Tibial tuberosity advancement in two cats with cranial cruciate ligament deficiency

K. Perry*; N. Fitzpatrick
Fitzpatrick Referrals, Eashing, Godalming, Surrey, UK

Keywords
TTA, tibial tuberosity advancement, feline, cranial cruciate ligament

Summary
Two Domestic Shorthaired cats were diagnosed with longstanding lameness attributed to cranial cruciate ligament deficiency without any history of trauma. One cat had a previous operation in which the lateral nylon suture technique was used, and the other cat was affected by a partial tear of the cranial cruciate ligament. Tibial tuberosity advancement was carried out in both patients, which resulted in long-term resolution of lameness for both. The results of these cases concur with previous studies performed on canine patients in terms of viability of technical application and satisfactory return to weight bearing postoperatively. Further investigation of tibial tuberosity advancement in feline patients is justified.

Introduction
While there is a paucity of reports in the veterinary literature concerning disease of the cranial cruciate ligament (CCL) in cats, there is a plethora of reports concerning etiopathogenesis, epidemiology and treatment of this pathology in dogs. A traumatic aetiology is assumed in most reports of rupture of the CCL in feline patients (1). However, a proportion of cats may be affected by degeneration of the ligament which may precede rupture, but in the absence of ultrastructural histology, the association is putative in most cases (1).

It has been suggested that degenerative disease of the CCL in cats with atraumatic ruptured CCL may be successfully managed conservatively, but that surgical intervention with extracapsular ligamentous augmentation may produce quicker and more durable recovery (1, 2). Surgical management of ruptured CCL, particularly when significant multi-ligamentous structural derangement of the stifles is evident, has been successfully addressed using lateral or lateral plus mediolateral extracapsular prosthetic sutures (3–7).

Many techniques have been applied in canine patients to address dynamic laxity of the stifle (12–15). Surgical techniques described to be successful in the cat include extracapsular surgical repair, tibial plateau levelling osteotomy (TPLO) and cranial closing wedge osteotomy (1, 6, 16). The aim of performing the tibial tuberosity advancement procedure in dogs is to achieve a 90 degree angle between the patellar ligament and the tibial plateau at a standing limb angle of 135 degrees by osteotomy and advancement of the tibial tuberosity, thence neutralising the femorotibial shear force associated with a ruptured CCL by recruiting appropriate co-contraction of the quadriceps muscle group, the gastrocnemius muscle and caudal thigh musculature (7, 13, 17). The angle between the patellar ligament and tibial plateau is dependent upon the degree of joint flexion with extension producing a larger angle and a cranially directed shear force, and flexion producing a smaller angle and a caudally directed force (18).

A custom-designed tension band plate and spacer cages have been employed to anchor the advanced bone segment in an appropriate orientation; this is calculated on preoperative radiographs with the stifle positioned in 135 degrees of extension. Several recent studies have documented technique used, results and complications of TTA in canine patients (9, 19–24).

Our objective was to report the application of technique and clinical outcome of TTA in two feline patients. One had already under...
gone an operation in which the fabello-tibial tuberosity suture was used, but the animal suffered chronic debilitation. The second sustained a partial tear of the CCL. To the authors’ knowledge the application of TTA in cats has not previously been reported.

**Case history**

Both cases were treated as secondary referrals and both were operated on by one surgeon (NF).

**Case 1**

A 3.9-year-old, 3.9 kg neutered, female Domestic Shorthaired cat was referred for investigation of chronic left pelvic limb lameness. The lameness had been unresponsive to medical management for more than two months before being operated on by the primary care clinician eight months prior to referral. There was no history of trauma, but the stifle was positive for cranial drawer laxity. The surgical intervention involved a mattress suture of 18 kg nylon from the lateral fabella, subjacent to the patellar ligament and through a bone tunnel drilled in the proximal aspect of the tibial tuberosity, and secured with a metal crimp. The primary care clinician reported damage to the lateral meniscus, which was treated by debridement of the axial rim. Twelve weeks postoperatively, moderate to severe lameness persisted. At 14 weeks postoperatively, acute deterioration to frequent non-weight-bearing intensity became evident. Exercise restriction and medication with meloxicam (0.05 mg/kg SID p.o.) produced limited improvement. An alteration in demeanour had also been noticed with the patient becoming more aggressive, constantly guarding the left pelvic limb, and allowing neither petting nor grooming, which had previously been actively sought out.

Gait assessment at the referral consultation revealed a persistent 8 out of 10 lameness score of the left pelvic limb, and intermittent non-weight-bearing. The patient appeared to be extremely distressed and would not allow touching of the affected limb whilst conscious. Following sedation, pronounced cranial drawer and cranial tibial thrust were easily elicited upon manipulation of the left stifle. Restriction in range of motion, moderate crepitus and disuse atrophy of the thigh musculature were also apparent.

Direct digital radiography was employed. Radiographic examination of the right stifle was without salient anomaly. Pelvic radiographic examination revealed bilateral coxofemoral laxity with remodelling of the acetabulae. Orthogonal radiographs of the left stifle revealed periarticular osteophytosis at the margins of the trochlear sulcus and tibial plateau. The metal crimp from the previous surgery was also apparent and it was noted that the tibial bone tunnel was positioned more distally than is considered optimal. Effacement of the infrapatellar fat pad and caudal bulging of the sub-gastrocnemius fascial plane, suggestive of stifle effusion, were also noted (Fig. 1A). Medial-lateral radiographs were taken with the stifle positioned at an estimated standing angle; images were life-sized using custom planning software that facilitated application of standardised TTA planning transparency. This allowed for measurement of the advancement distance required to move the patellar ligament perpendicular to the tibial plateau, and the size of plate required to cover the entire extent of the infrapatellar fat pad.

The patient was positioned in dorsal recumbency with a hanging-limb preparation, thus providing access to the limb from mid-thigh to hock. Pre-emptive analgesia included meloxicam (0.1 mg/kg) and methadone (0.2 mg/kg). Cefuroxime was administered.

---

*Fig. 1 Medial-lateral radiographs of pelvic limbs of (A) affected stifle of Case 1 illustrating stifle effusion, periarticular osteophytosis and transverse tibial bone tunnel positioned suboptimally distally, and (B) affected stifle of Case 2 illustrating stifle effusion with effacement of the infrapatellar fat pad.*
ministered intravenously (15 mg/kg) 30 min before skin incision. Surgical exploration of the affected stifle by medial para-
patellar arthrotomy and extension of sub-
cutaneous dissection to incorporate lateral extracapsular exploration confirmed breakage of the previously placed nylon pros thesis and fibrosis of periarticular fascia, which had ostensibly failed to stabilise the joint. Joint inspection confirmed ab-
sence of the previously excised CCL. The lateral meniscus had not been aggressively debrided and was largely intact; the medial meniscus was intact. Access to the crani-
medial aspect of the tibial tuberosity was achieved by incising the aponeurosis of the gracilis and semitendinosus muscle inser-
tions. The periosteum of the tibial tuberosity was reflected cranially to expose the cranial bone margin. The drill guide was positioned parallel to the cranial border of the proximal tibia with the first hole aligned approximately 2 mm distal to the insertion of the patellar ligament. Two 2 mm holes were drilled. A two-prong plate was appropriately contoured (Fig. 2A). A linear osteotomy was performed perpendi-
cular to the sagittal plane of the tibia from a point immediately cranial to the cranial pole of the medial meniscus. The lateral cortex remained intact proximally to facili-
tate application of a two-prong tension band plate by gentle mallet-tapping using standard TTA technique (Fig. 2B). The osteotomy was then completed proximally and a spacer corresponding to the 6 mm cage was employed to facilitate insertion of the cage at the level of the proximal tibial margin. The screw ‘ears’ of the cage were contoured so as to allow the plate to be se-
cured to the tibia and the osteotomised ti-
bial tuberosity. The caudal ‘ear’ of the cage was anchored first using a 2.4 mm screw. The second and third screws, each of which were 2.4 mm screws, were then placed to se-
cure the distal end of the plate. Finally, the cranial ‘ear’ of the cage was anchored using a 2.4 mm screw.

Due to the proximal position of the plate on the tuberosity, there was very limited bone stock available for purchase of the cranial screw. Autogenous cancellous bone graft harvested via trephine-aperture from the ipsilateral distal femur was placed in the osteotomy gap caudal to the tuberosity (Fig. 2C). Closure was routine and a sup-
port dressing was not placed. Postoperative radiography revealed suboptimal implant positioning for this case. The osteotomy was directed obliquely from cranial to cau-
dal, and resulted in two distinct edges being visible on the medio-lateral projection. As a result, the cage was also, in a similar fashion, obliquely directed from cranial to caudal. The cage was also angled from proximal to distal, which was evident on the cranio-caudal projection, because otherwise the end of the cage would have protruded subcutaneously. It was also evi-
dent that the distal screw in the plate did not seat well due to oblique direction. Ad-
ditional intervention was considered to be unnecessary at this time. (Fig. 3A and 3B). Manipulation of the joint confirmed elimination of cranial tibial thrust.

The patient was weight-bearing ten-
tatively the day after surgery and was dis-
charged. Cage rest was enforced for six

---

Fig. 2  Surgical approach and technique. A) A two-prong plate is appropri-
ately contoured following drilling of two 2 mm holes in the proximal tibial tuberosity by standard technique. B) Linear osteotomy has been performed. The lateral cortex remains intact proximally to facilitate application of a two-
prong tension band plate by gentle mallet-tapping. The distal anchor point of the plate is marked. Care has been taken to avoid creation of a narrow ‘isthmus’ in the tibia caudal to the osteotomy, which might hypothetically predispose to fracture at this site. C) The osteotomy is completed; a 6 mm spacer cage is placed at the proximal tibial margin and the plate is secured distally with 2.4 mm screws. The screw ‘ears’ of the cage are contoured and secured to the tibia and tibial tuberosity. Note that the cranial ear of the cage slightly overlaps the proximal aspect of the plate due to the limited available bone stock for screw placement.

© Schattauer 2010
weeks postoperatively, and medication with meloxicam (0.05mg/kg SID p.o.) was continued for two weeks.

Three weeks postoperatively, the patient was brought in for follow-up examination, during which marked improvement upon gait assessment with only mild weight-bearing lameness was evident (3 out of 10). The owners reported marked improvement in demeanour and tolerance of petting. Range-of-motion of the affected stifle had improved, and appeared to be relatively pain-free, with concomitant improved patient demeanour during examination. Crepitus, as previously detected, remained evident. Clinical examination at six weeks postoperatively confirmed maintenance of joint stability and comfort on manipulation. Lameness had resolved. Radiography revealed satisfactory progression of osseous union across the osteotomy site, and no implant complications were noted (Fig. 4A). The owner was very satisfied with the outcome, and reported a much quicker recovery by comparison to the previous extracapsular repair. Between six and 12 weeks postoperatively, mild lameness was reportedly associated with running around the owners’ home, but lameness was no longer evident when full range exercise with unconstrained outdoor activity resumed at 12 weeks postoperatively. At the 12 week follow-up examination, the thigh muscle mass of the affected limb had significantly improved. Follow-up performed 15 months postoperatively revealed maintenance of this 12 week status and the owner reported the patient was capable of full-range outdoor activity including climbing trees and fences without difficulty and that no pain or lameness was evident. The only adverse observation by the owner was a tendency by the cat to abduct the affected limb without full flexion when sitting. Muscle mass bulk of the affected limb had recovered.

**Case 2**

A 1.6-year-old, 3.4 kg, male neutered Burmese cat was referred for investigation of right pelvic limb lameness of five months duration. The primary care clinician had noted signs of pain upon extension of the right stifle but no palpable laxity. Exercise restriction and medication with meloxicam (0.05mg/kg SID p.o.) had failed to produce significant improvement. The owner reported a moderate decrease in activity and persistent lameness, which was sometimes non-weight-bearing in intensity.

On the day of presentation, gait assessment revealed a 5 out of 10 weight-bearing lameness. Physical examination revealed signs of significant pain, evident as vocalisation, wriggling, and attempts to scratch and bite upon manipulation of the right stifle. This was particularly evident upon stifle extension, and upon attempts to elicit cranial drawer in mild flexion, which was negative, and cranial tibial thrust, which was positive. Range-of-motion remained within normal limits.

Radiography in medio-lateral projection revealed effacement of the infrapatellar fat pad, and caudal bulging of the subgastrocnemius fascial plane, which were suggestive of stifle effusion (Fig. 1B). All other joints of the pelvic limbs were radiographically within normal limits, including the contralateral stifle, as was radiography of the thoracic and lumbar spine.
Medial parapatellar arthrotomy revealed a partial tear of the CCL. Gross degeneration with visible fraying of longitudinal fibres was evident on palpation with a blunt probe. A biopsy was not taken because of the potential for an iatrogenically induced rupture. Both menisci were within normal limits. Surgical planning and application was similar to that for case 1, with the exception that preoperative measurements indicated that a 3 mm advancement would be required in order to achieve a patellar ligament angle of 90 degrees. Therefore in this case a 3 mm cage was placed intraoperatively. Postoperative radiography also revealed suboptimal implant positioning in this case. The 3 mm cage was tilted considerably from proximal to distal, and the positioning of the osteotomy left a paucity of caudal tibial cortex at the level of the second prong. It was also noted that the distal plate screw did not seat into the plate well due to over angulation, and that the screw in the cranial ‘ear’ of the cage appeared inappropriately large and very close to the osteotomised edge (Fig. 3C and 3D). However, no additional intervention was elected at this stage. Cranial tibial thrust was deemed to be negative.

Gait assessment the day after surgery revealed significant weight-bearing lameness and the patient was discharged from the hospital. Cage rest was enforced for six weeks postoperatively and medication with meloxicam (0.05mg/kg SID p.o.) continued for two weeks.

Ten days postoperatively, there was a marked improvement in lameness noted with mild weight-bearing lameness (scale of 2 out of 10). By four weeks postoperatively, the lameness had almost resolved in the owners’ opinion, although only leash-harness exercise was allowed. Mild lameness again became evident at week five upon resumption of free-range indoor activity. Repeat radiography performed six weeks postoperatively revealed satisfactory osseous union across the osteotomy site, but the cranial cage screw had loosened and the small segment of tuberosity proximal to the screw had fractured off. The occurrence of this fracture may have corresponded with the onset of lameness observed at week five postoperatively. The distance between the patellar ligament insertion point on the tibial tuberosity and the caudal edge of the osteotomy was maintained at 9 mm (Fig. 4B). The screw was removed via a stab incision while the cat was under sedation. Cranial tibial thrust test was negative. Full-range exercise with unrestrained outdoor activity resumed twelve weeks postoperatively, and follow-up examinations performed at three and nine months postoperatively revealed maintenance of normal range-of-motion without pain or lameness. The owner was very satisfied with the outcome and reported that exercise tolerance and willingness to exercise had returned to what they had previously considered normal.

**Discussion**

Two cats affected by significant, long-standing pain and lameness attributable to CCL disease in spite of exercise restriction and non-steroidal anti-inflammatory medication, and the previous surgical stabilisation performed in Case 1 are reported. Trauma was not recognised in either case. The TTA was technically viable in both cats and resulted in resolution of lameness. Minimally-displaced tibial tuberosity avulsion fracture occurred postoperatively in Case 2 through the cranial cage screw hole, and was managed by screw removal without direct stabilisation of the proximal extent of the tibial tuberosity.

The complication rate of TTA has been reported as 31–59% in dogs, with approximately one in five patients suffering from a major complication (19, 24). In Case 2, the complication was due to surgeon error and inappropriate implant application. In both cases, implant positioning was suboptimal. The plate should be positioned proximally at the level of the proximal extent of the tibial tuberosity, and parallel to the cranial border of the proximal tibia. The 2.4 mm screw was too large for the relatively weak bone-implant construct and resulted in resolution of lameness. Minimal displacement of the tibial tuberosity was considered normal.

The plate was not inserted proximally to the plate end. It is possible, to drill the holes for the prongs of the ears of the cage so that a screw can be inserted proximal to the plate end. It is deemed important in cats to accurately gauge the compromise between a large enough tuberosity for prong and cage anchorage but not so large that there is risk of iatrogenic fracture of the tibia. Perpendicularity of the cut to the transverse bone axis is also important to avoid placement of the cage in transverse torsion. An alternative would be to not place a screw in the cranial ear of the cage in cats, the assumption being that it is only necessary to secure the caudal ear to prevent cage migration. However, the influence of this on the stability of the bone-implant construct remains unknown, and as such this cannot currently be recommended. Placement of a 2 mm screw and washer rather than a 2.4 mm screw in the cranial cage ear might represent the most elegant solution. Alternatively, placement of a small Kirschner wire from cranial to caudal through the tuberosity and cage and into the proximal tibia may suffice. While in these two cases, positioning of the screws in the Tibia was not associated with problems, it should be noted that if required, this plate can be bent longitudinally distal to the holes for the prong in order to facilitate distal screw placement. We recommended confinement of the cats for four to six weeks, but recognised that early mobilisation was important and therefore harness-only walking was encouraged. Lameness did not occur in Case 2 until unrestricted activity resumed at four weeks postoperatively, but it was deemed more likely that technical error rather than permission for full activity level was responsible for the proximal tuberosity complication noted. As a general comment, the goal of surgical intervention should be early functional recovery and six weeks cage-confinement is potentially excessive. Since review of these two cases, the primary surgeon (NF) favours two weeks of cage rest, followed by two weeks of confinement...
to one room concomitant with physio- and hydro-therapy where possible. Finally, the 6 mm cage is overly long for most cats, and it could be trimmed using appropriate cutting pliers, where necessary, to avoid having to place the cage at an obliquity and causing potential mild torsion of the tuberosity when anchored, as in Case 1.

There exists a perceived difference regarding the pathogenesis of ruptured CCL between dogs and cats, with a degenerative aetiology commonly inferred for canine patients and a presumed traumatic aetiology for the feline patients (1). The CCL is larger than the caudal cruciate ligament in the cat whereas the reverse is true in the dog (3). The relative size of the cruciate ligaments has been assumed to be the reason for the low prevalence of clinical ruptured CCL in cats. However, Harasen reported increased body weight as a potential predisposing factor toward ruptured CCL in cats without known trauma as compared with a population of cats affected by traumatic multiligamentous stifle injury, and reported histopathological similarities between ruptured feline CCL and the CCL from dogs suffering with degenerative disease (1). It is noteworthy that both cats in this report were of normal bodyweight and were young. The signalment of these two cases does not preclude degenerative ruptured CCL as a possibility, and the partial tear in Case 2 was grossly comparable with the appearance of confirmed degenerative ruptures in dogs (NF). Unfortunately, histopathological analysis of cruciate ligament tissue was precluded by removal during previous surgery in Case 1 and the risk of iatrogenic trauma in Case 2.

The finding of lateral meniscal pathology at initial intervention for Case 1 may indicate that trauma remains a potential aetiology for this case. Lateral meniscal damage in this case may also have been the result of chronic instability, but this is purely supposition. It has been reported that lateral meniscal damage may occur with greater frequency than medial meniscal pathology in feline patients, but this is generally associated with multi-ligamentous traumatic stifle joint injuries rather than isolated ruptured CCL (1). In studies incorporating traumatic cases, meniscal pathology is reportedly found in at least 50% of cases, however Harasen reported that only one out eight cats with isolated CCL injury was affected by medial meniscal damage (1, 3, 25). This correlates with the low incidence of tearing of the medial meniscus in an experimental study following transection of the CCL. In this study, only one of six cases went on to develop a tear of the meniscus, although damage to the medial meniscus without overt tearing was noted in all cases (26). This low incidence of feline meniscal injury was considered a contraindication for medial meniscal release in these cases as meniscal integrity is desirable to maintain function (27). However, it should be noted that a high frequency of post-surgical meniscal injuries has been reported following TTA in dogs (19, 24). Signs of long-term meniscal pathology has not been observed in either cat to date.

Radiographic findings in the early stages of feline osteoarthritis may be subtle and difficult to discern with confidence (29). In Case 2 only stifle effusion was present and was overlooked by the primary care clinician, emphasising the importance of quality radiographs and careful interpretation. It is also likely that ruptured CCL remains under-reported in the cat as patients might not be examined for medium-term lameness which resolves without treatment (1).

The recommendation that conservative management should be undertaken for feline ruptured CCL in isolation is based upon a very small number of published cases (1). Anecdotal reports of successful outcomes with cage rest alone are common, but surgical extracapsular stabilisation is reported to provide more rapid return to function (1, 8, 30). Non-surgical management of dogs weighing <15 kg has reportedly resulted in acceptable limb function with reported success rates ranging from 84% to 90% (28, 31). However, regardless of weight, surgical intervention has been recommended for most dogs with ruptured CCL to re-establish joint stability, mitigate secondary osteoarthritis, and to address concurrent meniscal injury (32, 33). There is however no definitive evidence that any one technique is superior for treatment of ruptured CCL in the canine patient, and given the paucity of reports regarding feline ruptured CCL, similar inference is likely (34).

Stifle angle in dogs is 135° during the stance phase, and the typical angle between the patellar ligament and the tibial plateau is 105° (13, 18, 35–38). Reducing this to 90° by TTA has been shown to stabilise the CCL-deficient stifle by negating the cranial tibial shear force (9, 20, 23). The stance angle of the cat is reported as 110° when walking, prompting radiographic evaluation at 110–120° for the purposes of preoperative planning in this study (38). Further investigation is required to determine the biomechanical impact of TTA in the feline stifle, to elucidate the normal patellar ligament – tibial tuberosity angles in cats and to optimise preoperative radiographic evaluation.

Clinical outcome data for canine TTA has been similar to that previously documented for TPLO, with 83–90% of owners reporting a marked improvement or return to full function (19, 24, 41–43). Kinetic data intimated early return of limb function, and that function of approximately 90% of normal function can reasonably be expected (21). The long-term outcome for both of these feline cases was very satisfactory. It has been mentioned that owners feel that recovery from TTA in canine patients is faster and easier compared with other techniques such as lateral suture or TPLO (19). However case numbers here and in the literature are insufficient to make conclusions in this regard for feline patients.

Limitations of this report include lack of objective outcome criteria. Further data on effect of stance angle on preoperative planning and monitoring progression of osteoarthritis following TTA in cats in comparison to other management techniques is warranted. However, we feel that the very satisfactory long-term clinical outcomes reported for these two cases justify further investigation of application of TTA in cats affected by disease of CCL deficiency.

Acknowledgements
The authors would like to thank Dr. Dylan Clements and Mr. Russell Yeawdon for their significant contributions to the preparation and review of this manuscript.
References