numbers were 4 (36%) and 7 (64%), respectively. These distributions did not differ significantly ($P = 0.47$) between groups. Six (30%) dogs in the return group had bilateral CrCL tears (that were both repaired during the study period), as did 2 (18%) dogs in the nonreturn group ($P = 0.47$). Six (30%) dogs in the return group and 4 (36%) dogs in the nonreturn group had concurrent meniscal injury at the time of TPLO ($P = 0.72$).

Surgeon distribution was similar between the groups as well ($P = 0.73$).

Sixteen (80%) dogs in the return group were classified as having mild osteoarthritis, and 2 (10%) dogs each were classified as having no or moderate osteoarthritis. In the nonreturn group, 8 (73%) dogs were classified as having mild osteoarthritis and 3 (25%) were classified as having moderate osteoarthritis. These distributions did not differ significantly ($P = 0.28$) between groups.

Outcome for dogs in the nonreturn group

Owners of 6 of the 11 dogs in the nonreturn group decided not to enter them into competition because of factors unrelated to prior CrCL tears or TPLO. For 2 of these dogs, owners reported family changes that restricted their available time for retraining. Three owners indicated that they wanted to avoid risking injury to their dogs contralateral CrCL or to other limbs. The sixth dog had another concurrent orthopedic problem that prevented it from jumping well.

The remaining 5 dogs had returned to agility training but were not performing at their preinjury level, so their owners decided not to return them to agility competition. No evidence was available to establish that the lack of return to competition for these 5 dogs was definitively related to the previous CrCL tear or TPLO. No history of other orthopedic disease was identified in the medical record or via owner email correspondence to establish that the decrease in the ability to perform was unrelated to the previous CrCL tear or TPLO. Three of these dogs were reported to have participated in other activities, including rally and obedience competitions.

Outcome for dogs in the return group

For the 6 dogs in the return group that had required bilateral CrCL repair, the calculated duration of the convalescent period was based on the total recovery time for both procedures. Sixteen of the 20 (80%) dogs in the return group returned to agility competition within 9 months after TPLO. Mean ± SD duration of the convalescent period for dogs in this group was 7.5 ± 2.7 months (range, 3 to 12 months). No dog had a reported subsequent injury to the affected limb during the follow-up period.

Eighteen of 20 (90%) owners reported whether the mean number of bars that their dog dropped during agility competition before and after TPLO increased, decreased, or remained the same. Fourteen of 18 (78%) dogs had no change in mean number of dropped bars, 3 (17%) had a decrease, and 1 (6%) had an increase. Eight of 20 (40%) owners knew the MYPS for their dog, with a mean ± SD preoperative value of 4.9 ± 1.5 (range, 2.8 to 8) and postoperative value of 4.8 ± 1.5 (range, 2.8 to 8.5). Four of these dogs had a similar to improved MPYS after TPLO, whereas the other 4 had a lower MPYS. Fourteen of 20 (70%) owners knew the jump height of their dog pre- and postoperatively. The mean ± SD preoperative value was 17 ± 6 inches (range, 8 to 26 inches) and postoperative value was 16 ± 6 inches (range, 8 to 24 inches). Nine dogs maintained the same preoperative jump height, and 5 had a decrease in jump height after TPLO.

Discussion

For human athletes, the mean rate of return to sports involving pivoting and cutting (quick directional changes while running) movements at 12 months after anterior cruciate ligament reconstruction is reportedly as high as 64%.[14,15,17,24,28,29] The reinjury rate for human athletes returning to a high-impact sport after such a procedure is between 6% and 9%.[30–32] In the present study, a similar rate of return to agility competition (65%) was identified for dogs undergoing TPLO for treatment of cruciate ligament tears. Mean duration of the convalescent period for these dogs was 7.5 months, and no dog reportedly sustained reinjury to the affected limb.

To the authors' knowledge, no information has been published regarding factors associated with a dog's ability to return to agility competition after TPLO for a CrCL tear. In the present study, we evaluated factors known to influence return to sport and athletic performance in humans as well as previously characterized TPLO-related complications for associations with performance outcomes in dogs.

Studies[33,34] have shown that humans with intact menisci and no cartilage damage are more likely to return to their preoperative performance level than those with substantial meniscal and cartilage defects. Similarly, TPLO-treated dogs with an intact meniscus in the affected limb have faster recovery times than TPLO-treated dogs with concurrent meniscal injury.[2] Although a greater proportion of dogs that did not return to agility competition in the present study had a meniscal tear (36%), compared with the proportion for dogs that returned to competition (30%), this difference was not significant. The lack of a significant difference might have been attributable to the low number of dogs in both groups, or it could also be that treatment with meniscectomy was sufficient to restore adequate comfort and function in dogs with meniscal injury.

In a study[35] in which articular cartilage in dogs was examined after TPLO, complete and severe partial CCL tears were associated with more severe cartilage damage and osteoarthritis formation than early partial tears. We believed that the difference in osteoarthritis severity and CrCL tear completeness would therefore influence function of the stifle joint and affect the ability of dogs to return to agility competition. Although a greater proportion of dogs in the return group had partial CrCL tears (50%) than did dogs in the nonreturn group (36%) in the present study, this difference was not significant. The severity of osteoarthritis in the affected joint was also no different

between groups. Hence, we concluded that complete CrCL tear and osteoarthritis severity had no effect on a dogs' ability to return to agility competition after TPLO. However, it should be noted that osteoarthritis severity was low in the included dogs.

In human athletes, gender also influences the rate of return to sport, with women significantly less likely to return after anterior cruciate ligament reconstruction than men.[36] This difference is believed to be due to hormonal differences.[36] No significant difference in sex distributions was identified between dogs in the return and nonreturn groups in the present study, but differences by neuter status (which would affect hormone status) were not evaluated owing to small numbers.

A return to preinjury level of sport is believed to represent the most rigorous assessment of surgical success in human sports medicine.[14,17] In 1 study,[17] 64% of human athletes returned to professional sports after anterior cruciate ligament reconstruction, but only 33% of those returning athletes were able to perform at their preinjury level. Because of these findings, we wanted to identify components of canine agility competitions that may be useful for assessing performance following orthopedic procedures. The variables considered included MYPS, mean number of dropped bars per race, and jump height. Agility titles were excluded as a potentially useful outcome variable because of the influence of time and skill level on achievement of competing dogs. Agility titles are based on performance in several races over the course of dog's career and are cumulative. Therefore, preoperative performance would influence achievement of these titles. This variable was also excluded because we wanted to consider variables that could be evaluated across all skill levels, from novice to champion.

In the study reported here, only 20% of owners whose dogs returned to agility recorded their dog's pre- and postoperative MYPS data, whereas most (70% to 90%) knew the trend in their dog's jump heights and numbers of dropped bars at these points. The questionnaire included no inquiry regarding whether owners based their responses on memory versus written records, and specific values for the number of dropped bars was excluded, therefore the accuracy of these data is unknown.

For dogs involved in AKC agility competitions, the AKC reports the awards a dog has received and the total points earned to achieve those awards. However, no publicly accessible database is available to provide information on specific agility performance variables. The available data pertaining to performance of dogs that returned to agility competition in the present study indicated that at least half of those dogs were performing at or superior to their preoperative level in all 3 evaluated categories after TPLO, as recalled or known by their owners. Because only 8 of 20 (40%) owners reported their dog's MYPS, possibly indicating that this is an uncommon variable for owners to track (providing the potential for recall bias) or that owners were unwilling to report their dog's change in MYPS (providing the potential for response bias), no conclusions could be drawn regarding overall performance of dogs that returned to agility competition after TPLO.

No information was collected in the present study regarding degree of agility competition experience held by dogs prior to TPLO, and this variable could have been important to control for in our analysis. For example, outcomes for an inexperienced dog with room to improve in both time and accuracy could be expected to differ from those for an experienced dog with little room to improve, thereby affecting the degree of postoperative improvement. This lack of information represents a study limitation and should be considered in future investigations of agility performance.

An important factor to consider when interpreting the results of the present study is that dogs, unlike people, are not responsible for the decision to return to sport after an injury. When questioned, 6 of the 11 owners whose dogs did not return to agility competition reported that this decision was made because of an inability or unwillingness to train their dog and not because of factors related to their dog's ability to perform. Several of these owners also reported that although their dog did not return to agility competition, the dog did participate in rally and obedience competitions. Consequently, the rate of return to competition could have been even higher had these dogs been allowed to attempt retraining. It is important to consider the influence of the owner's time and finances when evaluating rate of return to agility competition because these variables could represent important confounding factors in the present and future studies.

Further research is warranted into rates of return to agility competition and durations of convalescent periods for stifle joint stabilization procedures other than TPLO. These objective outcome measurements could then be compared among procedures and assist in the identification of an optimal joint stabilization method for dogs with a CrCL tear. Additional research is also needed to validate the outcome variables reported here for objective measurement of agility performance. A prospective study design could avoid caregiver response bias and allow for standardized clinical postoperative follow-up that includes evaluation of limb function with validated mechanical testing methods such as force plate or electronic pressure analysis.

Acknowledgments

The authors report that there were no conflicts of interest.

The authors thank Dr. Quinn Hart and Justin Merz for assistance with the statistical analysis.

Footnotes

a. SurveyMonkey, Palo Alto, Calif. Available at www.surveymonkey.com. Accessed Sep 15, 2014.

b. Microsoft Excel, version 16.12, Microsoft Corp, Redmond, Wash.

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