Comparison of Long-Term Outcomes Associated With Three Surgical Techniques for Treatment of Cranial Cruciate Ligament Disease in Dogs

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Submitted July 2011
Accepted December 2011

DOI:10.1111/j.1532-950X.2013.12001.x

Objective: To evaluate long-term (>1 year) outcomes with respect to function and complications in dogs undergoing TightRope (TR), tibial plateau leveling osteotomy (TPLO), or tibial tuberosity advancement (TTA) for treatment of cranial cruciate ligament (CCL) disease.

Study Design: Retrospective clinical cohort study.

Methods: Medical records from 2006 to 2009 were searched and cases included when all data were available and clients returned a completed questionnaire based on their assessment of their dog at least 1 year after surgery. Outcomes associated with TPLO, TTA, and TR were determined and compared based on medical records and questionnaires data regarding return to function, presence and degree of pain, and complications.

Results: Case meeting inclusion criteria were: TPLO (n = 65), TR (n = 79), and TTA (n = 18). TTA was associated with significantly ($P < .03$) higher rates of major complications and subsequent meniscal tears than TPLO and TR, and TPLO had significantly higher rates of major complications and meniscal tears than TR. Percent of function >1 year after surgery was 93.1% + 10.0% for TPLO, 92.7% + 19.3% for TR, and 89.2% + 11.6% for TTA. Significantly ($P = 0.016$) more TPLO and TR cases were classified as reaching full function than TTA. The highest levels, frequency, and severity of pain were noted in TTA cases, however, no significant differences were noted among groups.

Conclusion: Long-term outcomes for TPLO and TR were superior to TTA based on subjective client and DVM assessments. Each technique was associated with a high long-term success rate with TR showing the highest safety-to-efficacy ratio.

INTRODUCTION

Cranial cruciate ligament (CCL) disease is one of the most common orthopedic conditions of dogs has become a multi-billion dollar business in veterinary medicine.[1] Despite the prevalence of disease and its economic impact, few, if any, studies directly compare the long-term safety and efficacy of the major surgical procedures used to manage CCL disease in dogs.

Three of the most commonly used surgical treatments for CCL disease are tibial plateau leveling osteotomy (TPLO),[2–6] tibial tuberosity advancement (TTA)[6–11] and Tightrope CCL (TR).[12] The proposed advantages of the osteotomy procedures, TPLO and TTA, include their theoretical "dynamic" mechanisms of stifle stabilization[13] and anecdotal reports regarding subjectively better outcomes in large and giant-breed dogs compared to other stabilization techniques.[14–16] The advantages proposed for TR in comparison to osteotomy techniques include its relative technical ease, shorter total surgical and anesthesia times, and better safety profile.[12] However, the superiority of one surgical procedure over another has not been demonstrated and no surgical treatment method for CCL disease in dogs halts progression of osteoarthritis or abolishes associated pain.[9–11,17–21] Based on the differences among these 3 procedures and their theoretical advantages, it seems likely that these techniques are associated with significantly different outcomes with respect to safety and efficacy long term. Thus our purpose was to compare long-term (>1 year) outcomes associated with TPLO, TTA, and TR with respect to safety and efficacy. We hypothesized that the TightRope technique (TR) would have significantly fewer complications and significantly more functional long-term outcomes than the osteotomy techniques (TPLO and TTA).

Presented in part at the 2011 Annual Veterinary Orthopedic Society Conference Snowmass, CO.

MATERIALS AND METHODS

Case Selection

Medical records (November 2006–May 2009) were searched for dogs that had surgical treatment for CCL disease with either TPLO, TTA, or TR. Cases were excluded when complete medical record data was not available or when client questionnaires were not completed and returned.

Data Collection and Comparison

Age at surgery, breed, reproductive status, weight, body condition score (BCS), intended function, affected limb, procedure performed, and any other relevant physical examination and diagnostic data were collected. Intended function was classified as companion, working, or agility. BCS was evaluated on a scale of 1–9 with 1 being emaciated, 5 being ideal, and 9 being morbidly obese.[22]

The experience level of the primary surgeon (resident versus ACVS Diplomate), stifle joint evaluation method (arthroscopy, arthrotomy), and presence and type of meniscal pathology at the time of the index surgery were determined and recorded.

Complications after surgery were determined from medical records to include all documented communications with the clients and referring veterinarians. Complications were classified as catastrophic, major, or minor.[23]

Long-Term Assessments

Each client was sent a questionnaire (US Postal Service or electronic mail) >1 year after surgery to evaluate: (1) complications noted by clients (may or may not have been recorded in medical records); (2) current level of function; (3) current presence and degree of pain; and (4) current use of nutritional supplements, nonsteroidal antiinflammatories, and/or analgesics associated with CCL disease.

Return to function was evaluated on a 0–100 visual analog scale (VAS) with 0 being defined as no use of the treated limb and 100 being return to preinjury/intended level of function of the treated limb without the use of medications. Functional outcome was also categorized as full, acceptable, or unacceptable.[23] Degree of pain was evaluated on a VAS of 0–100 with 0 being no pain noted at any time in the treated limb and 100 being constant severe pain in the treated limb.

Statistical Analysis

Data were compiled and analyzed in a blinded fashion and unblended after repeat verification of the statistical data. Fisher's exact tests and χ^2 tests were used to determine statistical significance and odds ratios were calculated for statistically significant data. ANOVA was performed on quantitative analysis of return to function and pain assessment. A P-value of $<.05$ was considered statistically significant.

RESULTS

Case Inclusion

From November 2006 to May 2009, 344 cases met the initial inclusion criteria. Of these 152 were TPLO, 32 were TTA, 144 were TR, and 16 were lateral fabellotibial suture extracapsular stabilizations. Fabellotibial suture extracapsular stabilization cases were excluded because of the relatively small number of cases in conjunction with noted differences in signalment for this cohort at our hospital. Appropriately completed responses to client questionnaires were received for 162 cases: 65 TPLO (43%), 18 TTA (56%), and 79 TR (55%).

Epidemiologic Data

For 162 dogs with completed questionnaires, 79 were spayed females (48.8%), 5 were intact females (3.1%), 65 were castrated males (40.1%), and 13 were intact males (8%). These distributions were consistent across treatment cohorts. Weight, BCS, and age at surgery data are provided in Table 1. The most common breed in each group was Labrador retriever: 20 (30.8%) TPLO, 7 (36.8%) TTA, and 22 (27.8%) TR. There was 1 working dog (1.5%) in the TPLO cohort, 1 working dog (5.6%) in the TTA cohort, and 1 working dog (1.3%) and 1 performance dog (1.3%) in the TR group. Of dogs considered pets, there were 64 (98.5%) TPLO, 17 (94.4%) TTA, and 77 (97.4%) TR. No statistically significant differences in assessed preoperative variables were found among treatment cohorts.

Surgical Procedures

Overall, the stifle joints were predominantly evaluated with an arthrotomy in TPLO and TTA cases whereas TR were evaluated arthroscopically. With the exception of TTA cases, full cruciate tears were more common. Partial cruciate bands were debrided in 12 TPLO, 9 TTA, and 18 TR. Meniscal pathology was also present in over 50% of TPLO and TR. TTA overall had fewer meniscal injuries at the time of surgery (Table 1).

Thirty-one (47.7%) TPLO were performed by board certified surgeons, 13 (72.2%) TTA, and 60 (75.9%) TR. The other cases included in this study were performed by residents under the direct supervision of board certified surgeons.

Complications (Table 2)

Minor complications including bruising, swelling, and/or seroma formation occurred in 6 (9.2%) TPLO, 4 (22.2%) TTA, and 7 (8.9%) TR. There were no significant differences among cohorts for minor complications ($P = .22$; Table 2).

Major complications occurred in 12 (18.5%) TPLO, 7 (38.9%) TTA, and 7 (8.9%) TR. TTA was associated with significantly more major complications than TPLO, and TPLO and TTA were both associated with significantly more major complications than the TR cohort ($P < .006$). TPLO was 2 times more likely to be associated with major complications

Table 1 Epidemiologic and Surgical Data of Dogs That Had Surgical Treatment of Cranial Cruciate Ligament Disease With Either Tibial Plateau Leveling Osteotomy (TPLO), Tibial Tuberosity Advancement (TTA), or Tight Rope (TR)

		Surgical Technique		
		TPLO	TTA	TR
Weight (kg)	Mean (range)	38.4 (17.6–92.6)	40.2 (22.3–72.0)	41.3 (18.5–75.0)
BCS	Median (range)	6 (4–9)	6 (4–8)	6 (4–8)
Age (years)	Mean (range) median	4.76 (1.4–10.1) 4.2	5.05 (1.8–8.7) 5.4	5.27 (1.9–11) 5
Follow up (years)	Mean (range) median	2.7 (1.2–3.7) 2.9	2.4 (1.7–3.3) 2.3	2.1 (1.2–3.5) 2.0
Arthroscopy	Cases (% total)	13 (20%)	0 (0%)	76 (96%)
Full arthrotomy	Cases (% total)	41 (63%)	13 (72%)	3 (4%)
Mini arthrotomy		11 (17%)	5 (28%)	0 (0%)
Partial cruciate tear	Cases (% total)	18 (28%)	9 (50%)	19 (24%)
Meniscal pathology	Cases (% total)	34 (52%)	5 (28%)	56 (71%)
Meniscal release		5 (7.7%)	4 (22.2%)	7 (8.9%)

than TR, whereas TTA was 3 times more likely to be associated with major complication than TPLO and 7 times more likely than TR. The most common major complication for all treatment cohorts was subsequent meniscal tear: 8 (12.3%) TPLO, 5 (27.8%) TTA, and 5 (6.3%) TR. TTA was significantly ($P = .011$) and 3 times more likely to be associated with subsequent meniscal tear than TPLO, and significantly ($P < .001$) and 6 times more likely than TR. TPLO was significantly ($P = .044$) and 2 times more likely than TR to be associated with subsequent meniscal tear.

Catastrophic complications occurred in 1 (1.5%) TPLO and 1 (5.6%) TTA, and 0 TR, with no significant differences among groups.

With respect to surgeon experience level, all complications, and major complications specifically, were significantly higher for all procedures when performed by residents ($P = .036$). Surgeries performed by residents were 3 times more likely to be associated with major complications than those performed by board certified surgeons. For TPLO, procedures performed by residents were significantly ($P = .024$) and 2 times more likely to be associated with a major complication than those performed by a board certified surgeon. However, there were no significant differences for subsequent meniscal tears for TPLO based on surgeon experience level. TTA procedures were not associated with significant differences in complication rates, or subsequent meniscal tears specifically, based on surgeon experience level. For TR, procedures performed by residents were significantly ($P = .009$) and 5 times more likely to be associated with major complications than those performed by a board certified surgeon. Subsequent meniscal tears were 6 times more likely ($P = .001$) to be diagnosed for TR procedures performed by residents compared to those performed by a board certified surgeon.

Client-Based Assessments

Client–based assessments were evaluated to examine the role that postoperative duration may play in discrepancies among surgical techniques. There were no significant differences in follow-up times among techniques (Table 3).

Based on the clients' perception >1 year after surgery, minor complications were recognized in 5 (7.7%) TPLO, 2 (11.1%) TTA, and 6 (7.6%) TR with major complications recognized in 7 (10.8%) TPLO, 5 (27.8%) TTA, and 5 (6.3%) TR. Catastrophic complications were recognized in 1 (1.5%) TPLO, 1 (5.6%) TTA, and 0 TR.

Client VAS assessment of level of function was 93.1 ± 10 for TPLO, 89.2 ± 11.6 for TTA, and 92.7 ± 19.3 TR cases (Table 3). Client VAS assessment of degree of pain was 12.2 ± 21.9 for TPLO, 17.1 ± 23.4 for TTA, and 14.7 ± 23.8 for TR (Table 4). There were no significant differences among treatment cohorts for either of these outcome measures. When just the presence or absence of pain was evaluated, 31 (47.7%) TPLO, 11 (61.1%) TTA, and 35 (44.3%) TR were judged to have some degree of long-term pain, and though not statistically significant ($P = .44$), TTA cases were 2 times more likely to be associated with presence of pain as perceived by their owners compared with TPLO and TR dogs.

For subjective assessment of overall long-term functional outcome, full function was achieved in 50 (76.9%) TPLO, 8 (44.4%) TTA, and 60 (75.9%) TR. Acceptable function was achieved in 13 (20%) TPLO, 8 (44.5%) TTA, and 18 (22.8%) TR. Combining full and acceptable levels of function together

Table 2 Complications in Dogs That Had Surgical Treatment of Cranial Cruciate Ligament Disease With Either Tibial Plateau Leveling Osteotomy (TPLO), Tibial Tuberosity Advancement (TTA), or Tight Rope (TR)

Medical Records Complications (%)	TPLO (n = 65)	TR (n = 79)	TTA (n = 18)	χ^2 or Fisher's Exact Tests
Catastrophic	1.5	0	5.6	NSD ($P = .15$)
Major	18.5	8.9	38.9	TTA > TPLO > TR ($P < .006$)
Minor	9.2	8.9	22.2	NSD ($P = .22$)
Subsequent meniscal tears (%)	12.3	6.3	27.8	TTA > TPLO > TR ($P < .03$)

Table 3 Mean ± SD Visual Analogue Scores for Return to Function Assessed by Owners in Dogs That Had Surgical Treatment of Cranial Cruciate Ligament Disease With Either Tibial Plateau Leveling Osteotomy (TPLO), Tibial Tuberosity Advancement (TTA), or Tight Rope (TR)

Owner Assessed Function (%)	TPLO (n = 65)	TR (n = 79)	TTA (n = 18)	Statistical Analysis
Quantitative assessment	93.1 ± 10.0	92.7 ± 19.3	89.2 ± 11.6	NSD (ANOVA)
Full	76.9	75.9	44.4	TPLO = TR > TTA ($P = .016$)
Acceptable	20	22.8	44.5	NSD ($P = .093$)
Unacceptable	3.1	1.3	11.1	NSD ($P = .093$)

to determine "successful" outcomes resulted in 96.9%, 88.9%, and 98.7% success rates for TPLO, TTA, and TR, respectively. Two (3.1%) TPLO, 2 (11.1%) TTA, and 1 (1.3%) TR were determined to have an unacceptable level of function long term. There were no significant differences in acceptable or unacceptable levels of function among treatment cohorts; however, TPLO and TR were both significantly ($P = .016$) and 4 times more likely to be associated with return to full function than TTA. TTA was 10 times more likely than TR and 4 times more likely than TPLO to be associated with an unacceptable outcome, whereas TPLO was 2 times more likely to be associated with an unacceptable outcome compared with TR. With respect to surgeon experience level, there were no significant differences within each treatment cohort or for all cases combined for level of function or degree of pain between residents and board certified surgeons.

DISCUSSION

We found that all 3 surgical procedures for treatment of CCL disease in dogs were associated with high long-term "success" rates; however, TR and TPLO were significantly more likely to be associated with "full function" outcomes compared with TTA, and TR was associated with the fewest and least severe complications of the 3 techniques. These data suggest that all 3 of these techniques can be appropriately recommended for surgical treatment of CCL disease in dogs, but that there are notable differences with respect to expected long-term outcomes for both safety and efficacy, which clients should be informed of.

One catastrophic complication was seen in each of the TPLO and TTA cohorts whereas no catastrophic complications occurred with TR. Major complications were highest for TTA and least for TR, whereas minor complications were similar among treatments. Interestingly, except for catastrophic complications, clients reported lower complication rates than those recorded in the medical records. This suggests that, in general, clinicians are more stringent in defining and documenting major and minor complications than clients. This is important to consider when evaluating complication rates reported in studies with different experimental designs and when assessing client perception of outcome.

The most common major complication reported for all 3 techniques was subsequent meniscal pathology. TTA was associated with the highest rate of subsequent meniscal pathology at nearly 30%, whereas for TPLO it was 12% and for TR, 6%. These differences may be because of differences in resultant stifle kinematics, postoperative management, patient-specific factors, and/or assessment and treatment of the menisci at the index surgery. Arthroscopy with meniscal probing was performed in most TR, much fewer in TPLO, and in no TTA. The ability of arthroscopy with probing to evaluate meniscal pathology may account for the larger number of meniscal tears documented during the index surgery in the TR cohort.[24] Assessment technique may be the major factor in explaining the differences in subsequent tears documented as it has been reported that many "subsequent" tears are actually missed tears[25]; however, based on experimental design and the outcome instruments used in this study, joint assessment technique (arthrotomy versus arthroscopy), other aforementioned variables and meniscal release could not be assessed as contributors to subsequent meniscal pathology. The only statement we can make from these data is that subsequent meniscal pathology is the most common major complication associated with all 3 techniques and was seen most commonly with arthrotomy and TTA.

Importantly, 44–61% of dogs were reported by their owners to show "at least some pain" 1 year or more after surgery. While this may or may not be true prevalence or clinically significant, and certainly can be because of a number of different reasons, it is important to realize that none of these techniques consistently resulted in long-term pain-free outcomes based on client perception. Similarly, restoration of function to full predisease status without the need for medications was achieved in ~75% of TPLO and TR dogs, and only 44% of TTA dogs. Therefore, it is important for surgeons to realize and to fully inform clients that no current CCL surgical treatment is a "cure" and that 50% of dogs can be

Table 4 Mean ± SD Visual Analogue Scores for Long-Term Postoperative Pain Assessed by Owners in Dogs That Had Surgical Treatment of Cranial Cruciate Ligament Disease With Either Tibial Plateau Leveling Osteotomy (TPLO), Tibial Tuberosity Advancement (TTA), or Tight Rope (TR)

Owner Assessed Current Pain (%)	TPLO (n = 65)	TR (n = 79)	TTA (n = 18)	Statistical Analysis
Quantitative assessment	12.2 ± 21.9	14.7 ± 23.8	17.1 ± 23.4	NSD (ANOVA)
At least some pain noted	47.7	44.3	61.1	NSD ($P = .44$)
No pain ever noted	52.3	55.7	38.9	NSD ($P = .44$)

expected to have at least some pain with 75% at best reaching full function without long-term medical management. This information should be even more conservatively presented to owners of working and performance dogs because of the fact that very few of the dogs in this study were in these 2 categories.

We attempted to evaluate the contribution of surgeon experience to clinical outcome by comparing complication rates and outcomes for cases with a resident versus an ACVS diplomate as the primary surgeon. Significant differences were noted for this comparison for major complications with TPLO, major complications with TR, subsequent meniscal pathology in the TR cohort, and major complications for all cohorts combined, all of which had significantly higher rates for residents compared with board certified surgeons. Therefore, experience may have played a role in the frequency of major complications observed. This could be related to technical capabilities, longer surgery times, or lower levels of experience with orthopedic surgery and these techniques specifically. However, these factors were not specifically analyzed and we interpret these data with caution as an ACVS Diplomate directly supervised the residents for all cases included in this study.

The major limitations of our study include its retrospective nature, reliance upon owner assessments and responses, and the relatively limited number of TTA cases included. However, the number of cases included is still appropriate for rigorous statistical analyses, the treatment cohorts were fairly compared, and client based assessments have been shown to have validity, and have to be considered one of the most relevant outcome measures for clinical veterinary surgery. To our knowledge, this is the first study providing any direct head-to-head long-term comparisons for TPLO, TTA, and TR, and as such provides an initial database for further work in this important area. It is important to remember that joint assessment techniques were not equally distributed among the 3 treatment cohorts. Therefore, instead of directly comparing TPLO, TTA and TR, this study must be considered to be comparing TPLO with arthroscopy, full arthrotomy or mini arthrotomy, TTA with full arthrotomy or mini arthrotomy, and TR with arthroscopy or full arthrotomy.

We concluded that TPLO, TTA, and TR were all associated with high long-term "success" rates in dogs treated surgically for CCL disease based on subjective client and veterinary medical record assessments. TPLO and TR were superior to TTA in terms of dogs achieving full function, TR was associated with the fewest complications, and TTA was associated with the most complications. None of these CCL surgical techniques eliminated pain. Based on the assessments we used, TightRope CCL showed the best long-term balance of safety to efficacy for treatment of CCL disease in dogs.

DISCLOSURE

Dr. Cook is a patent holder on and receives royalties related to TightRope CCL.

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