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Evaluation of partial cranial cruciate ligament rupture with positive contrast computed tomographic arthrography in dogs

Sungyoung Han[1], Haengbok Cheon[1], Hangmyo Cho[1], Juhyung Kim[1], Ji-Houn Kang[1], Mhan-Pyo Yang[1], Youngwon Lee[2], Heechun Lee[3], Dongwoo Chang[1,*]

[1]*Veterinary Medical Center, College of Veterinary Medicine, Chungbuk National University, Cheongju 361-763, Korea*
[2]*Department of Veterinary Medicine, College of Veterinary Medicine, Chungnam National University, Daejeon 305-764, Korea*
[3]*Department of Veterinary Medicine, College of Veterinary Medicine, Gyeongsang National University, Jinju 660-701, Korea*

Computed tomographic arthrography (CTA) of four cadaveric canine stifles was performed before and after partial cranial cruciate ligament rupture in order to verify the usefulness of CTA examination for the diagnosis of partial cranial cruciate ligament rupture. To obtain the sequential true transverse image of a cranial cruciate ligament, the computed tomography gantry was angled such that the scanning plane was parallel to the fibula. True transverse images of cranial cruciate ligaments were identified on every sequential image, beginning just proximal to the origin of the cranial cruciate ligament distal to the tibial attachment, after the administration of iodinated contrast medium. A significant decrease in the area of the cranial cruciate ligament was identified on CTA imaging after partial surgical rupture of the cranial cruciate ligament. This finding implies that CTA can be used for assessing partial cranial cruciate ligament ruptures in dogs.

Keywords: arthrography, computed tomography, cruciate ligament, dog, rupture

Introduction

Most ligament injuries in canine stifle joints involve some kind of cranial cruciate ligament rupture, including partial rupture [9]. This results in severe instability and predisposes the joint to degenerative changes [7].

The cranial cruciate ligament is attached to a fossa on the caudal aspect of the medial side of the lateral femoral condyle. It courses cranially, medially, and distally across the intercondylar fossa and attaches to the cranial intercondyloid area of the tibia [1]. The cranial drawer test is diagnostic of cranial cruciate ligament injuries. A positive test result implies craniocaudal movement beyond the 0 mm to 2 mm mobility found in a normal stifle joint. However, if a partial tear is present, the cranial drawer sign may reveal only 2 mm to 3 mm of instability when the test is done with the stifle flexed and no instability with the stifle in extension [13]. In addition, one study found that 12 of 25 dogs with partial rupture of the cranial cruciate ligament had no detectable cranial drawer sign in response to manipulation of the involved stifle [9]. Hence, it is not surprising that veterinarians encounter difficulties in diagnosing partial ruptures of the cranial cruciate ligament.

Echography is a useful technique in the evaluation of intra-articular proliferation of reactive fibrotic tissue of unstable stifle joints affected by cranial cruciate ligament rupture as a result of chronic synovitis [6]. However, ultrasonographic examination is not an accurate test for cranial cruciate ligament rupture evaluation [6]. To overcome the diagnostic limitations of ultrasonographic examination for the detection of cranial cruciate ligament rupture in one study, the stifle was imaged via dynamic intra-articular saline injection. The investigators concluded that ultrasonographic examination of stifle joints had potential as a diagnostic tool for assessing cranial cruciate ligament rupture [10]. Nevertheless, ultrasonographic examinations are highly operator-dependent, and a great deal of flexibility is often required for good images to be obtained.

Arthroscopy and magnetic resonance imaging (MRI) may be useful diagnostic procedures for confirming the diagnosis, although arthroscopy is invasive and MRI is expensive [3,4]. The advantages of computed tomographic arthrography (CTA) over MRI include increased availability of equipment, shorter examination time, and decreased imaging artifacts [4,12]. Dual-detector helical CTA is as sensitive and specific as MRI in identifying stifle intraarticular ligamentous

*Corresponding author
Tel: +82-43-261-3372; Fax: +82-43-261-3224
E-mail: dwchang@cbnu.ac.kr

pathology [8,11]. However dual-detector helical computed tomography (CT) is not yet readily available for use in canine patients.

Recently, the diagnostic utility of single-detector CTA for identifying ligamentous structures in the normal canine stifle has been investigated and has been established as a repeatable imaging protocol [8]. The ligamentous structures of the normal canine stifle are easily identified using the CTA protocol described.

The purpose of this study was to optimize the CTA protocol to obtain sequential true transverse images of cranial cruciate ligaments and to evaluate the effectiveness of CTA for detecting partial cranial cruciate ligament rupture in dogs.

Materials and Methods

Animals

All experimental procedures were approved by the Institutional Animal Care and Use Committee (Chungbuk National University, Korea). Four hind limbs obtained from 4 mongrel dogs (body weights 20 to 30 kg) euthanized for reasons unrelated to this study were used for CTA investigation. The average age was 16 months. All dogs had body condition scores (BCS) of 3 on the 5-point BCS system [5]. Radiographs and synovial fluid examination of the stifle were performed to confirm the absence of abnormal findings. The specimens were disarticulated at the hip joint, and all soft tissues distal to the hip joint were preserved.

CT protocol

Each limb was mounted on a custom-made v-shape positioner, with the cranial surface of the limb apposed to the CT couch. The stifle was flexed visually at a 90 degree angle. All data were collected using a fourth-generation CT scanner (Picker IQ; Philips Medical Systems, USA). After acquisition of lateral pilot images, the stifle angle was readjusted to 90 degrees with the built-in goniometer (Fig. 1). To obtain the true transverse image of the cranial cruciate ligament, the CT gantry was angled such that the scanning plane was parallel to the fibula. Two-millimeter thick, contiguous transverse pre-arthrography CT images were obtained from just caudal to the femoral epicondyle to just cranial to the femoral epicondyle. All scans were performed using a bone algorithm, 85 mA, 130 kVp, and field of view of 50 mm.

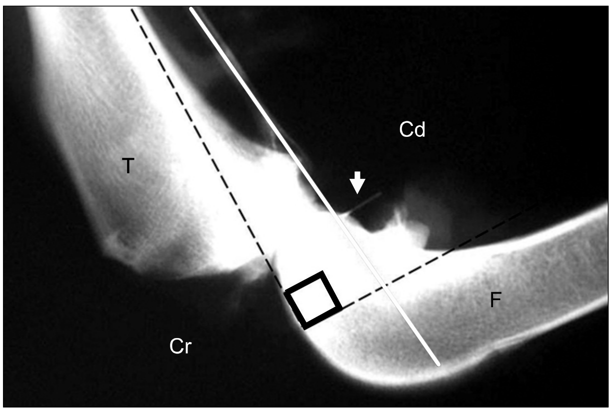

Fig. 1. Lateral radiograph of the stifle showing the relationship between stifle angle and the cranial cruciate ligament. Metal landmarks implanted in the cranial cruciate ligament (arrow) are shown. The cranial cruciate ligament and the fibula cross at a right angle when the stifle is flexed at 90 degrees. Cr: cranial, Cd: caudal, F: femur, T: tibia.

CTA protocol

A 21-gauge needle was directed midway between the cranial point of the patella and the tibial tuberosity and just medial to the patella [2]. Digital pressure was applied to the caudal aspect of the joint opposite the point of entry into the joint. Iohexol (Omnipaque 300; Nycomed, USA) 150 mg I/ml was injected into the joint at a volume of 0.3 ml/cm of the medial to lateral thickness of the joint [2,6]. The joint was manipulated and massaged to assure even distribution of the material. The limb was repositioned on the CT couch as before, and the CT acquisition protocol was repeated.

Surgical procedure

After CTA scans of the intact stifle joint were performed, the cranial cruciate ligaments were partially transected by lateral stifle arthrotomy in a routine manner [12]. Partial transection of the cranial cruciate ligament was performed locally at the craniomedial band 2 mm distal to the tibial insertion (Fig. 2). After partial transection was performed, an extracapsular technique involving lateral imbricating sutures was used to ensure sealing of the stifle joint. Residual air within the joint space was removed using the 21-gauge needle. After the procedure was completed, CTAs were done in the same manner.

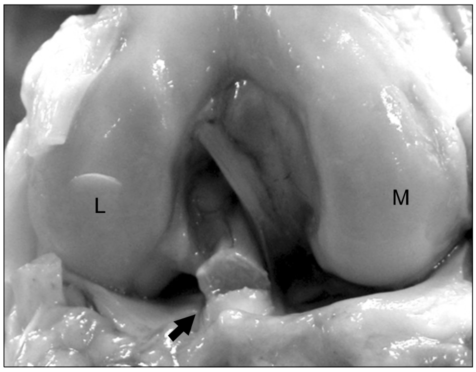

Fig. 2. Photograph of the canine cadaveric stifle joint illustrating the cranial cruciate ligament. Experimental cranial cruciate ligament rupture is identified (arrow). L: lateral, M: medial.

Image analysis

Using Visus Image Analysis software (Ista-Video Test; Foresthill Products, USA), the sequential transverse images of the cranial cruciate ligament were evaluated. Pre-operative images were compared with post-operative images in each cadaver.

Results

Nine sequential transverse cranial cruciate ligament images were obtained (Fig. 3). The initial transverse CTA image of the intact cranial cruciate ligament at the tibial attachment revealed a comma shape. The middle stage revealed a round shape. The final CTA transverse image obtained at the attachment of the cranial cruciate ligament to the menisci was eclipse shaped. Total cranial cruciate ligament slices involved the femoral attachment to the tibial attachment. The mean number of slices for five cadavers was 5.7. Five slices were obtained from cadaver 4, while six slices were obtained from the other cadavers.

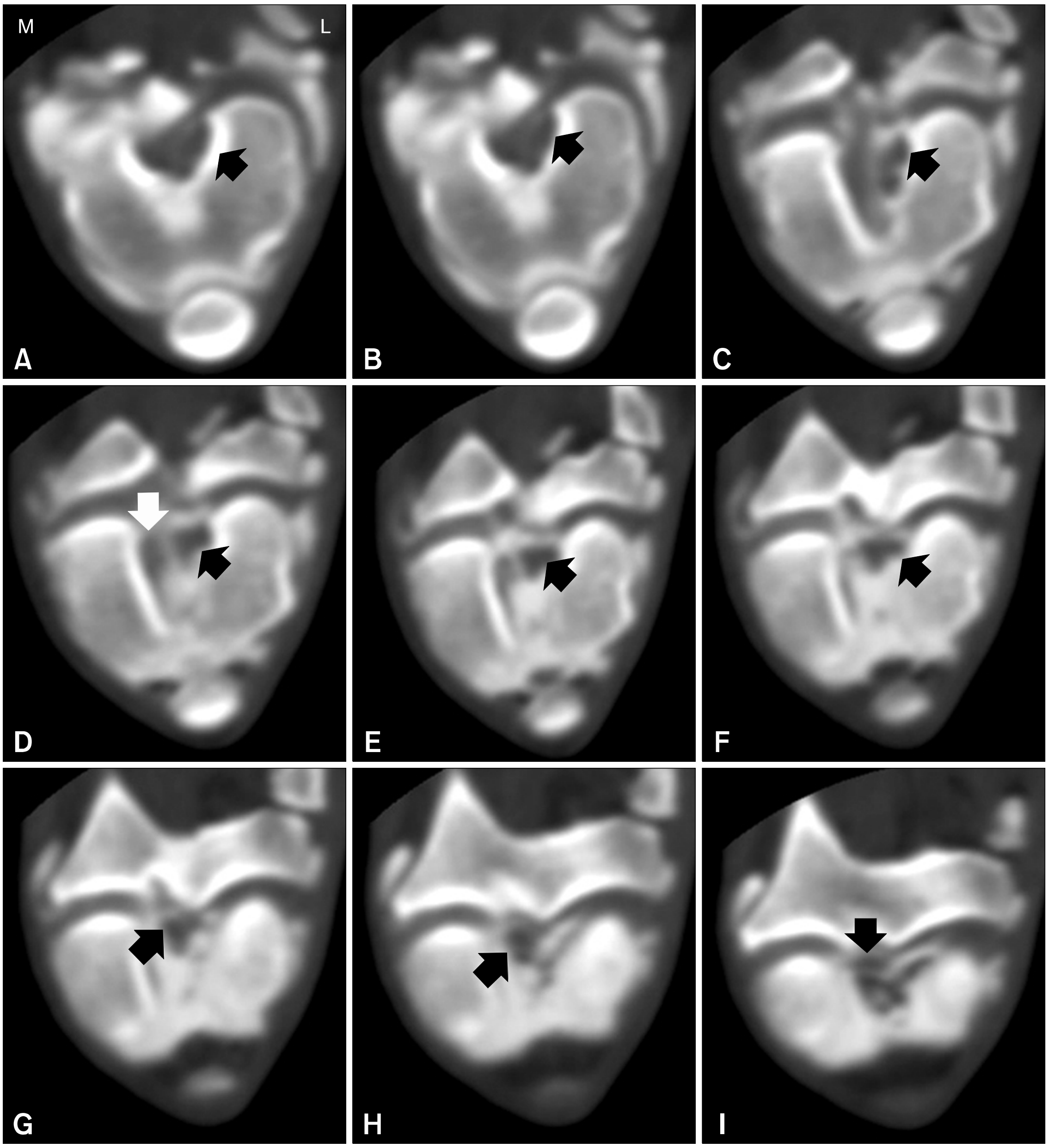

Fig. 3. Two-millimeter sequential transverse computed tomographic arthrography images were scanned parallel to the fibula, femoral attachment (A), and tibial attachment (I). The cranial cruciate ligament (black arrow) transverse images and caudal cruciate ligament sagittal images (white arrow) were clearly identified. L: lateral, M: medial.

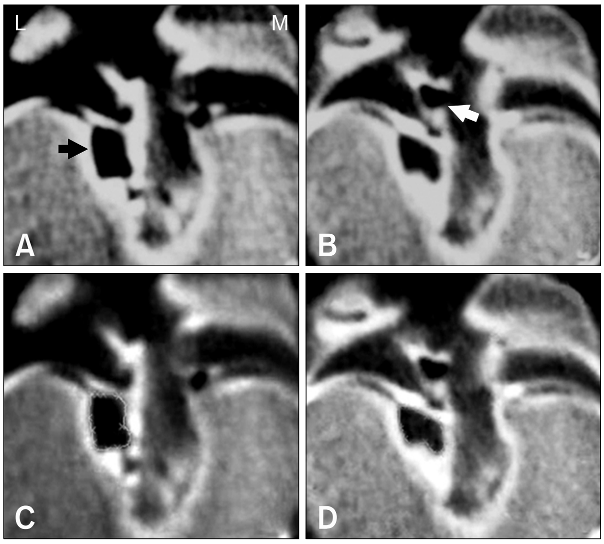

Fig. 4. Comparison of the pre-operative conventional view (A) and tracing view (C) with the post-operative conventional view (B) and tracing view (D). The transverse area of the cranial cruciate ligament image (black arrow) was decreased by 25% on the post-operative image. The small gas artifact (white arrow) was considered a normal finding. L: lateral, M: medial.

Table 1. Transverse area (mm^2) before and after partial cranial cruciate ligament rupture

Cadaver No.		Slice No.					
		1	2	3	4	5	6
1	Pre	0.33	0.48	0.46	0.57	0.56	0.56
	Post	0.34	0.47	0.45	0.25*	0.1*	0.3*
	%	104	99	99	44	17	59
2	Pre	0.54	0.66	0.68	0.71	0.74	0.71
	Post	0.5	0.52	0.62	0.52*	0.49*	0.64
	%	91	78	90	73	66	90
3	Pre	0.55	0.58	0.68	0.7	0.8	-
	Post	0.47	0.56	0.23*	0.17*	0.71	-
	%	85	94	33	25	88	-
4	Pre	0.5	0.56	0.55	0.5	0.58	0.66
	Post	0.46	0.51	0.46*	0.33*	0.5	0.61
	%	93	90	83	65	87	93

Pre: pre-operative computed tomographic arthrography, Post: post-operative computed tomographic arthrography. *The slice in which the partial cranial cruciate ligament rupture was done, % = post-operative value/pre-operative value ×100.

Images at the same anatomical location were compared before and after surgery. Defect lesions were identified on post-surgery CTA images (Fig. 4). Air artifact were also identified after the procedure was complete.

In the pre-operative period, the cranial cruciate ligament area range was 0.3~0.6 mm^2/kg for cadaver 1, 0.5~0.7 mm^2/kg for cadaver 2, 0.6~0.8 mm^2/kg for cadaver 3, and 0.5~0.7 mm^2/kg for cadaver 4. In the post-operative period, decreases in the area of the cranial cruciate ligament defect in cadaver 1 were 56% in the fourth slice, 83% in the fifth slice, and 41% in the sixth slice; in cadaver 2 they were 27% in the fourth slice and 34% in the fifth slice; in cadaver 3 they were 67% in the third slice and 75% in the fourth slice; in cadaver 4 they were 17% in the third slice and 35% in the fourth slice (Table 1). The decreases in non-defect lesion area ranged from -4% to 15%.

In cadaver 2, the area of the lesion in the second slice decreased by 22%; this finding may have been due to contrast medium infiltrating the cranial cruciate ligament.

Discussion

We sought to determine the diagnostic utility of single detector CTA for identifying ligamentous structures in the normal canine stifle and to establish a repeatable imaging protocol. The ligamentous structures were easily identified using the CTA protocol described. Multiplanar reconstructions were helpful for the evaluation of cranial cruciate ligaments, medial and lateral menicsi, long digital extensor tendons, and popliteal tendons.

We tried to orient reconstruction planes to parallel the axis of the cranial cruciate ligament in order to evaluate its entire length. The obliquity required to achieve this was variable within and between dogs. Subtle differences in limb positioning were not resolved. In addition, there were limitations in describing the total cranial cruciate ligament appearance. In an earlier study, the stifle position had no definite angle and was extended caudally at random. The CT gantry was angled such that the scanning plane was parallel to the tibial plateau. For this reason, transverse cranial cruciate ligament images were obtained atypically [8]. For successful examination to occur, each patient needed to be in a fixed position while scanning for constant images of the cranial cruciate ligament occurred. During the primary examination, cranial cruciate ligament tension was observed in various positions. We found that, when the stifle angle was 90 degrees, the assumption line was horizontal to the cranial cruciate ligament and vertical to the fibula. For this reason, the CT gantry was angled such that the scanning plane was parallel to the fibula. As a result, we obtained sequential transverse CTA images of the cranial cruciate ligament.

In the present study, an average of 5.7 slices were taken from some regular-distant cross sections of whole images in four cadavers. In the pre-operative stage, the cross sections of the cranial cruciate ligament progressed from ‘comma’, to ‘round’, to ‘eclipse’, in sequence from the femoral attachment to the tibial attachment, and the margination was constantly smooth [4]. However, in the post-operative period, the comma and round shapes were maintained at the initial site of femoral attachment, and afterward the margination became relatively irregular. As a result, when the area of the two cranial cruciate ligament pieces were compared, the area in the post-operative period was smaller than that seen in the pre-operative period at the same anatomic location. This finding was also noted in the case of experimental partial ruptures around the tibial attachment, which we made intentionally.

There are a number of reasons why partial tears were used as an experimental model. Partial tears in dogs consistently progress to complete ligament rupture, usually within one year of the onset of lameness [13]. Furthermore, the definite diagnosis of partial cranial cruciate ligament tears is more complicated than the diagnosis of complete tears is. If earlier surgical procedures prove to retard the progression of osteoarthritis, it is appropriate to recommend surgery as soon as possible after the diagnosis of partial tearing has been confirmed. Thus, partial tear models were used.

In this study, medium to large sized dogs were used for several reasons. Cruciate ligament disease is particularly common in large and giant breed dogs, such as the Labrador Retriever, Rottweiler, and Saint Bernard [7,14], and large breed dogs are more commonly presented for surgical management of cranial cruciate ligament rupture. In addition, the quality of CTA images in large breed dogs is expected to be better than that seen in small breed dogs [6].

When each experimental partial rupture was performed in this study, air entered the articular capsule. After the procedure, air artifact was created near the cranial cruciate ligament. However, this did not affect the cranial cruciate ligament.

In all cadavers, the image area for the cranial cruciate ligaments decreased in partial transection slices. When the slices from the post-operative period were compared with those from the pre-operative period in all cadavers, some decrease in cranial cruciate ligament defect area was seen in 2 to 3 slices from each cadaver. Considering that the CTA image thickness is 2 mm, the expected loss would be between 4 mm and 6 mm in actuality. However, this may not always be true in clinical practice because we fashioned a clear transection in the experiment. On post-operative images, the defects were shown to be cranial in location. Through CTA image analysis, it was found that the transverse area of the cranial cruciate ligament decreased anywhere between 17% and 83%. If the experimental defect area was not overlooked, the gap could have been attributed to slight anatomical deviation or to artifact. These findings support the idea that tears of the cranial cruciate ligament are visible with the unaided eye using only CTA, which enables practitioners to make a standard list for objective examination. Furthermore, our findings suggest the possibility of establishing a specific protocol for other ligamentous structures. It is necessary to do more studies on contrast agent dosing in living subjects, as well as to better examine the transverse images.

This study showed clear CTA images of acute partial ruptures of the cranial cruciate ligament. However, most partial ruptures of the cranial cruciate ligament seen in clinical practice are chronic, and lesions of the stifle are effusive or fibrotic. In humans, it is recommended that an effusive knee be drained prior to the infusion of contrast medium [4,12]. For this reason, future studies will require adjustments in the volume or concentration of contrast medium, as conditions dictate.

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