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CASE REPORT

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Computed tomographic imaging and surgical management of distal insertional avulsion fragments of the caudal cruciate ligament in four horses

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Abstract

Objective: To describe cases with caudal cruciate ligament (CdCL) avulsion fragments diagnosed based on computed tomography (CT) examination and report on arthroscopic fragment removal.

Animals: Four Warmblood horses with hindlimb lameness and osseous fragments located in the caudal medial femorotibial joint (mFTJ).

Study design: Short case series.

Methods: CT and arthroscopic evaluation of the caudal mFTJ were performed. The caudal mFTJ and the insertion of the CdCL on the tibia were assessed and removal of the avulsion fragments was attempted in three horses using a cranial intercondylar approach.

Results: The fragment was not accessible via caudomedial approaches in one horse. A cranial intercondylar approach was used in three horses, allowing removal of the intra-articular fragment in two horses, and removal of two-thirds of the proximal fragment in the last horse. Acute, profuse, arterial bleeding occurred in this horse during surgery with transient postoperative soft tissue swelling. Comorbidities included medial femoral condyle cartilage defects (3), cranial cruciate ligament lesions (2), and medial collateral ligament lesions (2). Horses were followed up for 16 months (median, range 11–28 months), at which point all were back in ridden exercise; owners' satisfaction was good.

Conclusion: CT examination confirmed the diagnosis and allowed evaluation of the stifle joint for comorbidities. A cranial intercondylar arthroscopic approach facilitated the removal of CdCL insertional avulsion fragments, although not always complete.

Clinical significance: A cranial intercondylar approach can allow access to CdCL avulsion fragments, but complications and incomplete removal remain possible.

1 | INTRODUCTION

The equine caudal cruciate ligament (CdCL) originates from the medial aspect of the intercondylar fossa of the femur, courses in a caudodistal direction, and inserts at the area intercondylaris caudalis and the incisura poplitea of the tibia.[1] This central location makes ultrasonographic examinations of the CdCL difficult.[2,3] In contrast, several studies describe the value of computed tomography (CT) and computed tomographic arthrography (CTA) for the evaluation of cruciate ligaments.[4–8] Cruciate ligament desmitis is detected in CT as enlargement of the ligament and abnormal attenuation, and in CTA with intraligamentous contrast accumulation.[4–8]

To the best of the authors' knowledge, only two case reports have previously described CdCL avulsion fractures at the level of the tibia in horses.[9,10] While in the past the involvement of the CdCL with these fragments was confirmed during post-mortem examination,[10] recently CTA was able to confirm the association of the CdCL with the osseous fragmentation.[9]

The intracapsular location of the CdCL in the medial femorotibial joint (mFTJ) facilitates arthroscopic evaluation and traditionally a caudomedial approach is used for the assessment of the caudal compartment of the mFTJ.[11] Detection rates for CdCL pathologies were reported at a lower rate with this arthroscopic approach when compared to CTA in one study, which may be explained by the limited arthroscopic access to the mid to distal portion of the CdCL, where the most CdCL defects were detected.[8] Improved visualization of the CdCL body and insertion has been reported with a cranial intercondylar approach.[12]

The aim of this case series was to describe cases with CdCL avulsion fragments diagnosed based on CT examination and report on the feasibility of arthroscopic fragment removal.

2 | MATERIALS AND METHODS

2.1 | Horse signalment, clinical presentation, and diagnostic imaging

Detailed information about the horse's signalment and clinical presentation is available in Table 1. At least one large, isolated radiopaque fragment was detected at the caudoaxial aspect of the tibia on standard radiographic projections of the stifle joint in all horses (Figure 1). A large calcification was additionally present at the insertion of the medial collateral ligament in horse 3 (Figure 2). CT examination in lateral recumbency was performed immediately prior to arthroscopic surgery in dorsal recumbency in horses 1–3 using a 32-detector-row CT scanner (Aquilion One, Canon Medical Systems). In horse 4 the CT examination was performed by the referring veterinarian under a separate anesthetic event. In the soft tissue window, it was possible to follow the CdCL from the axial medial part of the femur traversing towards the most proximal tibial fragment in all cases (Figure 3). Horse 3 had only one large osseous fragment. The other horses had smaller fragments located distal and cranial to the main large proximal fragment. Intra-articular contrast application was added in horses 2 and 4 and confirmed the intra-articular location of the cranial portion of the proximal fragment in both cases (Figure 4). For the CTA, an iodinated contrast agent (200 mg/kg, Solutrast 200 M, Bracco Imaging, Germany) diluted with isotonic saline solution to a concentration of 100 mg/mL was used and a volume of 60–80 mL was injected in each joint compartment. Enlargement of the CdCL, with heterogeneous opacity or central hypoattenuation, was identified in all cases. For each horse, concomitant stifle joint pathology detected with CT/ CTA is listed in Table 1.

2.2 | Surgical technique

Flunixin meglumine (1.1 mg/kg IV), amoxicillin (15 mg/kg IV), and gentamicin sulfate (6.6 mg/kg IV) were administered 30 min preoperatively. General anesthesia was induced with xylazine (0.4–1.1 mg/kg IV), diazepam (0.02 mg/kg IV), and ketamine (2.2 mg/kg IV) and maintained with isoflurane and a continuous rate infusion of xylazine.

Horses were positioned in dorsal recumbency with the stifle flexed to approximately 90°. CT images were projected on a screen in the surgical theater with both multiplanar and 3D bone reconstruction images available. An artificial equine stifle specimen including ligaments, tendons, and menisci was present to improve understanding of the arthroscopic anatomy during surgery (Anatomy Department, University of Zurich, Switzerland).

Initially, a central cranial approach was used in all horses to access the femoropatellar joint (FPJ) and the cranial pouches of the femorotibial joints (FTJ), with the medial and lateral portals placed approximately 50%–60% of the distance from the tibial crest to the distal patella just medial and lateral to the middle patellar ligament.[13] The dissection of the synovial septa between the FPJ and FTJ with arthroscopic scissors (Storz, Germany) was followed by exploration of all cranial joint compartments.

In horse 2 only a caudomedial approach was used to access the caudal mFTJ pouch. The first portal was created 6 cm caudal to the medial collateral ligament, 1 cm proximal to the level of the line between the palpable tibial tuberosity and tibial condyle cranial to the saphenous

TABLE 1 Case overview of four adult Warmblood horses that underwent computed tomography and arthroscopic evaluation of the stifle joint for assessment of caudal cruciate ligament (CdCL) avulsion.

Variables	Horse 1	Horse 2	Horse 3	Horse 4
Signalment (age, sex, bodyweight)	9 years, mare, 730 kg	10 years, mare, 550 kg	12 years, mare, 500 kg	6 years, stallion, 575 kg
History				
Etiology	Kick injury	Tight turn in stable	Lame after turnout	Not reported
Affected limb (lameness AAEP)	Right hind (3/5)	Left hind (4/5)	Left hind (3/5)	Right hind (2–3/5)
intra-articular anesthesia of affected stifle joint	No	Yes (negative)	No	No
Swelling of joint, pain on palpation, flexion test	Mild swelling, painful, no flexion	Mild swelling, painful, positive on flexion	Swelling, not painful, positive on flexion	Mild swelling, not painful, positive on flexion
Time between injury and presentation	Days	One week	Three months	Weeks
CT/CTA findings	One large, several smaller, isolated dislocated avulsion fracture fragments at insertion of CdCL	Large isolated dislocated avulsion fracture fragment at insertion of CdCL Desmopathies of CdCL and medial collateral ligament Middle patellar ligament enthesopathy at the apex of patella Protrusion of cranial medial meniscus Osteoarthritis mFTJ	Large round isolated dislocated avulsion fracture fragment at insertion of CdCL CdCL with enlargement and hypoattenuating region Calcification medial collateral ligament	Five isolated avulsion fracture fragments at insertion of CdCL CdCL with enlargement and linear hypoattenuating region Small subchondral cyst MFC

Abbreviations: CT, computed tomography; CTA, computed tomographic arthrography; LFC, lateral femoral condyle; MFC, medial femoral condyle; mFTJ, medial femorotibial joint.

vein.[11] An additional instrument portal was created cranial to the first portal. The caudal joint pouch was explored and the fragment could not be visualized.

In the other three horses a cranial intercondylar approach was used to access the caudal mFTJ pouch. After exploring the cranial mFTJ a 4 mm switching stick (smooth shafted conical obturator, Storz, Germany) was inserted into the portal lateral to the middle patellar ligament and advanced towards caudal between the CdCL and the axial part of the medial femoral condyle (MFC) (Figure 5A).[12] In horses 1 and 3 the initially created portal lateral to the middle patellar ligament did not allow the placement of the switching stick at the correct angle. To identify the correct portal location a spinal needle (20G–1½") was guided into the intercondylar space between the CdCL and the MFC and a third portal was created proximal or distal to this portal. To avoid inadvertent penetration of the thin caudal joint capsule caudal advancement of the switching stick was performed under fluoroscopic guidance (C-arm, BV Pulsera; Philips) using a lateromedial projection. A second arthroscopic sleeve was subsequently advanced over the switching stick into the caudomedial mFTJ compartment and the arthroscope was inserted (Figure 6). The caudal compartment of the mFTJ was explored by turning the 30° angled arthroscope around its longitudinal axis in both directions to localize the CdCL and the associated avulsion fragment (Figure 7).

To create a caudomedial instrument portal a spinal needle was inserted 4–8 cm caudal to the medial collateral ligament and directed towards the cranial, articular part of the fragment under fluoroscopic guidance using a lateromedial and/or caudocranial beam angle (Figure 6).[11] A portal was subsequently created following the direction of the needle to access the caudal mFTJ.

Extensive soft tissue attachments were present in all fragments. Several instruments including a 6 mm round

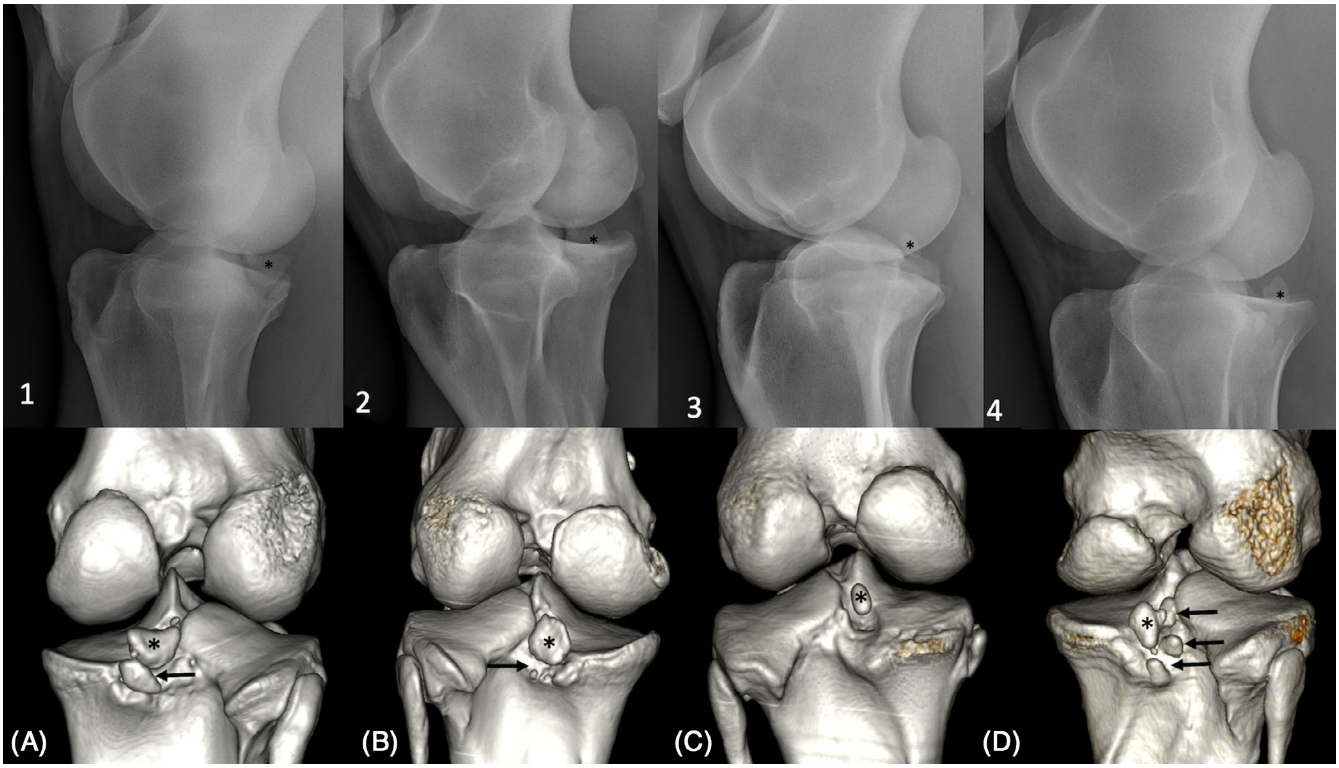

FIGURE 1 Caudal 45°lateral-craniomedial oblique radiographs of the affected stifle of horses 1 to 4 and corresponding 3D bone volume rendering computed tomographic images (A–D). Large caudal cruciate ligament insertional avulsion fragments are evident on the caudoaxial aspect of the tibia on radiographs (small asterisk *). In horses 1, 2 and 4 several smaller fragments are visible distal to the main fragment on CT imaging (black arrows). Large asterix, large avulsion fragment; black arrows, smaller avulsion fragments.

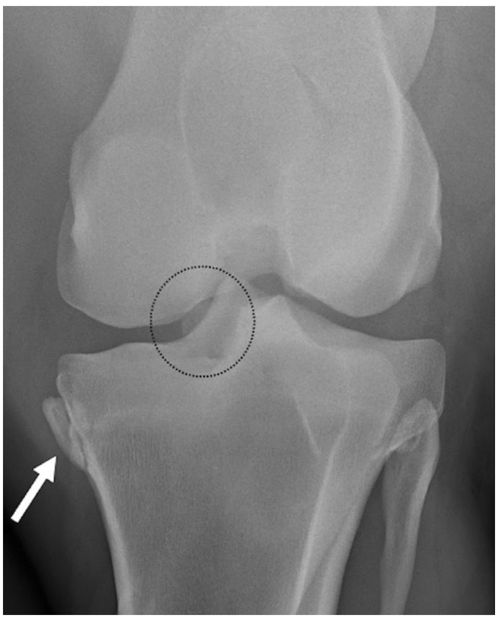

FIGURE 2 Caudal 10° proximal-craniodistal oblique radiograph of the left stifle of horse 3. The white arrow points to the large calcification at the insertion of the medial collateral ligament. The dotted circle highlights the area of the CdCl avulsion fragment that is partially visible medial to the medial intercondylar eminence of tibia.

edge periosteal elevator (DePuy Synthes, Switzerland), a beaver blade (SM64, Swann-Morton, England), a banana knife (11.5 cm working length, Storz, Germany), a curette (Spratt no. 0 and 00, Storz, Germany), and a motorized synovial resector (aggressive full radius 4.5 mm resector, Drillcut-X ARTHRO Shaver, Storz, Germany) were used to free the fragment from the inserting fibers. Dissection was hampered by the deep location of the fragments, the risk of causing trauma to the axially located popliteal neurovascular bundle, and the restricted mobility of the instruments. A second caudomedial portal was created further proximal to improve access to the fragment in horse 4. The fragment was removed in toto using a large Ferris-Smith rongeur (Storz, Germany) in horse 3 and the size of the fragment was reduced with a motorized burr (large joint burr, Drillcut-X ARTHRO Shaver, Storz, Germany) in horses 1 and 4 (Figure 5B). Due to prolonged anesthesia time, complete fragment removal was postponed in horses 1 and 4. The fragment was harvested piecemeal during a second procedure in horse 1. In horse 4 approximately two-thirds of the proximal, intra-articular part of the fragment was removed using the motorized burr during the second surgery. However, further attempts to mobilize and resect the fragment in

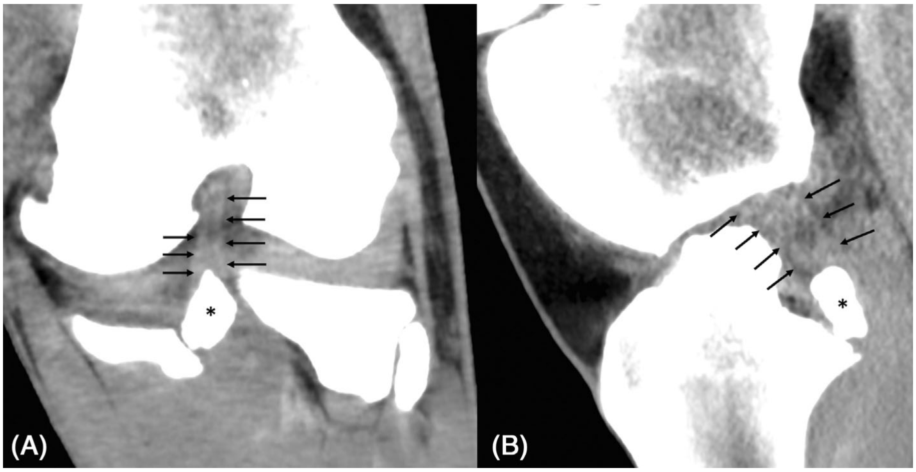

FIGURE 3 Frontal plane (A, medial to the left) and sagittal plane (B, cranial to the left) computed tomographic images of the left stifle of horse 2 in soft tissue window. The caudal cruciate ligament (black arrows) is coursing from the medial intercondylar area of femur towards the avulsion fragment (*).

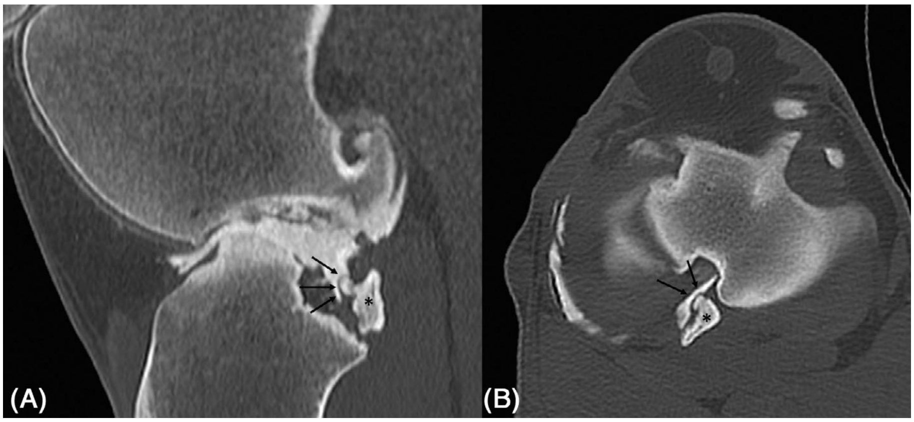

FIGURE 4 (A) Sagittal and (B) transverse plane computed tomographic images (bone window) with iodinated intra-articular contrast in the medial femorotibial joint (horse 2). The contrast is in contact with the cranial face of the avulsion fragment (black arrows) confirming the intra-articular location. Asterisk, avulsion fragment.

toto were unsuccessful. Continued resection with the motorized equipment in a caudomedial direction resulted in profuse arterial bleeding. Arthroscopic surgery was discontinued and the bleeding was controlled with pressure applied and firm closure over the caudal portals.

All joint compartments were lavaged with polyionic fluids prior to skin closure (USP 2–0 polypropylene; simple interrupted) in the remaining cases. Recovery from anesthesia was assisted with head and tail ropes.

3 | RESULTS

3.1 | Surgical findings

A cranial intercondylar arthroscopic approach was used successfully in three horses to explore the caudal mFTJ. The mean total surgery time for each horse was 240 min (range 150–330 min; $n = 4$). In horses 1 and 4 surgery took place in two sessions, with surgery times for each surgery recorded to be 150 and 180 min for horse 1 and 180 and 150 min for horse 4. In horses 1 and 3 the CdCL avulsion fragment was readily visible when the arthroscope was inserted into the caudal mFTJ over a cranial intercondylar approach. In horse 1 the fragment was surrounded by hyperemic synovium and torn ligament fibers (Figure 5C). In horse 3 ligamentous fibers inserted on the fragment without obvious fibrillation. In horse 4 the fragment was palpable with an arthroscopic probe, but local soft tissue dissection (motorized synovial resectors) was required to facilitate visualization.

Removal of CdCL avulsion fragments was attempted in three horses and successful removal of the large intra-articular fragment was possible in horse 3, in horse 1 the large and a small intra-articular fragment could be removed, and an extra-articular fragment was left in place. Removal of approximately two-thirds of the proximal, intra-articular fragment was achieved in horse 4. In horse 3 additional findings during arthroscopic exploration included a partial tear of the cranial cruciate ligament, fibrillation of the medial meniscotibial ligament, and moderate chondromalacia of the lateral and medial femoral condyle. The fibrillated cranial cruciate ligament was debrided. A focal chondral lesion surrounded by chondromalacia was visible arthroscopically in horse 4, in the area where the small subchondral bone cyst was visible with CT.

Horse 2 was explored using a direct caudomedial approach only. Visualization of the fragment was not

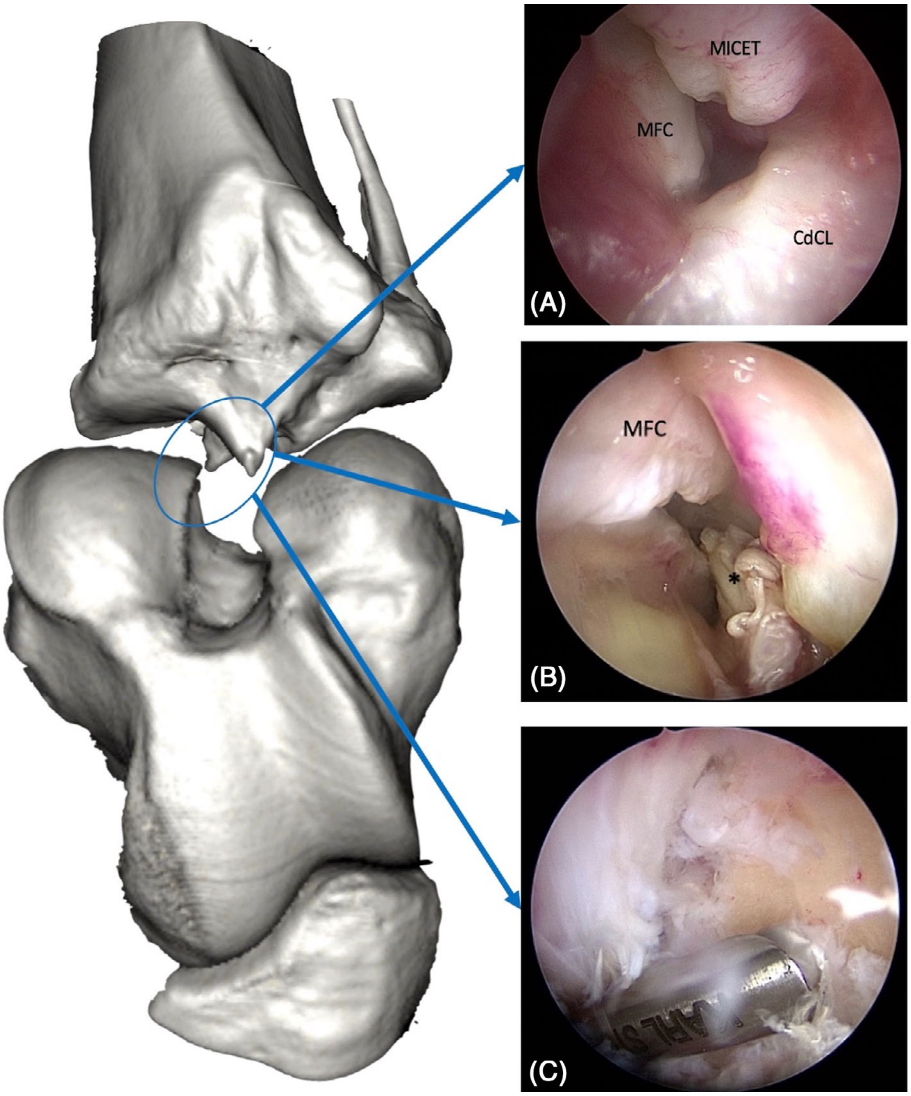

FIGURE 5 Composite of arthroscopic images obtained from the medial femorotibial joint of a right stifle using the cranial intercondylar approach, distal is to the top, medial to the left. (A) Arthroscopic view from the cranial medial femorotibial joint towards the intercondylar space. (B) View towards the caudal medial femorotibial joint with torn fibers of the caudal cruciate ligament insertion on an avulsion fragment. (C) Arthroscopic burr in place to reduce the size of avulsion fragment. MICET, medial intercondylar eminence of tibia; MFC, medial femoral condyle; CdCL, caudal cruciate ligament; asterisk, avulsion fragment.

possible with this approach. Arthroscopic findings included ruptured fibers of the CdCL, an extensive full-thickness cartilage defect of the MFC, and cranial protrusion of the medial meniscus. Fragment removal was not attempted and the cartilage defect was treated with local microfracture.

3.2 | Postoperative management

After assisted recovery by head and tail ropes, all horses were bearing full weight on the operated limb. In horse 1 difficulties protracting the right front limb with a painful triceps area were diagnosed hours after the otherwise uneventful recovery. The suspected triceps myopathy resolved over 24 h. The horse received a single dose of ketamine 0.5 mg/kg IM and morphine 0.1 mg/kg IM in addition to flunixin meglumine 1.1 mg/kg IV twice daily.

NSAID treatment was continued for 3–14 days. Antimicrobial therapy was discontinued postoperatively in horses 1–3. Horse 4 developed moderate local inflammatory swelling of the surgical site at the level of the inner thigh following intraoperative hemorrhage. Amoxicillin (15 mg/kg IV TID) and gentamicin sulfate (6.6 mg/kg IV once daily) were administered for 3 days and trimethoprim sulfonamide (30 mg/kg orally twice daily) for further 4 days in this case.

Figure 8 shows the postoperative radiographs of horses 1,2 and 3. Suture removal was performed under strict asepsis between 10 and 14 days postoperatively, with mild seroma formation noted in horse 2 and mild local swelling at the medial portal in horse 4.

Horses remained hospitalized for 6 to 22 days (mean 13 days) and all horses were sound at the walk at the time of discharge. Box rest with hand walking exercise was advised for 8–12 weeks, followed by an orthopedic examination to decide on the exercise regime to follow.

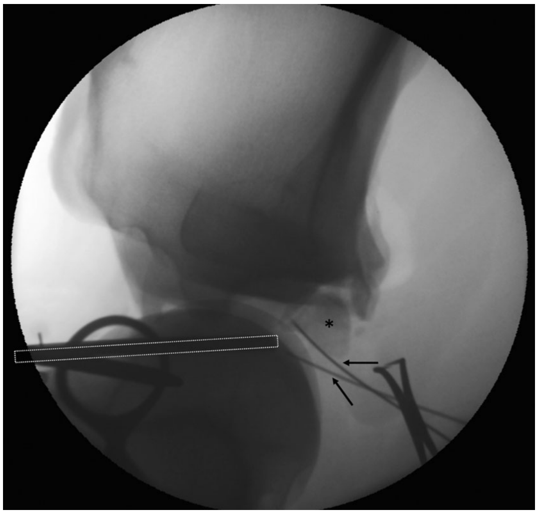

FIGURE 6 Lateromedial fluoroscopic view with the arthroscope in the intercondylar space facing caudally towards the avulsion fragment (*), with two spinal needles inserted from a caudomedial direction, one in contact with the fragment and a second needle tip closer to the arthroscope in the medial femorotibial joint (cranial to the left, distal to the top). Dotted line, arthroscope; asterisk, avulsion fragment; black arrows, spinal needles.

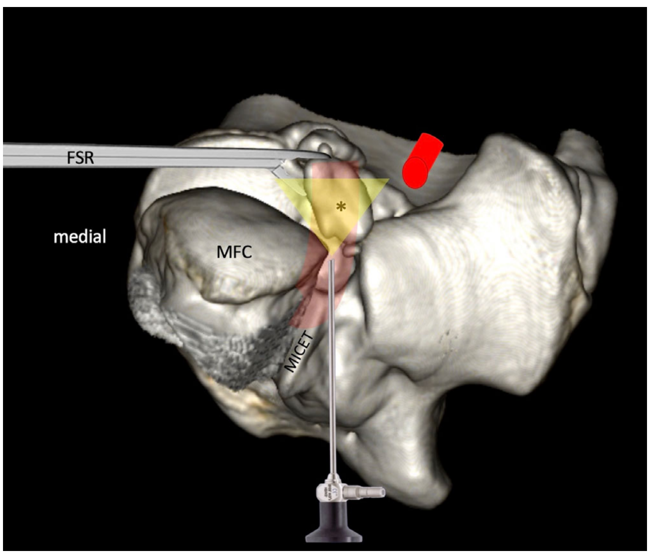

FIGURE 7 Right stifle of horse 1, 3D bone volume rendering computed tomography image with the femur removed except for the medial femoral condyle. View from proximal to distal onto the tibia plateau. Arthroscope inserted over a cranial intercondylar approach, yellow triangle, field of view when turning 30° arthroscope around its longitudinal axis, Ferris Smith rongeur (FSR) inserted over a caudomedial portal, MICET, medial intercondylar eminence of tibia; MFC, medial femoral condyle; asterisk , avulsion fragment; red transparent band, course of caudal cruciate ligament; red tube, popliteal artery.

3.3 | Follow-up

Upon telephone follow-up 11–28 months post-surgery (median follow-up time 16 months) all horses had returned to ridden exercise and owners confirmed a high level of satisfaction with the postoperative outcome. Three out of four horses were sound at the walk and trot 3 months postoperatively. In horse 3 intra-articular medication of the affected mFTJ with 10 mg triamcionolone was performed during the first orthopedic re-examination post-surgery and the horse was judged to be sound 6 weeks later by the referring veterinarian. Horses 1 and 3 were in ridden exercise on the same level as before (pleasure riding), horse 2 was retired from showjumping but in regular exercise as a pleasure horse, and horse 4 was again successfully participating in high-level showjumping competitions. The median time to return to ridden exercise after surgery was 8 months (6–12 months). Horse 1 underwent colic surgery 6 months after arthroscopy explaining the longer convalescence time in this case.

4 | DISCUSSION

This case series describes preoperative CT findings and the minimally invasive surgical access to CdCL insertional avulsion fragments located in the equine mFTJ. A cranial intercondylar approach facilitated visualization as well as partial or complete arthroscopic removal of CdCL fragments in 3 horses.

The axial and caudal location of the CdCL insertion on the tibia makes the arthroscopic visualization and removal of fragments at this site particularly difficult, even if the intra-articular location of the fragment has been confirmed with CTA (Figure 4). In line with a recent report, visualization of a CDCL fragment appeared not possible in this study using the caudomedial approach only (horse 2).[9]

The benefits of the cranial intercondylar approach include the central location of the arthroscope with direct visualization of the CdCL insertion and the option to create the caudomedial instrument portal under arthroscopic guidance. Whilst the maneuverability of the arthroscope in the intercondylar space is limited to mainly rotational movements of the lens, triangulation is improved with the arthroscope inserted cranially when compared to the use of the caudomedial approach only. The previously reported difficulty of not being able to reach the caudal mFTJ with the arthroscope, due to the arthroscope's limited length, was not experienced in our patients using a standard equine arthroscope with a working length of 13.5 cm (Storz, Germany).[12,14]

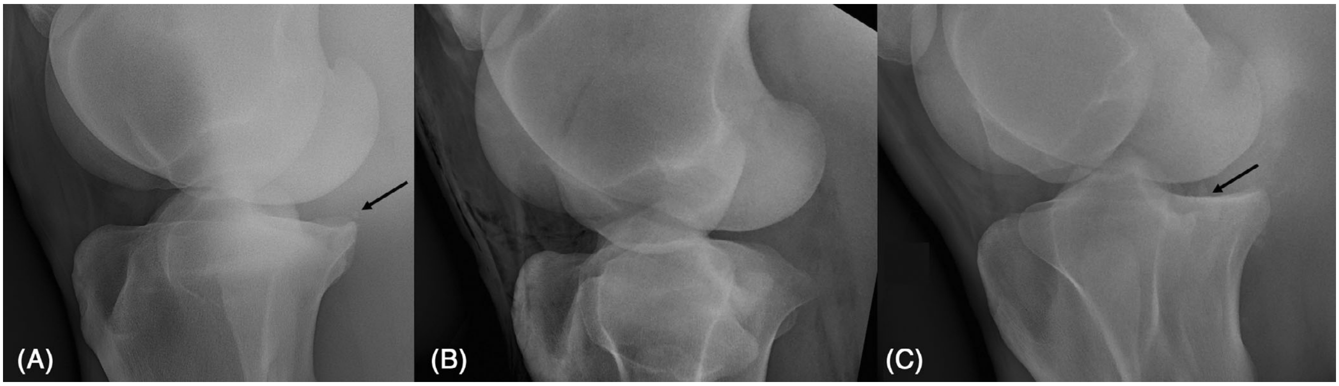

FIGURE 8 Postoperative caudal 45°lateral-craniomedial oblique radiographs of the stifle of horses 1, 3, and 4. (A) Right stifle of horse 1, black arrow indicates the remaining fragment at the caudoproximal tibial plateau. (B) Left stifle of horse 3, complete fragment removal was achieved. (C) Right stifle of horse 4, black arrow indicates the remaining fragment at the caudoproximal tibial plateau. Black arrow, remaining avulsion fragments.

CdCL avulsion fragments were accurately diagnosed and localized with CT and CTA imaging. Due to the prolonged anesthesia time in two horses, the authors would consider splitting advanced diagnostic imaging and arthroscopic surgery into a two-step procedure. This way there would be more time available for presurgical planning and potential inadvertent contrast leakage would have no impact on the arthroscopic surgery.

High rates of concomitant injuries in the femorotibial joint have been reported in horses and humans suffering from CdCL/ posterior cruciate ligament desmopathy.[6–8,15–17] Collateral ligament lesions were detected in horses 2 and 3. It has been reported that these lesions rarely occur as a sole diagnosis and should prompt the clinician to suspect other soft tissue lesions in the stifle, as was the case in the abovementioned two horses.[18] Additionally, moderate to severe cartilage erosions were detected on the MFC during arthroscopy in three horses. CdCL insertional avulsion fractures have been associated with an excessive force acting on the CdCL during maximum stifle extension. This could lead to extensive pressure being transferred over the medial condyle before rupture of the CdCL occurs.[17]

Due to the rare occurrence of the described condition, limitations of the current report are the small number of horses included in the study with a lack of controls and the potential bias of the follow-up information obtained. The effect of fragment removal on the long-term outcome cannot be evaluated due to the aforementioned limitations. The results of this study and a recent case report suggest a better prognosis for return to ridden exercise in horses with CdCL insertional avulsion fracture than previously anticipated.[9] Even horse 2 with severe cartilage damage of the MFC returned to low-level athletic activity. This is in accordance with a publication reporting that the degree of cartilage damage was an inaccurate predictor of long-term outcome in horses with stifle pathology.[19]

In human orthopedic surgery, good outcomes are described for the operative screw- and wire fixation of dislocated posterior cruciate ligament avulsion fragments.[15–17] Promising results have additionally been proposed considering the stabilization of the bovine cranial cruciate ligament with a nitinol prosthesis.[20] Whether an adaption of this technique might be feasible for the surgical treatment of equine stifle joint instability associated with CdCL avulsion warrants further investigation.

In conclusion, the cranial intercondylar arthroscopic approach facilitated the assessment and surgical treatment of CdCL insertional avulsion fragments in Warmblood horses. Pre-operative CT examination confirmed the diagnosis, was useful for surgical planning, and allowed evaluation of the stifle joint for comorbidities. Arthroscopic removal of CdCL fragments was difficult and fluoroscopy proved to be a helpful aid for intraoperative instrument orientation.

AUTHOR CONTRIBUTIONS

Bolz NM, Ehrle A, Dipl. ECVS, Dipl. ECVSMR, Mählmann K, Dipl. ECVS and Lischer CJ, Dipl. ECVS, Dipl. ECVDI: Contributed to the conception of the study, data collection, and critical revision of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest related to this study.

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