Reconstruction of chronic triceps tendon avulsion using synthetic mesh graft in a dog

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Keywords
Dog, tendon, avulsion, graft, Artelon

Summary
Avulsion of the triceps tendon insertion was diagnosed in a two-year-old Poodle mixed breed dog 10 weeks after traumatic injury. Diagnosis was confirmed with clinical examination and magnetic resonance imaging (MRI). The tendon was reconstructed using tension-relieving sutures augmented with a synthetic degradable porous polyurethane onlay mesh graft. The repair was immobilized using a transarticular external skeletal fixator with staged increases in elbow flexion. Treatment was successful, with signs of healing confirmed by MRI and normal clinical function one year after surgery. The successful outcome in this case suggests that surgical repair of a chronic triceps tendon injury using a synthetic mesh augmentation may be successful in similar cases.

Introduction
Tendon injuries are commonly diagnosed in dogs, most often affecting the biceps tendon and Achilles mechanism (1, 2). The rupture is often a result of a traumatic event, although chronic degeneration after repeated loading events has also been described (1). The tendon rupture may be partial or complete, and severity often dictates the degree of clinical disability. Surgical treatment is directed at restoring the normal function of the supporting joint by primary apposition of the tendon ends. Various tension-relieving suture patterns have been described for repair of tendon ruptures such as the three-loop pulley or locking-loop patterns (3). In cases where a gap persists or the repair is tenuous, various autogenous, xenogenic, or synthetic materials have been used to bridge the gap or provide additional support (4). Early immobilization of the joint spanned by the damaged tendon is essential to allow for healing and to protect the repair (5).

Treatment of chronic tendon injuries by primary repair is especially challenging, as the tendon ends may retract, leaving inadequate tissue for reconstruction. Furthermore, excessive scar tissue formation, and soft tissue contracture may limit success. For these reasons, salvage treatment with a joint arthrodesis is often pursued in cases of chronic tendon rupture (6).

Avulsion of the triceps tendon in companion animals has rarely been reported and is limited to single case reports in dogs and cats (7-11). The cause of injury is usually traumatic, although triceps tendon rupture after local corticosteroid injection has been described in dogs, as it has in people (10, 12). In most cases, repair is performed shortly after tendon injury. To the authors’ knowledge, successful surgical repair of a chronic triceps injury incorporating the use of a synthetic graft has not been previously described in dogs.

Case report
A two-year-old 7.0 kg spayed female Poodle mixed breed dog was referred to the University of Wisconsin Veterinary Medical Teaching Hospital (UW-VMTH) 10 weeks after a traumatic left forelimb injury resulting from a dog fight. Immediately following the dog fight, the patient was treated at an emergency hospital for a pneumothorax, prepubic tendon rupture, and several open wounds on the left thoracic limb and hemithorax. At the time of presentation, the patient was also unable to bear weight on the left thoracic limb. The pneumothorax was managed successfully using a chest tube, and surgical repair of the hernia and closure of all wounds was successful. The patient recovered from these injuries, however remained non-weight bearing lame on the left thoracic limb until time of referral. Conservative management was attempted with administration of carprofen, tramadol, amoxicillin and clavulanic acid, and low-level laser therapy without improvement, although a specific diagnosis was not made.
The patient was referred to the UW-VMTH for further evaluation. On examination 10 weeks after the initial injury, no persistent external signs of the previous trauma were noted. The patient was unable to bear weight on the left thoracic limb and carried the limb in a flexed position. There was moderate muscle atrophy of the left thoracic limb, and a palpable void was noted proximal to the olecranon in the region of the triceps tendon insertion. No signs of pain or limitations were appreciated on left elbow passive range-of-motion. Neurological examination was considered normal except for absent conscious proprioceptive paw placement of this limb.

Radiographs of the left humerus revealed regional soft tissue swelling centred on the left olecranon. Magnetic resonance imaging\(^d\) of both the left and right thoracic limbs to include the shoulder to the carpus were performed. The heads of the left triceps muscle were decreased in size when compared to the right. The long and lateral heads were the most severely affected with a diffuse T2/T1/STIR hyperintensity and minimal contrast enhancement (proximal portion of the muscle bellies) (Figure 1). The examination and imaging findings were consistent with a chronic left triceps tendon insertion avulsion and disuse muscle atrophy.

The patient was sedated with intramuscularly administered dexmedetomidine\(^e\) (5 mcg/kg) and hydromorphone\(^f\) (0.15 mg/kg). Anaesthesia was induced with intravenous (IV) ketamine\(^g\) (5 mg/kg) and midazolam\(^h\) (0.25 mg/kg) and then maintained with isoflurane\(^i\). A lateral surgical approach to the triceps tendon insertion was made. The lateral, long and medial heads of the triceps brachii muscles were identified proximally with the associated tendons enfolded in fibrous tissue and retracted along the humeral diaphysis. Complete rupture of the triceps tendon was confirmed.

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\(a\) Multihance®, gadobenate dimeglumine: Bracco Diagnostics Inc, Monroe Township, NJ, USA

\(d\) MRI, GE 1.5T CX HiSpeed: GE Medical Systems, Milwaukee, WI, USA

\(e\) Dexmedetomidine: Zoetis Pharmaceutical Inc, Florham Park, NJ, USA

\(f\) Hydromorphone: Hospira, Lake Forest, IL, USA

\(g\) Ketamine: Phoenix, St. Joseph, MO, USA

\(h\) Midazolam: Westward, Eatontown, NJ, USA

\(i\) Isofluorane: Piramal Healthcare, Andhra Pradesh, India
enhancement, consistent with localized inflammation and fasciitis. Tr = triceps tendon, Ol = olecranon.

...obtained four months after surgical reconstruction of a triceps tendon avulsion. There is a continuous, 

Figure 5  Sagittal T1-weighted (A), and T1-weighted post contrast (B) magnetic resonance images obtained four months after surgical reconstruction of a triceps tendon avulsion. There is a continuous, enlarged, moderately heterogeneously enhanced (intact) triceps tendon and mild non-uniform contrast enhancement, consistent with localized inflammation and fasciitis. Tr = triceps tendon, Ol = olecranon.

in the lateral and medial heads. All sutures were passed through the olecranon bone tunnel and tied with tendon ends approximated to the original insertion. The passive range-of-motion was measured to be 90° of flexion and 140° of extension. A degradable porous polyurethane urea mesh onlay graft was applied over the triceps repair using 3.5 metric polypropylene sutures in a Krakow suture pattern along the abaxial margin of the lateral and long heads of the triceps muscles and through the olecranon tunnel (Figure 3). The anconeus muscle was mobilized proximally and sutured over the tendinous portion of the repair. The subcutaneous layers and skin were closed routinely.

A type IA transarticular external skeletal fixator was placed with three pins in the humerus and three pins in the radius with a single lateral connecting bar (Figure 4). The elbow joint was fixed at 115° to reduce tension on the triceps repair. Intraoperative fluoroscopy and postoperative radiography confirmed satisfactory pin placement. Cefazolin (22 mg/kg IV) was administered every two hours intra-operatively. Postoperatively, carprofen (4.4 mg/kg IM) was administered and a 25 mcg transdermal fentanyl patch was placed. Hydromorphone (0.05 mg/kg IM) was administered every six to 12 hours as needed for pain the evening after surgery. The patient was discharged from hospital 48 hours after surgery, with instructions to administer carprofen (1.8 mg/kg orally every 12 hours), tramadol (3.6 mg/kg PO as needed), and amoxicillin and clavulanic acid (21 mg/kg PO every 12 hours) for 14 days following surgery as well as for strict activity restriction and external skeletal fixator care.

Postoperative management and rehabilitation

Assessments were performed monthly until external skeletal fixator removal at 12 weeks, and then at four, six, and 12 months after surgery. At four weeks, the fixed elbow joint angle of the external skeletal fixator device was changed from 130° to 115°. The external skeletal fixator transarticular connecting bar was temporarily removed under sedation to test the elbow passive range-of-motion limits, which were 95° of flexion and 135° of extension. At eight weeks, the transarticular connecting bar was removed and a soft-padded bandage was placed over the external skeletal fixator extending from the toes to the proximal humerus to allow some degree of active elbow joint range-of-motion and weight-bearing on the triceps repair. The humeral and radial components of the external skeletal fixator were left in place in order to maintain the bandage position above the elbow and resist excessive active elbow range-of-motion.

At 12 weeks, the entire external skeletal fixator and bandage were removed and a physical rehabilitation evaluation was performed. No imaging of the limb was performed at this time. The patient had a grade III/V left thoracic limb lameness with moderate atrophy of the affected limb. The triceps tendon appeared to be intact based on clinical examination, and the margins of the graft material were firm and easily palpable. Elbow passive range-of-motion limits of 85° of flexion and 130° of extension were noted. Techniques to encourage an increase in passive joint mobility, protected range-of-motion, and application of controlled weight bearing stress

k  Artelon®: Artelon Worldwide, Nashville, TN, USA
l  IMEX Vet, Longview, TX, USA
m  Cefazolin: Westward, Eatontown, NJ, USA
n  Fentanyl Transdermal System: Mylan Pharmaceuticals Inc, Morgantown, WV, USA

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through instruction in functional activities and therapeutic exercise were initiated.

The patient returned four months after surgery for clinical evaluation and imaging. The patient’s lameness had improved to grade II/V, and elbow passive range-of-motion limits at this time were 30° of flexion and 150° of extension. Magnetic resonance imaging of the left thoracic limb was performed and showed an intact triceps tendon repair with associated fasciitis and mild disuse muscle atrophy (Figure 5). Six months after surgery, the patient ambulated with intermittent grade I/V lameness with a mild decrease in stance time and a subtle shift to the contralateral thoracic limb during standing. There was mild muscle atrophy, the triceps tendon was palpably intact, and margins of the graft were less distinct. Elbow passive range-of-motion limits were normal at this time (measured to be similar to the contralateral elbow limits of 30° of flexion and 160° of extension). At long-term follow-up one year after surgery, the patient ambulated normally with no detectable lameness and without activity limitations. No clinical evidence of surgical infection or discomfort over the repair site was noted in this patient long-term.

**Discussion**

In this case, an initial presumptive diagnosis of triceps tendon rupture was made on physical examination, based on a palpable void proximal to the olecranon in the region of the triceps tendon insertion, and the patient’s inability to bear weight on that limb. Triceps rupture was confirmed both on subsequent magnetic resonance imaging and at the time of surgery. The chronicity of the injury was based on the history of non-weight bearing lameness for ten weeks, along with the magnetic resonance imaging study demonstrating significant muscle atrophy of the left triceps muscle when compared to the contralateral limb. The triceps tendon is an essential structure for weight bearing in quadrupedal animals, therefore treatment was required to achieve a functional outcome for this limb.

Management of tendon ruptures is challenging from many perspectives. Primary repair to re-approx tendon ends with suture can be difficult, as tendon bundles are often disrupted and large gaps may be present. Immobilization of the tendon to allow for healing can be problematic in veterinary patients, and does not eliminate the muscle contraction force on tendons (13). Furthermore, if diagnosis and treatment are delayed, tendons may contain excessive scar tissue with poor suture holding strength, and may be retracted from their insertion preventing anatomical reconstruction (14). Use of surrounding autogenous tissues is often considered in people with neglected tendon ruptures (14). However, depending on the anatomical site or other patient factors, local tissue may not be available. The use of synthetic materials may be considered in these cases to bridge the gap (14, 15). These techniques in animal models suggest that synthetic materials form a framework for ingrowth of normal, orderly collagen bundles similar to those found in the original tendinous structure (16). The biomechanical properties of augmented Achilles tendon repairs were superior to sutured tendons alone in a human cadaveric model, and approached that of intact Achilles tendon in a rabbit model (15, 16).

In this patient, the decision to reinforce the repair with a synthetic graft was based on the concern for compromised blood supply and delayed healing with a chronic tendon rupture. Mesh augmentation would also provide biomechanical support for tendon healing during the early phase after surgery when the repair is vulnerable to failure (17). Artelon® is a degradable porous polyurethane urea that provides soft tissue reinforcement with excellent biocompatible properties (18). It acts as a scaffold for cellular ingrowth to encourage healing, stabilizing the tendon to promote neovascularization and collagen formation (15). It is available in a pliable knitted sheet with excellent handling characteristics compared to many other biomaterials (18). To our knowledge, this is the first time that the use of this mesh graft has been described for augmentation of a tendon avulsion in veterinary surgery. The texture of the graft was initially relatively firm with palpably distinct margins. This became progressively softer and less distinct by six and 12 months postoperatively, suggesting continued incorporation of host tissue and breakdown. This graft is proposed to retain 50% of its strength over four years, and degrade over five to seven years after implantation (18).

A transarticular external skeletal fixator was used successfully for support of the tendon repair in this patient. This does not eliminate muscle contraction forces; however physiological loading is thought to account for only 25–33% of the tendon strain capacity (13, 19). To facilitate controlled increase in tendon length with elbow flexion, the length of the connecting bar spanning the humeral and radial components of the ESF was shortened one month after repair. Subsequently, removal of the connecting bar and placement of a soft padded bandage over the entire limb allowed for a small degree of controlled active range-of-motion during weight bearing.

Less invasive alternative strategies than external skeletal fixation to prevent bandage slipping, such as a spica splint or custom orthotic could have been considered. However there was no evidence of pin tract morbidity at the time of transition. Static progressive increase of the elbow mobilization was directed to minimize muscle contracture and premature failure of the tenorrhaphy. Tendon healing is protracted, and achieves only 56% of its original strength at six weeks, slowing increasing to 79% of normal at one year post repair in a triceps tenotomy model (17). Studies in experimental animals found that controlled loading across the repair from three to four weeks onward results in more rapid return of tendon strength compared with longer immobilization (20). However, the timeline for healing of tendon to bone, as achieved in this case, is not as clear, and other factors such as chronicity and vascular supply probably affected the rate of healing.

Avulsion of the triceps tendon is a rare condition in small animals and historic reports would suggest that chronic ruptures are associated with a guarded prognosis (21). The diagnosis can often be made based on a thorough physical examination in conjunction with directed imaging of the
region such as ultrasound or MRI examinations. The results achieved in this case suggests that with appropriate surgical management and physical rehabilitation, neglected chronic tendon injuries may have a good prognosis for return to normal limb function.

Conflict of interest

Only internal funding was used for this study. The authors do not have any corporate interests that pertain to this work.

References