Incidence of Medial Meniscus Injury Detected by Arthroscopy in Toy Breed Dogs (≤5 kg) with Cranial Cruciate Ligament Rupture

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Abstract

Objective To investigate the frequency and factors of medial meniscal injury (MMI) associated with cranial cruciate ligament rupture (CrCLR) in toy breed dogs by arthroscopic evaluation.

Methods Toy breed dogs (≤5 kg) diagnosed with CrCLR using stifle arthroscopy were included. Age, sex, body weight, breed, medial patellar luxation grade, degree of lameness at diagnosis, and duration of lameness until diagnosis were obtained from medical records. The tibial plateau angle was evaluated using preoperative radiography. On arthroscopic evaluation, degree of CrCLR was classified as partial or complete; MMI was classified as no, mild, or severe injury. MMI grade was used as objective variable; ordered logistic regression was used, and the final model was created using forward–backward stepwise selection.

Results Overall, 202 stifles of 178 dogs were evaluated. Arthroscopic evaluation revealed partial and complete CrCLR, and MMI in 58, 144, and 74 stifles, respectively. MMI with mild and severe damage was noted in 50 and 24 stifles, respectively. Final model included body weight, lameness score, and degree of cranial cruciate ligament damage. A grade 3 lameness score had a higher MMI factor than grade 1. Higher body weight was associated with MMI, and complete rupture had a higher MMI factor than partial tears.

Conclusion Arthroscopic evaluation of CrCLR cases showed MMI in toy breed dogs. Cases with complete CrCLR or severe lameness are at high risk of MMI and should be evaluated cautiously.

Keywords
- toy breed dog
- cranial cruciate ligament rupture
- medial meniscus injury
- arthroscopy

Introduction

Medial meniscal injury (MMI) in dogs is commonly associated with cranial cruciate ligament rupture (CrCLR).[1–3] The function of the meniscus includes the absorption and distribution of mechanical loads, congruity and stabilization, lubrication, nutrition, and mechano- and proprioception.[4] Meniscal injuries cause pain and joint inflammation that results in morbidity for affected dogs.[4] In the stance phase, cranial tibial thrust is generated at the femorotibial joint, and the tibia is displaced cranially when the cranial cruciate ligament (CrCL) is ruptured.[5,6] Cranial cruciate ligament rupture causes craniocaudal translational and axial rotational instabilities that are particularly pronounced during the

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stance phase.[7] As a result of these anatomic and biomechanical factors, femorotibial subluxation causes shearing forces on the medial meniscus (MM).[4]

Many types of MMI exist, including vertical–longitudinal, bucket handle, flap, radial, horizontal, complex, and degenerative.[1,4] Additionally, patients diagnosed and treated for concurrent meniscal tears were 1.3 times more likely to have successful long-term outcomes.[1] Thus, evaluation of the meniscus in CrCLR cases is important. Although studies focusing on the incidence and risk factors of MMI have included dogs of various sizes, they often focused on large-breed dogs and did not include toy breeds within the sample.[2,8–11] Moreover, in studies on the treatment of CrCLR in small breed dogs, there was mention of incidence; however, no associated factors were investigated, and most of the sample weighed 5 to 15 kg.[12–16]

Arthroscopic examination is known to improve diagnostic accuracy and postoperative functional recovery than arthrotomy in large breed dogs.[17,18] However, whether arthroscopy is superior to arthrotomy in toy breed dogs remains unknown. Owing to the small size of the stifle joint in toy breeds, a risk of potential underdiagnosis exists with gross evaluation during arthrotomy. In this context, we thought it important to show the extent of incidence by arthroscopy. Therefore, we investigated the frequency and factors associated with MMI in toy breed dogs with CrCLR weighing $\leq$5 kg. We hypothesize that MMI would be associated with complete CrCLR in toy breed dogs.

Materials and Methods

Case Criteria and Record Case Information

Toy breed dogs weighing $\leq$5 kg diagnosed with CrCLR by stifle arthroscopy between January 2016 and December 2022 at VCA Japan YPC Tokyo Animal Orthopedic Surgery Hospital were included. All owners consented to the arthroscopic stifle procedure, as well as the use of the associated data for study purposes. Data regarding age, sex, body weight, breed, medial patellar luxation (MPL) grade according to Singleton's classification,[19] degree of lameness at diagnosis, and duration of lameness until diagnosis were collected from the medical records. The degree of lameness during walking was graded from 0 to 3 (0, no observable lameness; 1, mild weight-bearing lameness with minimal change in gait; 2, moderate weight-bearing lameness with noticeable change; and 3, nonweight-bearing lameness).[11] The tibial plateau angle (TPA) was evaluated using preoperative mediolateral radiography according to the method of Warzee and colleagues.[20]

Anesthesia Protocol and Surgical Preparation

The procedure was performed following standard anesthesia protocols. The dogs were premedicated with midazolam (0.2 mg/kg, intravenous [IV]), followed by propofol (dosed to effect). After intubation, anesthesia was maintained using sevoflurane and 100% oxygen. Considering that all patients underwent tibial plateau leveling osteotomy along with arthroscopy, intraoperative analgesia included morphine (0.5 mg/kg, intramuscular) and a femoral–sciatic nerve block (0.5% bupivacaine, 0.2 mL/kg). Intramuscular or subcutaneous injections of medetomidine (7 µg/kg) were administered as needed. Fentanyl patches were also used for postoperative analgesia. Cefmetazole sodium (25 mg/kg IV) was given preoperatively and every 2 hours intraoperatively.

The pelvic limb was clipped from the greater trochanter to the level of the metatarsus. Prescrub comprised chlorhexidine (Saraya Co., Ltd., Osaka, Japan). The dogs were then transferred to the operation room, positioned in dorsal recumbency with the hind limbs extending over the edge of the surgical table. A surgical scrub was performed by a gloved assistant using chlorhexidine, followed by the application of povidone–iodine spray (Mundipharma K.K., Tokyo, Japan) to the surgical area. A water-repellent drape with a hole (Japan Medical Products Co., Ltd, Asahikawa-shi, Hokkaido, Japan) was placed, and an antibacterial film (Ioban, 3M, Minnesota, United States) was firmly adhered to the exposed limb before incision.

Arthroscopic Evaluation

For arthroscopic evaluation, intra-articular exploration was performed using a 2.4-mm arthroscope (Stryker Corporation, Michigan, United States); a standard arthroscopic approach via a craniolateral and craniomedial parapatellar portal was used. The CrCL, caudal cruciate ligament, MM, and lateral menisci were evaluated. The degree of CrCL damage was classified as either partial or complete. The continuity of CrCL was assessed using a probe (Karl Storz Endoskope, Tuttlingen, Germany); those with continuity were considered to have partial damage, while those without continuity were classified as having a complete rupture. If the torn CrCL or synovitis made MM evaluation difficult, the field of view was secured with a shaver (Stryker Corporation). The medial meniscus was arthroscopically inspected and probed, and the presence or absence of medial and lateral meniscal tears was recorded. During evaluation of the meniscus, the surgical assistant manually opened the joint space. In this study, MMI is classified as "mild" when the effects on the meniscus structure are minimal, whereas injuries requiring partial resection for treatment are classified as "severe" (►**Fig. 1**). The damaged area is incised using either an 18G needle or a No. 11 scalpel and debrided with a shaver.

Statistics Analysis

Stata software (version 14; StataCorp LLC, College Station, Texas, United States) was used for all the analyses. Body weight and TPA are shown as means (95% confidence interval [CI]), and age and time from the onset of clinical symptoms to arthroscopic evaluation are shown as medians (range).

The MMI grade was used as the objective variable; its associated dependent variables included age, sex, body weight, sex, breed, MPL grade, degree of lameness at diagnosis, duration of lameness until diagnosis, and degree of CrCL damage. For this purpose, ordered logistic regression was used, and the final model was created using the forward–backward stepwise selection method. Dependent variables

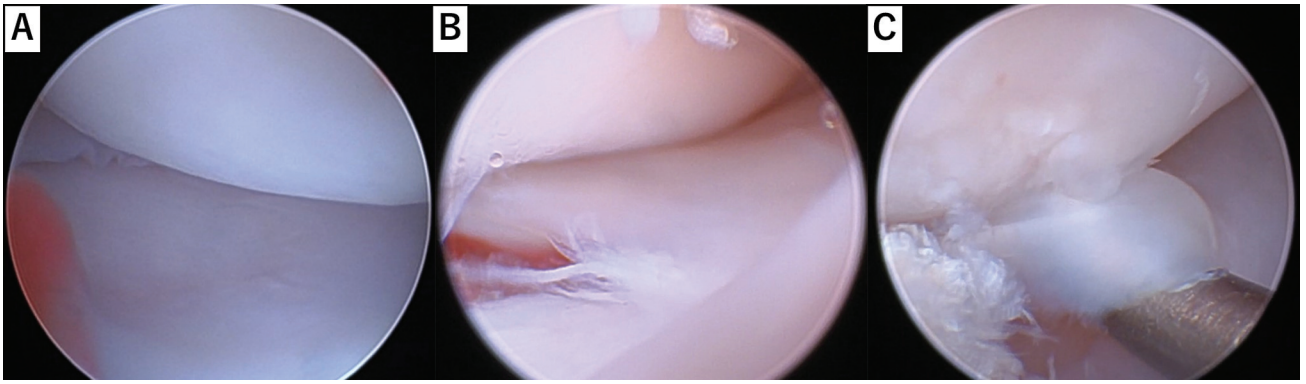

Fig. 1 Arthroscopic evaluation of the medial meniscus. (**A**) Arthroscopic view of the left stifle joint of a dog with a normal medial meniscus. (**B**) Arthroscopic view of the left stifle joint of a dog with a small radial tear (mild damage) of the medial meniscus. (**C**) Arthroscopic view of the left stifle joint of a dog with a bucket-handle tear (severe damage) of the medial meniscus.

with $p < 0.20$ were selected for evaluation using simple regression, followed by multivariable regression analysis. Multiple regressions with backward stepwise selection were performed to identify a model containing the variables that remained after excluding those with large p-values. The final model was used when all variables had a p-value < 0.05. Two-sided hypothesis tests were used at a 5% significance level for statistical estimation and inferences.

Result

Animals

In total, 202 stifles in 178 dogs were included in this study. The mean body weight and age at arthroscopic evaluation were 3.59 (95% CI: 3.08–4.11) kg and 101 (range: 12–185) months, respectively. Several breeds were included, with Toy Poodles being the most common (51 dogs, 58 stifles), followed by Chihuahua (47 dogs, 50 stifles) and Yorkshire Terrier (40 dogs, 45 stifles). The time from the onset of clinical signs to arthroscopic evaluation was 3 (range: 1–32) weeks. The degree of lameness was mild (grade 1) in 127, moderate (grade 2) in 34, and severe (grade 3) in 41 stifles. Mediolateral radiographs showed a TPA of 27.6 (95% CI: 26.8–28.4) degrees. Grade 1 MPL included one stifle (0.5% of all stifles), grade 2 MPL included 25 stifles (12.3% of all stifles), grade 3 MPL included 106 stifles (52.2% of all stifles), and grade 4 MPL included nine stifles (4.43% of all stifles).

Arthroscopic Evaluation

Arthroscopic evaluation revealed a partial CrCL tear in 58 stifles (28.7%) and a complete rupture in 144 stifles (71.3%). Caudal cruciate ligament damage was observed in 13 stifles (7.3% of all stifles), all with superficial fraying of the ligament fibers. Lateral meniscal damage was observed in 12 stifles (6.8%) with small radial tears. MMI was observed in 74 stifle joints (36.3% of all stifles). Mild damage was observed in 50 stifles (67.6% of stifles with MMI), and severe damage was observed in 24 stifles (32.4% of stifles with MMI). All menisci classified as having mild damage exhibited small radial tears, whereas 19 severely damaged menisci presented with bucket handle tears and 5 with flap injuries. Among the stifles with mild damage, four (6.9% of stifles with partial tear) were associated with partial tears, and 46 (31.9% of stifles with complete CrCLR) were associated with complete CrCLR; of the stifles with severe damage, 2 (3.4% of stifles with partial tear) stifles were associated with partial CrCL tears, and 22 (15.3% of stifles with complete CrCLR) were associated with complete CrCLR. Debridement or excision of the lesions was also performed as needed in all cases.

Without conducting a statistical comparison, the three breeds (Toy Poodles, Chihuahuas, and Yorkshire Terriers)

Table 1 Arthroscopic findings of the cranial cruciate ligament and medial meniscus in Toy Poodles, Chihuahuas, and Yorkshire Terriers, and proportions within each breed

	Toy Poodle ($n = 58$)		Chihuahua ($n = 50$)		Yorkshire Terrier ($n = 45$)	
	Number	Percentage	Number	Percentage	Number	Percentage
CrCL damage						
Complete rupture	41 stifles	70.7%	35 stifles	70.0%	39 stifles	86.7%
Partial tear	17 stifles	29.3%	15 stifles	30.0%	6 stifles	13.3%
MMI						
Total number	21 stifles	36.2%	15 stifles	30.0%	25 stifles	55.6%
Severe damage	8 stifles	13.7%	3 stifles	6.00%	8 stifles	17.8%
Mild damage	13 stifles	22.4%	12 stifles	24.0%	17 stifles	37.8%

Abbreviations: CrCL, cranial cruciate ligament; MMI, medial meniscus injury.

Table 2 Final models of the multivariable ordered logistic regression for medial meniscus injury

		Coefficient	95% CI	*p*-Value
Body weight		0.405	0.0130–0.797	**0.043**
Degree of lameness	Grade 2	0.634	-0.169–1.44	0.122
	Grade 3	1.45	0.714–2.19	<**0.001**
Degree of CrCL damage	Complete	1.72	0.794–2.65	<**0.001**

Abbreviations: CI, confidence interval; CrCL, cranial cruciate ligament.
Notes: For the degree of lameness, grades 2 and 3 were compared with grade 1. Degree of CrCL damage refers to complete rupture compared with a partial tear.

with the largest sample were selected for observation. The incidence of MMI was highest in Yorkshire Terriers (35.1% of stifles in Toy Poodles, 30.0% in Chihuahuas, and 55.6% in Yorkshire Terriers; ►**Table 1**). Particularly, Yorkshire Terriers demonstrated more cases of complete CrCLR than the other breeds (71.9% of stifles in Toy Poodles, 70.0% in Chihuahuas, and 86.7% in Yorkshire Terriers).

Factors of Medial Meniscal Injury

The results of the single regression analysis showed that breed, age, body weight, lameness score, and degree of CrCL damage satisfied $p < 0.05$ (►**Appendix Table A1**, available in the online version). The final model included variables such as body weight, lameness score, and the degree of CrCL damage (►**Table 2**). Compared with a grade 1 lameness score, grade 3 had a higher MMI factor. Higher body weight was associated with MMI, and complete tears had a higher MMI factor.

Discussion

To the best of our knowledge, this is the first study to determine the frequency and factors contributing to MMI in toy breed dogs weighing ≤ 5 kg. Arthroscopic evaluation of CrCLR cases revealed meniscal injuries in toy breed dogs. As hypothesized, the risk of MMI was higher in cases of complete CrCLR. Additionally, patients with severe preoperative lameness and a heavier weight had a higher risk of MMI.

The arthroscopic evaluation of CrCLR cases in this study revealed concomitant MMI in 36.3% of the affected limbs. A review related to meniscal injuries noted that meniscal injuries in dogs ranged from 0 to 84.6%;[3] additionally, in previous reports studying small dog breeds (≤15 kg), MMI was found in 28 to 67% of dogs.[12–16] It is inferred that multiple factors contribute to the variability of each result, including the characteristics of the sample (dog size, percentage of complete tear cases, lameness severity and duration, etc.) and the method of joint exploration.[1,9,10,21] The results of this study revealed that the degree of CrCL injury, lameness, and body weight were related to MMI in toy dog populations. The degree of CrCL damage (partial or complete rupture) is supported by several reports.[9,10,21] When the CrCL is completely torn, the craniocaudal and rotational instabilities of the tibia are significant.[7,22] When compressive forces are generated in the joint, the tibia subluxated cranially, resulting in an increased loading of the caudal meniscus. In CrCLR, this subluxation is repeated during gait, which places repetitive loading on the caudal horn.[4] Hence, damage is expected to be induced. Previous studies have confirmed that early surgical intervention preserves CrCL function.[23–25] Additionally, patients diagnosed and treated for concurrent meniscal tears were 1.3 times more likely to have successful long-term outcomes.[1] Early diagnosis and treatment of CrCLR may therefore be important for preserving intra-articular structures, as MMI can also exacerbate claudication. Moreover, body weight was a factor associated with MMI, which is possible because dogs with larger body weight may also have relatively larger stifle joints. This could facilitate arthroscopic evaluation and increase the likelihood of detecting a meniscus injury. While no cases in which the caudal horn of MM could not be observed occurred in this study, it could present a potential factor that reduces diagnostic accuracy.

The results of this study demonstrated a higher rate of MMI in Yorkshire Terriers than in other breeds; however, this result was excluded from the final multiple regression model. One reason for the higher rate of MMI may be that Yorkshire Terriers had a higher percentage of complete CrCLR than other breeds. In other words, there is a possible multicollinearity between breed and degree of CrCL damage. In several previous reports, Yorkshire Terriers showed a high prevalence of CrCLR.[26,27] In this study, Yorkshire Terriers had more cases of complete CrCLR than other breeds, suggesting that there may be a pathological progression of CrCL disease that is unique to Yorkshire Terriers and different from that in other toy breeds. However, there is no research to support this unique pathological progression; therefore, future investigation of breed-specific characteristics may lead to a better understanding of pathogenesis.

The limitations of this study include the use of data from a single center. The single-center study design limited the number of cases included and patient demographics; specifically, Japan has by far the largest number of Toy Poodles, followed by the largest number of Chihuahuas. A risk persists that such a bias in breeds bred in different regions and countries may affect the analysis of breed-specific differences, as well as other factors. While a 2.4-mm arthroscope was used for evaluation in this study, many clinicians employ a 1.9-mm arthroscope for toy breeds. The difference in scope size may impact diagnostic accuracy, particularly for smaller stifle joints. To date, no studies have examined the relationship between scope size and diagnostic accuracy, a factor that warrants consideration in future research.

Overall, the arthroscopic evaluation of CrCLR cases in this study revealed concomitant MMI in 36.3% of the affected limbs in toy breeds. Particularly, cases with complete rupture of CrCL or severe lameness are at high risk for MMI and should be evaluated with caution.

Authors' Contribution

Y.K. and M.S. contributed to the conception of the study, study design, data acquisition, data analysis, interpretation, and drafting of the manuscript. A.H., H.A., and F.T. contributed to data acquisition, data analysis, and interpretation. S.Y. contributed to study conception, study design, and data acquisition. All the authors have revised and approved the manuscript.

Conflict of Interest

M.S. was funded by a JSPS KAKENHI Grant-in-Aid for Early-Career Scientists (number: JP23K14096) and an AO Vet Seed Grant (number: 115492) outside of the submitted work.

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