Clinical Communication

Tibial tuberosity fracture as a complication of tibial tuberosity advancement

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TTA, tibial tuberosity, fracture, dog, stiffe

Summary

Objectives: To retrospectively compare two clinical subsets of dogs suffering tibial tuberosity (TT) fracture (incidental finding or sudden onset severe lameness) as a complication of tibial tuberosity advancement (TTA) and to report the surgical management and outcome of TT fracture as a complication of TTA.

Material and methods: The medical records of 10 dogs with eleven TT fractures or crest fractures after TTA were reviewed. The outcome and complications were determined from clinical and radiographic follow-up examinations. Limb function was evaluated between six and 12 weeks postoperatively. Owners were contacted by phone for long-term follow-up at least six months after the last examination.

Results: Four dogs required surgical stabilization and six dogs had conservative management. In the surgical group, every case experienced a sudden non-weight-bearing lameness after the initial TTA surgery. In three of the four cases an attempt was made to stabilize the TT and crest fracture while maintaining the TT advancement. Postoperative complications were encountered in three of the four surgically treated cases. Functional outcome was considered excellent in seven cases and good in the other three.

Clinical significance: Tibial tuberosity fracture is a complication of TTA that seems to have a favourable prognosis, although it can result in significant morbidity and in some cases revision surgery may be required.

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Introduction

Rupture of the cranial cruciate ligament is one of the most common orthopaedic problems observed in the canine stiffe joint (1). Restoration of function is achieved surgically by neutralizing the tibio-femoral shear forces in a cranial cruciate ligament-deficient stiffe using either a static or dynamic surgical procedure (2). Dynamic stabilization is achieved by neutralizing the cranial tibial thrust. Historically this has been achieved by a tibial plateau levelling osteotomy, in which a radial osteotomy of the proximal tibia is performed, and rotation of the tibial plateau allows a reduction of the tibial plateau angle (2).

Tibial tuberosity advancement was proposed in 2002 as an alternative to tibial plateau levelling osteotomy (3). Tibial tuberosity advancement achieves dynamic stiffe stabilization by advancing the tibial tuberosity, thereby altering the direction of the patellar tendon force vector. This results in either a neutral or caudally directed tibio-femoral shear force during the weight-bearing phase of the gait cycle (4).

Tibial tuberosity advancement has become popular over recent years. By comparison with tibial plateau levelling osteotomy, it is claimed that, tibial tuberosity advancement is less invasive and less technically demanding, with a reduced major complication rate (5, 6). However, some reports in the current literature suggest that the complication rates are similar for the tibial tuberosity advancement and tibial plateau levelling osteotomy procedures (1, 2, 6–11).

Fracture of the tibial tuberosity is considered one of the more serious complications following tibial plateau levelling osteotomy, because of increased patient morbidity and client expense; the reported incidence is three to nine percent (12). Tibial tuberosity fractures have also been reported after tibial tuberosity advancement, with an incidence ranging from one to four percent (1, 2, 6). Risk factors for tibial tuberosity fracture have been reported for both tibial plateau levelling osteotomy and tibial tuberosity advancement (12–14).

The majority of the tibial tuberosity fractures previously reported were incidental avulsion fractures detected on routine radiographic follow-up (1, 2, 7, 8). Although we acknowledge that this is the...
most common presentation, the authors have also recognized the presence of a different clinical subset of animals that are presented with a more complex fracture configuration and sudden onset of severe lameness.

The surgical management of three dogs suffering from tibial tuberosity fractures after tibial tuberosity advancement was mentioned in the literature (1, 7, 8). However, to our knowledge, no previously published studies have specifically compared these two clinical subsets (incidental or sudden onset of severe lameness) or have addressed the surgical management and outcome of tibial tuberosity fracture as a complication of tibial tuberosity advancement.

The objectives of this report are to firstly, describe the surgical management and outcome of tibial tuberosity fracture as a complication of tibial tuberosity advancement, as well as to compare the two clinical subsets of fracture patients (incidental avulsion fractures or complex fracture configuration with associated sudden onset of severe lameness). Our intention is to raise the awareness of a potentially serious and challenging tibial tuberosity advancement complication, particularly during the learning curve phase of this surgical procedure.

Material and methods

Inclusion criteria

The medical records of 10 dogs with eleven tibial tuberosity or tibial crest fractures after tibial tuberosity advancement that occurred within the first 200 consecutive tibial tuberosity advancement surgical procedures performed at Glasgow University and University College Dublin Veterinary Teaching Hospitals were reviewed. For each dog, the information regarding signalment, body weight, time to fracture after tibial tuberosity advancement, lameness score, pertinent medical history, clinical subset (incidental finding or acute onset lameness), type of treatment (conservative or surgical), fracture configuration, presence of new bone at the level of the osteotomy gap, follow-up, other complications, time from fracture detection to resolution, and outcome were all recorded. A detailed clinical examination was used to confirm that a clinically significant abnormality was specifically related to the fracture.

Surgical technique

For the initial tibial tuberosity advancement surgery, a standard medial para-patellar arthrotomy was performed in order to confirm rupture of the cranial cruciate ligament, and to assess meniscal integrity (15). If meniscal pathology was identified, a partial meniscectomy was performed. A standard tibial tuberosity advancement procedure as previously described by others (apart from case 5 where the cage was mistakenly placed upside down) was performed by seven different surgeons (2).

Titanium alloy tibial tuberosity advancement implants were used in all cases.

Subsequent patient management

The standard postoperative rest protocol included instructions to enforce strict rest with three or four ten minutes leash walks daily for six weeks. Radiographs were obtained after six weeks, and provided that signs of healing progression were documented, leash exercise was then increased by five minutes per walk on a weekly basis over a four week period. At the end of that month, off-leash exercise was re-introduced over an additional four week period.

Tibial tuberosity fracture repair surgery

The animals were positioned in dorsal recumbency and the affected limb was aseptically prepared for surgery. The animal was then rotated into lateral recumbency leaving the affected limb in contact with the surgery table and a medial approach to the proximal tibia was performed (15). Based on the fracture configuration, the presence of any radiographically apparent signs of osseous infilling of the osteotomy gap caudal to the advanced tibial tuberosity, and the number, size and shape of the bone fragments. Radiographs obtained immediately after fracture surgery were evaluated for evidence of tibial tuberosity under-advancement, reduction of the fragments, and the location and type of implants. The presence of complications as well as the progression or completion of healing were assessed with further follow-up radiographs.

Postoperative care

During the first 24 hours after surgery, pain control was achieved with the administration of methadone (0.2 mg/kg by intramuscular injection every four to six hours as needed). On recovery from anaesthesia, meloxicam (0.2 mg/kg subcutaneous injection) was administered and treatment with meloxicam was continued (daily oral dosing at 0.1 mg/kg) for at least four weeks. All dogs were discharged into the owner’s care within 48 hours of surgery. Early leash exercise was encouraged but dogs were not permitted free running activity until there was radiographic evidence that bone healing was proceeding – typically at least six weeks after surgery. All implants were left in place unless complications prompted removal or revision surgery.

Conservative management

Instructions were provided to the owners to continue strict rest for at least a further four weeks (depending on clinical progression), including continuation of the non-steroidal anti-inflammatory medication. The importance of avoiding stairs, steps,
slippery surfaces, and off-leash exercise was also emphasized.

**Post-treatment assessment**

The minimum follow-up for the conservatively managed cases included one physical and radiographic examination approximately six weeks after the initial tibial tuberosity advancement surgery, and a telephone conversation with the owner at least six months after fracture diagnosis. Minimum follow-up for the surgically managed cases included physical and radiographic examinations approximately six weeks after revision surgery, and a further physical examination approximately six weeks thereafter, and a telephone conversation with the owner at least six months after fracture surgery. Dogs that were presented for follow-up examinations were evaluated for lameness by observation at the walk and trot. The affected limb was palpated and manipulated for evidence of instability, discomfort, or crepitus, and to evaluate stifle joint motion. A questionnaire was used during the telephone conversation to record the presence of lameness, level of return to activity, and overall satisfaction.
I. Calvo et al.: Tibial tuberosity fracture as a complication of TTA (Appendix 1 – available online at www.vcot-online.com). Functional outcome was defined as excellent when lameness in these dogs was either minimal (less than grade 1/5) or not apparent at the last examination, the patients were able to exercise without restriction, and such activity did not exacerbate lameness or cause subsequent stiffness (as reported by the owners at least 6 months after the last clinical examination). Functional outcome was considered good when lameness in these dogs was either minimal or not apparent at the last examination; the patients were able to exercise without restriction, but heavy exercise exacerbated lameness or caused subsequent stiffness. Functional outcome was considered poor when lameness in these dogs was apparent at the last examination (more than grade 1/5) or the patients were not able to exercise without restriction. Full osteotomy healing was defined as no osteotomy line visible and obliteration at the osteotomy site was obvious. Progression of healing was defined as bone bridging the osteotomy space (increased bone density compared to postoperatively) but with the osteotomy space still clearly visible.

Results

Patient signalment and history

There were four dogs that were managed with surgical stabilization and six dogs that underwent conservative management. One of the conservatively managed cases had bilateral tibial tuberosity avulsion fractures after a staged bilateral tibial tuberosity advancement. This represents a tibial tuberosity fracture incidence of 5.5%. In the conservative group there were three Golden Retrievers, one Springer Spaniel (bilateral tibial tuberosity fracture), one Border Collie, and one English Mastiff. In the surgical group there were two Rottweilers, one Boxer, and one Labrador Retriever. The mean body weights were 34.6 kg for the conservative group and 42.2 kg for the surgical group. Only case 10 had a history of inappropriate postoperative confinement; the dog was allowed to jump in and out the owner’s car. The average additional convalescence was 8.5 weeks after surgical management and 5.14 weeks after conservative treatment. None of the cases had meniscal injury at the time of initial surgery or the revision surgery. The rest of the relevant clinical findings are summarized in Appendix 2 (Available online at www.vcot-online.com).

Surgical management

In the surgical group, every case experienced a sudden onset of non-weight-bearing lameness after the initial tibial tuberosity advancement surgery. In three patients, this was within two weeks of the initial tibial tuberosity advancement surgery. In three patients, this was within two weeks of the initial tibial tuberosity advancement surgery and five weeks for the fourth. The fracture con-

Figure 3   Medio-lateral radiographic images of the stifle of case 8. A) Prior to revision surgery: fracture of the tibial tuberosity and crest, involving the cranial cage screw and extending through the tine holes. B) Immediately following revision surgery: double tension band wire repair with two additional positional Kirschner wires and two cerclage wires whilst maintaining the advancement cage. C) Six weeks post revision surgery: there are signs of healing. Note the broken pin and fractured tibial tuberosity above the proximal pin.
configuration in the surgically managed cases differed slightly amongst patients but could be described as an avulsion fracture that involved all of the fork holes, resulting in proximal and caudal displacement of the tibial tuberosity and crest. The cranial cage screw was still holding in one case (case 10) (Figure 1A) and was affected by the fracture in three cases (cases 6, 7 and 8) (Figure 2). A moderate degree of comminution was present in case 8 (Figure 3). In three of the four cases, an attempt was made to stabilize the tibial tuberosity and crest fracture while maintaining the tibial tuberosity advancement. In these cases, the cranial cage screw, plate, fork and plate screws were removed. The advancement cage and caudal screw were left. The tibial tuberosity was reduced and fixed with two 1.6 mm Kirschner wires and a double tension band (each of the cerclage wires passing through one of the plate screw holes and looped around one of the Kirschner wires) (Figure 2B). No additional bone graft was utilized. Two additional Kirschner wires were placed in cases 7 and 8, and two additional hemicerclage wires were used in case 8 (Figure 3). Only in case 10, as part of the first revision surgery, and in case 6, as a result of failure of the first revision surgery, were all the previously placed tibial tuberosity advancement implants removed. In these cases, the tibial tuberosity was anatomically reduced, fixed with two 1.6 mm Kirschner wires and a double tension band wire, and the stifle was stabilized with an extra-capsular technique using an 445 N monofilament nylon prosthesis anchored around the lateral fabella and the proximal Kirschner wire and secured with two metallic crimps. Additionally, in case 10 due to the very active nature of the dog, an additional 1.1 mm Kirschner-wire and a type 1A trans-articular external skeletal fixator was placed to augment the fracture repair for four weeks (Figure 1) (16).

Postoperative complications were encountered in three of the four surgically treated cases (cases 6, 8, and 10). In case 8, a further asymptomatic tibial tuberosity fracture above the proximal tension band wire pin occurred (Figure 3). The rest of the complications are summarized in Appendix 1 (Available online at www.vcot-online.com); however only case six required further surgical intervention due to fixation failure and ongoing tibial tuberosity instability.

Conservative management

In five out of the six conservatively managed cases, the tibial tuberosity fracture was an incidental finding (including the bilaterally affected dog) at the six week routine radiographic follow-up examination, where lameness was not apparent or minimal (less than grade 1/15). Case 5, which was presented at the scheduled six week follow-up appointment, had a lameness score of 3/5 (lameness attributed to secondary patellar tendonitis due to an inappropriately placed cage rather than to the fracture) and conservative treatment was continued for an additional 14 weeks. Two of the six owners reported a transient worsening of the lameness (more lame but still weight bearing) between postoperative weeks two to three that took less than five days to improve.

Five of the seven conservatively managed fractures shared the same fracture configuration: an avulsion fracture where the fracture line (short oblique) involved the most proximal fork hole while the cranial cage screw remained functional, resulting in proximal and caudal displacement of the tibial tuberosity, while still maintaining a degree of tibial tuberosity advancement (Figure 4). Case 9 sustained an avulsion fracture that involved all the fork holes resulting in significant proximal displacement of the tibial tuberosity and crest and breakage of the cage ears (Figure 5). Case 5 sustained a minimally displaced fracture at the proximal extremity of the tibial tuberosity and cranial cage screw (Figure 6).

Radiographic outcome

At the time of the last radiographic follow-up, three of the four surgically treated cases were considered to be fully healed (Figure 1C). Mineralisation suggesting bone infilling at the level of the osteotomy was present in all of the conservatively managed fractures (Figure 4). Only one of the seven conservatively treated fractures were considered to be fully healed. Bone
healing was graded as being progressive in the other six fractures.

Functional outcome

Functional outcome (Appendix 2 – available online at www.vcot-online.com) was considered to be excellent in seven cases and good in the other three.

Discussion

The increased morbidity associated with tibial tuberosity fractures following tibial tuberosity advancement resulted in extended convalescence of 8.5 weeks after surgical management and 5.14 weeks after conservative management. This outcome was similar to that reported for the tibial plateau levelling osteotomy complicated by tibial tuberosity fracture (12).

The vast majority of the previously reported tibial tuberosity fractures associated with tibial tuberosity advancement were simple avulsion fractures, 23 of these 25 avulsion fractures were incidental findings and were treated non-surgically (1, 2, 7). The remaining two avulsion fractures were treated with a tension band wiring technique, and all cases were reported as having a good outcome, although no specific clinical information was provided. Only one comminuted tibial tuberosity fracture has previously been reported (1). Surgical treatment with a tension band wiring technique while maintaining the cage was reported, however no specific information was provided. We achieved a satisfactory outcome in our case with a comminuted fracture despite the occurrence of a further asymptomatic tibial tuberosity fracture above the proximal tension band wire pin (Figure 3). A fracture incidence of 5.5% following the tibial tuberosity advancement procedure is the highest yet reported. However five of the 11 fractures occurred within the first 40 cases (14% incidence) leaving an incidence of 3.75% for the 160 subsequent cases. This initial high incidence of tibial tuberosity fracture is probably explained by the lack of surgeon experience. A similar finding was reported with tibial tuberosity fracture after tibial plateau levelling osteotomy, where an initial higher incidence was reported (6.7% for the first 119 cases) (12). A recent study found that the tibial tuberosity advancement learning curve continues for approximately 22 procedures after which mistakes decrease significantly and the overall success rate improves steadily (17). Based on published data reporting complication rates, these authors proposed that an acceptable failure rate (major complication requiring revision surgery) be set at 15% and an unacceptable failure rate at 25%, during the initial learning curve.

Figure 6 Medio-lateral radiograph of the stifle of case 5. Small fracture proximal to the advancement cage. Note the increased soft tissue density at the level of the patellar tendon, consistent with significant patellar tendonitis. The cage was improperly placed (upside down).

Possible suggested aetiologies for the development of post-tibial tuberosity advancement tibial tuberosity fracture include reduced thickness of the osteotomized tibial tuberosity, reduced osteotomy contact, placement of the fork too close to the osteotomy, large preoperative patellar tendon angle, and iatrogenic damage to the region during surgical dissection (2, 6, 8, 13, 14). However, to date, statistical data in support of these proposals is only available for reduced thickness of the osteotomized tibial tuberosity and reduced osteotomy contact (13, 14). Although it was not a primary objective to study the risk factors for tibial tuberosity fracture after tibial tuberosity advancement, technical inaccuracies were identified in 10/11 cases, with the remaining case (case 10) being explained by inappropriate postoperative management. We believe that this complication may be avoidable through careful attention to surgical technique and decision making (13, 14).

Our decision to proceed with either surgical intervention or conservative management was clearly influenced by the severity of clinical signs, particularly the lameness grade, rather than by fracture factors such as configuration and displacement. All four surgically treated cases were presented with a non-weight bearing lameness. Due to the small size of our population, it is not possible to draw any further definitive conclusions. However, the stability of the cranial cage screw may play an important role in the stability of the fractured tibial tuberosity and therefore the associated clinical signs. In six of the seven conservatively managed fractures, the cranial cage screw appeared to be functional. In contrast, the cranial cage screw was involved in the fracture line in three of four surgically managed cases.

In our opinion, repair of the tibial tuberosity fracture whilst maintaining the advancement is a desirable goal, but it could only be achieved in two out of three of our cases. Failure in the third case was probably due to lack of caudal support, thus increasing the stress on the repair and therefore the risk of implant failure or subsequent fracture.

If tibial tuberosity fracture occurs prior to mineralization within the osteotomy gap and the tibial tuberosity advancement implants are removed, one approach is to stabilize the fractured crest fragments in their original anatomic position and perform an extra-capsular repair. However the outcome of such an approach requires long-term evaluation and a larger number of cases.

If the osteotomy gap caudal to the advancement (Figure 2) was healed, cage removal and stabilization of the crest fragments in their original anatomic position were not possible in two of our cases; therefore an attempt at tibial tuberosity fracture fixation whilst maintaining the tibial tuberosity advancement was made. In cases where the tibial tuberosity bone stock is comminuted, or in exceptional circumstances such as a very active patient, the
use of a temporary transarticular external skeletal fixator as described previously could be considered to protect the repair (16).

Although a double tension band construct was used in the surgically managed cases, we acknowledge that there is no biomechanical or clinical data supporting its use. The rationale behind the use of the two individual tension bands was to allow each to tightly conform the wire to each Kirschner wire, minimizing the amount of patellar ligament that was compressed by the wire.

Some degree of tibial tuberosity caudal displacement, and therefore partial loss of the initial tibial tuberosity advancement, was present in all the conservatively managed cases. Although the functional outcome for these dogs was graded as good or excellent, it is possible that the tibio-femoral shear forces were not fully neutralized.

There are several limitations in this study that must be considered when evaluating the data, including a small study population and the lack of long-term physical and radiographic examination. Radiographic examination under sedation for research purposes was not offered since it was considered to be unethical.

In summary, tibial tuberosity fracture is a complication of tibial tuberosity advancement that may have a favourable prognosis although it can result in significant morbidity and in some cases revision surgery may be required. It is a complication that is likely to be avoidable through careful attention to surgical technique and decision making. The severity of clinical signs was the main criterion that determined the treatment option in our cases. Although there are several options for revision surgery, further studies are needed to evaluate the outcome of each approach.

Our findings suggest that major and challenging complications of tibial tuberosity advancement may arise during the learning curve and therefore it is the authors’ opinion that tibial tuberosity advancement should not be performed without adequate training and initial supervision.

Conflict of interest

None declared.

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