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Biceps tendon and triceps tendon injuries

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Injuries to the biceps and triceps tendons about the elbow are relatively infrequent. Typically, they are traumatic events that occur as a result of a forceful eccentric contraction. Early recognition of these injuries and prompt intervention are the cornerstones to a successful outcome. Acute anatomic repair of complete injuries offers predictably good results. Conservative management, on the other hand, is typically reserved for partial injuries with little functional compromise, and for patients unfit for surgery. The challenges posed by chronic injuries can be addressed with a variety of surgical options. This article focuses on the timely identification and diagnosis of these injuries and specific indications and guidelines for their treatment.

Biceps tendon ruptures

Anatomy and biomechanics

Familiarity with the anatomy of the antecubital fossa is critical to the management of distal biceps tendon injuries. This fossa is defined as the space between pronator teres and brachioradialis muscles anterior to the elbow, and contains, most importantly, the brachial artery and the median nerve, in addition to the distal biceps tendon. The distal biceps tendon courses deep into the antecubital fossa and inserts onto the radial tuberosity. The bicipital aponeurosis (lacertus fibrosis) originates from the medial aspect of the muscle belly in the distal arm, where it traverses the roof of the antecubital fossa, interweaving with the fascia of the pronator-flexor mass, and inserting onto the dorsal aspect of the ulna.

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The brachial artery bifurcates at the level of the radial head in the antecubital fossa, giving rise to the radial and ulnar branches. Near its origin, the radial artery gives off the recurrent radial artery, which traverses laterally across the antecubital fossa. The musculocutaneous nerve arises from the lateral cord of the brachial plexus and innervates the biceps. Its terminal branch, the lateral antebrachial cutaneous nerve, courses lateral to the biceps tendon into the superficial fascia juxtaposed to the cephalic vein. It provides cutaneous sensation to the lateral-volar aspect of the forearm, and its location in the lateral subcutaneous tissue of the antecubital fossa makes it susceptible to iatrogenic injury [1]. The radial nerve traverses distally in a plane between brachialis and brachioradialis, and divides at the elbow joint to yield superficial and deep branches. The superficial branch lies anteromedial to brachioradialis, and lies within its fascial compartment. The posterior interosseous branch curves around the lateral neck of the radius and then enters the supinator muscle, where it can be prone to surgical injury [2–7].

Biomechanically, the biceps is the most powerful supinator of the forearm. It also serves as a secondary flexor, along with the brachioradialis, when strength of the brachialis is insufficient. These functions of the biceps are influenced by the position of the arm. The flexor function is augmented when the forearm is in a supinated position, and conversely, supination strength is optimized at 90° of flexion [6,8].

Etiology and pathophysiology

Distal biceps tendon ruptures account for approximately 3% of all biceps tendon injuries [9,10]. They occur most commonly in males in the fifth to sixth decades of life. The mechanism of injury is usually a single traumatic event in which an eccentric, sudden extension load is applied to a flexed, supinated forearm [3,11]. The occurrence of these injuries in women is exceedingly rare. Infrequent case reports of partial injuries in women have been described [12–14]. Recently, though, Toczylowski and colleagues published the only two reported cases of complete biceps tendon ruptures in women [15]. Both injuries occurred in athletically active female patients during sporting activities, and the authors speculated that these injuries may increase in the future to mirror the increased athletic activity of women in the general population.

The true cause of these injuries has been the matter of much study, and is most likely multifactorial in etiology. Some authors have asserted that intrasubstance degeneration and hypertrophic scarring of the radial tuberosity are predisposing factors to rupture [16–18]. These etiologies are supported by histopathologic studies of ruptured tendons that revealed hypoxic degenerative tendinopathy. Moreover, mucoid degeneration, tendolipomatosis, and calcific tendinopathy have also been described [19]. It is likely that subclinical degenerative changes occur that disturb the normal architecture of the tendon and predispose it to rupture with a sudden, eccentric contraction.

Anatomic and vascular causes have been implicated as well. Seiler and colleagues discovered a 2 cm region of relative hypovascularity between the enthesis and proximal portions of the distal biceps tendon [20]. This is analogous to the critical zone of the rotator cuff, which is subject to attritional changes and rupture because of its limited vascular supply [21]. Furthermore, the group discovered that the cross-sectional area available for the tendon decreased almost 50% from supination to pronation. In fact, in full pronation, the tendon occupies 85% of the available cross-sectional area. It was postulated this space could be further reduced by inflammation and spurring, making the tendon more susceptible to rupture.

Anabolic steroids and androgen substitution have also been implicated in the etiology of distal biceps tendon degeneration and rupture [22–24]. Michna reported that when administered anabolic steroids, the ultrastructure of mouse tendon was altered significantly and became more pronounced with exercise [25]. Clinically, there have been reports of distal biceps tendon ruptures attributed to steroid use [26,27]; however, in the only series looking specifically at this injury in athletes, most of whom were weight lifters, all the patients denied steroid use [9]. Therefore, the role of anabolic steroids as it relates to this condition remains unclear.

Clinical presentation and diagnosis

The typical presentation is a male in his forties or fifties who has the acute onset of a sharp, tearing pain in the antecubital fossa following an eccentric load applied to the elbow [3,6]. Frequently, these patients will report a subjective “popping” sensation over their antecubital fossa. The initial pain typically persists for several hours, and is followed by a dull ache that may last for weeks to months [11]. On physical examination, there is usually swelling and tenderness in the antecubital fossa that may be followed by ecchymosis extending both distally and proximally. The biceps muscle belly will retract proximally if the lacertus is involved, producing a tendinous defect distally. This gives rise to the so-called “Popeye sign.” Absence of a defect in the presence of a convincing clinical examination suggests a partial tear. Significant motion loss is not characteristic; however, supination weakness and corresponding deficits in elbow flexion and grip strength are universal. In partial tears the clinical findings may be more subtle, and the strength deficits may improve over time. Other etiologies of antecubital fossa tenderness to consider include biceps tendonitis, cubital bursitis, and lateral antebrachial cutaneous nerve entrapment [28,29].

The diagnosis of biceps tendon rupture is most commonly a clinical one. Routine radiographs, ultrasonography (US), or MRI are not required for diagnosis, but may help to clarify atypical presentations or difficult cases (Fig. 1). Osseous findings that have been reported with plain radiographs include irregularity and enlargement of the radial tuberosity, as well as avulsion of the tuberosity with complete ruptures [6,17]. US and MRI may be used to delineate whether or not a tendon has been completely ruptured, and to distinguish between partial ruptures and other antecubital fossa pathology [30,31].

Fig. 1. MRI sagittal fast spin-echo image of a ruptured distal biceps tendon. (Courtesy of Dr. Doug Mintz, Hospital for Special Surgery New York, NY.)

Classification

Distal biceps tendon ruptures can be classified as complete or partial. Partial ruptures are exceedingly rare and have only been reported in small series and case reports, and thus have no formal classification system [12–14]. Complete ruptures are further subdivided into acute and chronic, based on duration of time from injury. Injuries occurring within 4 weeks are considered acute, and can be repaired to the radial tuberosity with good, reproducible results [9,11,18,28]. Injuries presenting after 4 weeks are classified as chronic, and are further separated based on the integrity of the lacertus. A torn lacertus is associated with proximal retraction of the biceps tendon, scarring of the tendon to the brachialis muscle, and myostatic contraction, making results less predictable and the operative procedure more technically challenging [28,32,33]. An intact lacertus, on the other hand, usually restricts the tendon from retracting proximally, and may facilitate the repair of chronic ruptures [7,28,32,34].

Surgical indications

Historically, early reports advocated nonoperative management for the treatment of distal biceps tendon ruptures, observing that conservatively treated patients had normal return of function and earlier return to work [5,35]. This approach changed when Morrey et al [33] demonstrated that nonoperative management resulted in approximately a 40% loss of supination strength and an average 30% loss of flexion strength. Numerous studies since have clearly documented the superiority of early anatomic repair to nonoperative management [7,9,33,36–40]. Acute anatomic repair in active patients of all ages is therefore the current recommendation for treatment of distal biceps tendon ruptures [7,18, 28,33,34,38,41]. Nonoperative management should be reserved for sedentary or elderly individuals who do not require flexion or supination strength for activities of daily living, and for patients medically unfit for surgery. Persistent activity related pain, and diminished elbow flexion and supination strength and endurance can be expected in the nonoperatively treated patient [7,18,28,33,34,38,42]. Anatomic repair or autograft/allograft reconstruction should be attempted in active patients with chronic injuries [7,32–34,43]. In general, chronic repairs and reconstructions are technically more demanding than acute repairs, and have less predictable results [7,28,32,37,43]. This obviously has implications for athletes who are in-season. In a poll of National Football League team physicians, 90% favored early repair of these injuries during the season, rather than delaying repair until the end of the season [44].

Treatment

The surgical treatment of distal biceps tendon injuries has evolved since the initial reports of repair in 1898 [45]. Single- and double-incision techniques have been described, each having its advantages and limitations. Before the era of suture anchors, single-incision approaches consisted of attachment of the distal stump of the tendon either directly to the tuberosity or to the brachialis. Early reports described numerous radial nerve palsies secondary to the dissection required to expose and repair the tendon to the tubercle. Nonanatomic repair to the brachialis, therefore, gained popularity in the 1940s and 1950s to avoid these neurovascular complications [2,6]. In 1961, Boyd and Anderson [46] introduced a two-incision technique to minimize this risk. The approach they developed incorporated a second posterolateral incision, which by fully pronating the forearm, exposed the radial tuberosity in the second incision and obviated the need for deep dissection in the antecubital fossa. Reports of radioulnar synostosis began to surface with the introduction of this technique [33,40,47–49]. It was therefore subsequently modified by Failla et al [47], who added a muscle splitting approach through the common extensor tendon to avoid subperiosteal exposure of the ulna (Fig. 2). Theoretically, this decreased the risk of radioulnar synostosis and heterotopic ossification.

The recent advent of suture anchor technology has brought forth a renewed interest in the single-incision techniques [18,41,50–54]. Other novel single-

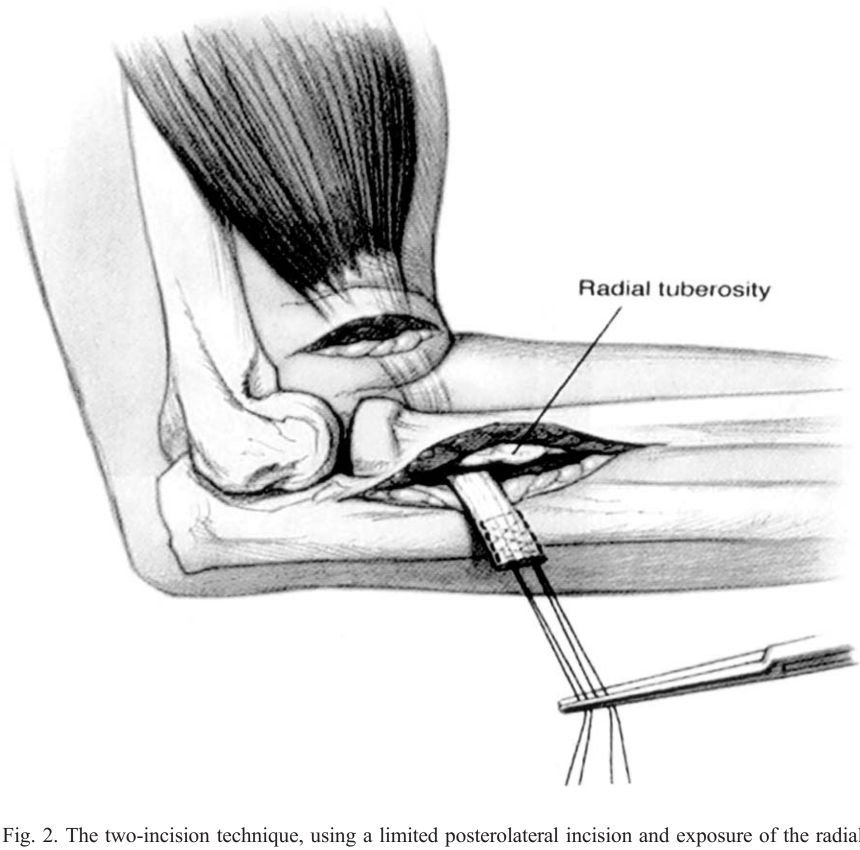

Fig. 2. The two-incision technique, using a limited posterolateral incision and exposure of the radial tuberosity with pronation of the forearm. (*From* Morrey BF. Injury of the flexors of the elbow: biceps in tendon injury. In: Morrey BF, editor. The elbow and its disorders. 3rd edition. Philadelphia: W.B. Saunders Co.; 2000. p. 473; with permission.)

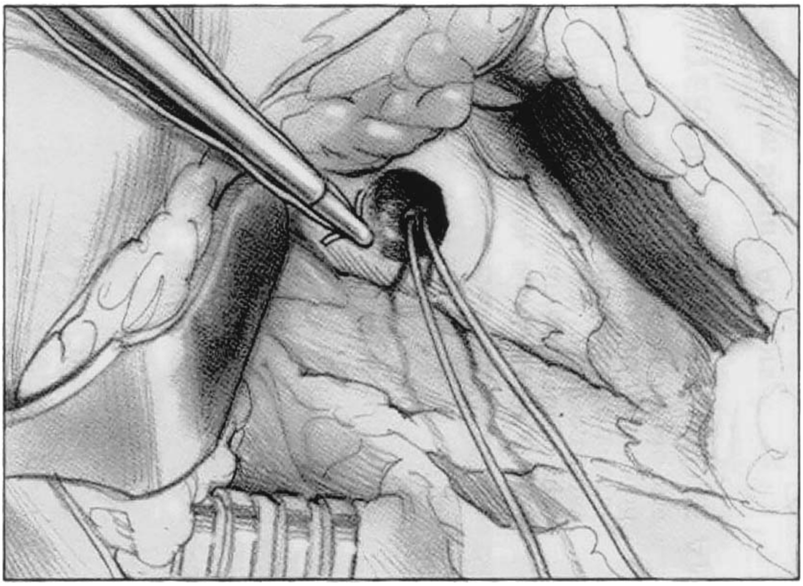

Fig. 3. Suture anchors being placed in prepared tuberosity using modern single-incision technique (*From* Morrey BF. Injury of the flexors of the elbow: biceps in tendon injury. In: Morrey BF, editor. Master techniques in orthopaedic surgery: the elbow. Philadelphia: Lippincott Williams & Wilkins; 2002. p. 182; with permission.)

incision variations, such as repair over an Endobutton (Acufex, Microsurgical, Mansfield, Massachusetts) are also being reported [51] (Fig. 3).

Treatment of partial ruptures

Partial biceps tendon ruptures are extremely rare injuries, with fewer than 30 described in the literature [14]. They typically result in less of a functional loss than their complete counterparts when treated nonoperatively [12]. Conservative management is recommended initially for these injuries [12–14,28,30,34,55]. Acute partial ruptures can be safely observed, and are typically noted to become asymptomatic within 6 weeks [34]. Conservative management entails rest and anti-inflammatory medication. The elbow is typically immobilized for 1 week, followed by dynamic flexion-assisted hinged bracing to protect the injured tendon. After about 6 to 8 weeks, the brace can be discontinued and strengthening exercises and unrestricted motion can be started. Full activity can typically be resumed within 4 months [55].

Surgical treatment is reserved for refractory cases [13,14]. Release and debridement of the damaged tendon and anatomic reinsertion to the radial tuberosity, either through a single- or double-incision technique, are recommended [12–14,30]. Bourne and Morrey suggested that tendon release, debridement, and reattachment avoid the persistent pain and weakness that can be associated with simple primary repair [13].

Elongation of the distal biceps tendon without frank anatomic failure is an exceptionally rare injury that can occur at the elbow, and is considered a variant of partial rupture [56]. Nielsen [56] described a case in which the lacertus ruptured and the biceps tendon was stretched, behaving clinically like a complete rupture. He used Z-plasty shortening of the tendon to restore the proper muscle-tendon length. Recently, Kragh and Basamania [57] described a series of 12 army paratroopers with acute traumatic closed transection of the muscle belly of the biceps brachii. They found that patients who underwent surgical repair did better than their nonoperative cohort with respect to supination strength, appearance, and patient satisfaction.

Treatment of chronic ruptures

Retraction of the biceps tendon with associated myostatic contracture and closure of the insertional path can make surgical repair of chronic distal biceps tendon ruptures challenging. In general, the results of late reconstruction are considered inferior and less predictable than those of acute repair [3,28,32,33]. Tenodesis of the biceps to the brachialis can be performed to improve flexion strength and alleviate pain in chronic injuries, but this is at the expense of supination. This should be reserved for patients who do not require improvement in supination strength or endurance [18,33,41]. On the other hand, if supination strength is required, anatomic repair is the goal. If proximal retraction of the tendon excludes the possibility of direct anatomic repair, then salvage procedures requiring grafts must be used [28,32,34,43].

There is no consensus regarding the optimal treatment of chronic injuries. Single- and double-incision techniques have both been advocated. Double-incision techniques are typically easier in the scarred antecubital fossa, and minimize the risk to the neighboring neurovascular structures. The use of fascia lata graft [58], flexor carpi radialis tendon graft [34,43], semitendinosis tendon graft [32], and Achilles allograft [18,42] have all been reported. The advantage of flexor carpi radialis autografts is keeping the donor site in the same extremity and performing the surgery under one regional anesthesia [34,43]. Morrey [18,42], however, prefers the Achilles tendon allograft, citing bone-to-bone fixation with a calcaneal bone plug as an advantage that allows for more aggressive post-operative rehabilitation.

Postoperative care

Regardless of repair technique, the elbow is typically immobilized in 90° of flexion for 7 to 10 days postoperatively. A hinged flexion-assisted brace with an extension block at 30 ° is used to protect the repair for 6 to 8 weeks. Early protected range of motion is encouraged. At 6 to 8 weeks, the brace is removed and unrestricted motion and light strengthening exercises are started. Return to full activity is typically allowed at 4 to 6 months [18,28,55].

Results

The superiority of acute anatomic repair of distal biceps tendon ruptures to nonoperative management is clearly supported in the literature. As noted, multiple different techniques have been described, with similar results in subjective and objective improvement [3,4,6,7,9,33,36–40,46,48–51,53,54,59–61].

Morrey et al [33] demonstrated that if treated conservatively, distal biceps tendon ruptures result in a significant loss of forearm supination and flexion strength. Supination strength is affected the most, with a predictable 40% loss of power. The influence on flexion strength is more variable, averaging a loss of about 30%. This loss of supination strength is also predictably present in patients treated with nonanatomic repairs to the brachialis. Furthermore, Morrey et al [33] demonstrated that patients treated with anatomic reinsertion of the tendon gained near normal flexion and supination power. Baker and Bierwagen [38] supported these findings in their comparison of surgically and nonsurgically treated injuries. They found supination strength and endurance were about 40% and 79% less, respectively, in the conservatively treated group when compared with their surgical cohorts. Similar deficits were found in flexion strength and endurance in the nonoperatively treated group.

The decision between a one- or two-incision approach lies mainly with the surgeon's preference and experience level. Excellent functional results have been described with either the single-incision or the modified Boyd-Anderson approach [7,50,51,53,54,59]. Proponents of single incision claim decreased rates of heterotopic ossification, diminished operating time, and decreased rates of posterior interosseous nerve injury as advantages. Conversely, Morrey [18] has voiced concerns about the initial strength of the suture anchors that would permit early motion. A recent biomechanical study looking at the strength of suture anchors compared with the strength of transosseous sutures in cadaveric, osteoporotic bone found that suture anchors fail at significantly lower loads than transosseous sutures [52]. They observed, though, that their cyclic loading results suggest that either type of bony fixation technique should be sufficient to allow immediate postoperative passive mobilization. Of concern, they did notice gap formation at the bone-tendon interface with cyclic loading in the anchor group. More recently, Pereira et al [62] performed a similar biomechanical study looking specifically at both older, osteoporotic and younger, nonosteoporotic elbows. They similarly found improved stiffness and tensile strength in their bone tunnel group when compared with their suture anchor group that was most pronounced in the nonosteoporotic bone.

Clinically, Rantanen and Orava [7] reviewed a combined 147 patients from the literature and 19 from their own series, and found no difference in the functional outcomes between these two techniques. El-Hawary et al [63] recently prospectively reviewed 19 patients who had undergone acute distal biceps tendon repair, either through a limited single incision with suture anchors or through a modified Boyd-Anderson approach. The two-incision technique, in their study, showed a slightly quicker recovery time and a lower complication rate when compared with the single incision. These complications were primarily transient nerve palsies. At 1 year, supination strength and motion were no different between the groups. At our institution, we retrospectively reviewed 26 patients with either single- or double-incision repairs. Subjective evaluation and objective evaluation using isokinetic strength and endurance testing were performed. Both techniques allowed for safe and effective reconstruction. Overall patient satisfaction was greater than 95%, and objective testing revealed no statistical difference between the groups; however, isokinetic testing and endurance testing revealed a trend toward better restoration of strength and endurance with the two-incision technique [64].

The only reported series of distal biceps tendon ruptures in athletes was performed by D'Alessandro and colleagues [9]. They used the modified double-incision technique for all of their patients, and all their athletes returned to full, unlimited activity.

Complications

The complications seen with operative repair of the distal biceps tendon rupture depend on the chosen operative approach. Injuries to the radial and posterior interosseous nerves are the most commonly reported neurologic complications with surgery, and are classically described with single incision approaches [2–4,6,7,41,46]. Rare case reports of median [65] and musculocutaneous nerve [39] injuries have also been reported. Although infrequent, nerve injuries have also been observed with the double-incision technique [41,46,66]. Typically, the injuries are neurpraxias and are transient, although permanent injuries have been reported [6]. In general, the reported incidence of nerve palsies seen with the single-incision approach has decreased with the advent of suture anchors [50,51,53,54,67]. El-Hawary et al, though, reported a 33% rate of lateral antebrachial cutaneous nerve parasthesias in their single incision group, all of which resolved [63].

Heterotopic ossification and radioulnar synostosis are potentially disabling complications associated with the classic Boyd-Anderson approach. Resection of the synostosis, if it develops, is the only treatment to restore forearm rotation but the results are variable [47,48]. Kelly et al [41] analyzed the complication rate in 74 consecutive acute repairs undergoing the two-incision technique using the muscle-splitting modification. They found heterotopic ossification in only four of their patients, none of whom developed limited forearm rotation or radioulnar synostosis. To our knowledge, there is only one reported case of radioulnar synostosis with the modified technique [61]. Heterotopic ossification has also been reported to develop with the single-incision technique, but with less frequency [59,63]. Secure fixation that allows early motion is the best way to avoid heterotopic ossification and radioulnar synostosis (Fig. 4).

Finally, rerupture is an exceedingly rare complication following surgical repair. Only two cases have been reported. One occurred in a patient with a subacute repair and the other in a chronic repair. The subacute repair that re-

Fig. 4. Radioulnar synostosis associated with two-incision technique (*From* Morrey BF. Injury of the flexors of the elbow: biceps in tendon injury. In: Morrey BF, editor. The elbow and its disorders. 3rd edition. Philadelphia: W.B. Saunders Co.; 2000. p. 474; with permission.)

ruptured failed at the suture-tendon interface 2 weeks postoperatively. The second failed 3 months after repair, but did not undergo reoperation, so the site of failure is unknown. Both were initially reattached using the two-incision technique [40,41].

Triceps tendon ruptures

Triceps tendon injuries are possibly the rarest of all tendon injuries [16,68]. There exists a male predominance of 2:1, and the injury has been described through a gamut of ages [69–72]. In particular, adolescents who have incompletely fused or recently fused physes are susceptible to triceps tendon rupture [72].

The mechanism of injury is typically an acute trauma in which the tendon avulses off the olecranon. Spontaneous ruptures and ruptures at the musculotendinous junction and muscle belly have also been described, but are less frequent [73–75]. Most commonly, the traumatic event is a fall on an outstretched hand in which a deceleration load is applied to the triceps while it is actively contracting. Other mechanisms include direct trauma, motor vehicle accidents, and power lifting [75–80]. Renal osteodystrophy, metabolic bone diseases, and anabolic steroid use are contributing etiologies that have also been reported [55,70,71].

Clinical presentation and diagnosis

As with the biceps, the diagnosis of triceps tendon rupture is typically made clinically. The patient usually reports a history of a fall on an outstretched hand that leads to acute pain and swelling on the posterior aspect of the elbow. On physical examination there is tenderness, swelling, ecchymosis, and a depression proximal to the olecranon. Active extension against resistance is typically diminished or absent, depending on whether or not there is a complete or partial tear [81,82]. A modification of the Thompson test used for Achilles tendon ruptures has been described to evaluate these injuries [72]. Radiographs should always be obtained with suspected triceps tendon ruptures, to evaluate for the "flake sign" that is pathognomonic of tendon avulsions, as well as to exclude radial head fractures, which are a frequently reported concomitant injury [75,83]. Similar to the biceps, in difficult cases where the distinction between complete and partial ruptures is ambiguous or the diagnosis is uncertain, MRI and US may be used to further clarify the pathology [31,84].

Treatment

The nonoperative management of triceps tendon ruptures has a role in partial injuries with insignificant loss of extension strength, and in elderly, debilitated patients who have complete tears. Nonoperative management consists of splint immobilization for approximately 4 weeks in 30° of flexion. The choice of nonoperative management should be made cautiously, with great care taken to assure that the injury is indeed a partial rupture. An untreated complete rupture typically results in significant functional impairment [70,71,77].

As with the treatment of biceps tendon ruptures, the treatment of choice for almost all complete triceps tendon ruptures is acute operative repair. Surgery should be performed within the first 2 weeks of injury if possible, although primary repair has been described as late as 8 months postinjury [85]. Acute repair involves primary reattachment of the avulsed triceps tendon to the olecranon through drill holes [70,71,86]. In cases where a portion of the olecranon has avulsed, large bone fragments can be fixed with screws or a tension band [72]. Smaller fragments can be excised and then primary reattachment of the tendon can be performed. Chronic cases that have minimal tendon retraction can be treated in the same fashion as primary, acute injuries. Reconstruction of chronic cases with retraction has been described using posterior fascial flaps, allograft Achilles tendon, autograft hamstring tendon, forearm fascial flaps, and ligament augmentation devices [55,69,70,77,86,87].

Postoperatively, the arm is immobilized in 30° to 45° of flexion for 3 to 4 weeks. Therapy begins after this period of immobilization with passive range of motion. At 6 weeks postoperatively, active range of motion is started. Lifting weights should be avoided for at least 4 to 6 months.

Overall results of repair of this rare injury have been universally good [70,71,75]. Morrey [70] stated that 13 out of 15 cases treated at the Mayo Clinic did well with various surgical procedures; however, recovery typically requires at least 6 months.

Summary

Biceps and triceps tendon ruptures at the level of the elbow are rare events. Early recognition and prompt surgical repair provide the most predictable, optimal results for complete injuries. Partial injuries are exceptionally rare, and can be amenable to successful conservative management. Patients undergoing surgery acutely, by and large, can be expected to have near-normal return of flexion and supination strength for biceps repairs and extension strength for triceps repairs, regardless of the chosen operative technique. Management of patients who have chronic ruptures can be a challenge, and various reconstruction techniques have been described. These chronic reconstruction techniques are successful at restoring function, but the results are considered less predictable than the results for acute repair.

References

[1] Hoppenfeld S, deBoer P. Surgical exposures in orthopaedics: the anatomic approach. 2nd edition. Philadelphia: J.B. Lippincott Co; 1984.
[2] Dobbie RP. Avulsion of the lower biceps brachii tendon: analysis of fifty-one previously reported cases. Am J Surg 1941;51:661.
[3] Boucher PR, Morton KS. Rupture of the distal biceps brachii tendon. J Trauma 1967;7:626–52.
[4] Friedman E. Rupture of the distal biceps brachii tendon. JAMA 1963;184:60–3.
[5] Kron SD, Satinsky VP. Avulsion of the distal biceps brachii tendon. Am J Surg 1954;88:657–9.
[6] Meherin JM, Kilgore ES. The treatment of ruptures of the distal biceps brachii tendon. Am J Surg 1960;99:636–8.
[7] Rantanen J, Orava S. Rupture of the distal biceps tendon. A report of 19 patients treated with anatomic reinsertion, and a meta-analysis of 147 cases found in the literature. Am J Sports Med 1999;27(2):128–32.
[8] Basmajian JV, Latif MA. Integrated actions and functions of the chief flexors of the elbow. J Bone Joint Surg 1957;39-A:1106–18.
[9] D'Alessandro DF, Shields Jr CL, Tibone JE, Chandler RW. Repair of distal biceps tendon ruptures in athletes. Am J Sports Med 1993;21(1):114–9.
[10] Gilcreest EL. Unusual lesions of muscles and tendons of the shoulder girdle and upper arm. Surg Gynecol Obstet 1939;68:903–17.
[11] Morrey BF. Tendon injuries about the elbow. In: Morrey BF, editor. The elbow and its disorders. Philadelphia: W.B. Saunders; 1993. p. 492–504.
[12] Durr HR, Stabler A, Pfahler M, Matzko M, Refior HJ. Partial rupture of the distal biceps tendon. Clin Orthop 2000;374:195–200.
[13] Bourne MH, Morrey BF. Partial rupture of the distal biceps tendon. Clin Orthop 1991;271:143–8.
[14] Vardakas DG, Musgrave DS, Varitimidis SE, Goebel F, Sotereanos DG. Partial rupture of the distal biceps tendon. J Shoulder Elbow Surg 2001;10(4):377–9.
[15] Toczylowski HM, Balint CR, Steiner ME, Boardman M, Scheller Jr AD. Complete rupture of the distal biceps brachii tendon in female patients: a report of 2 cases. J Shoulder Elbow Surg 2002;11(5):516–8.

[16] Waugh RL, Hatchcock TA, Elliot JL. Ruptures of muscles and tendons. Surgery 1949;25: 370–92.
[17] Davis BM, Yassine Z. An etiological factor in tear of the distal tendon of the biceps brachii. J Bone Joint Surg Am 1956;38:1365–8.
[18] Morrey BF. Biceps tendon injury. Instr Course Lect 1999;48:405–10.
[19] Kannus P, Jozsa L. Histopathological changes preceding spontaneous rupture of a tendon. A controlled study of 891 patients. J Bone Joint Surg Am 1991;73(10):1507–25.
[20] Seiler 3rd JG, Parker LM, Chamberland PD, Sherbourne GM, Carpenter WA. The distal biceps tendon. Two potential mechanisms involved in its rupture: arterial supply and mechanical impingement. J Shoulder Elbow Surg 1995;4(3):149–56.
[21] Lohr JF, Uhthoff HK. The microvascular pattern of the supraspinatus tendon. Clin Orthop 1990; (254):35–8.
[22] Balasubramaniam P, Prathap K. The effect of injection of hydrocortisone into rabbit calcaneal tendons. J Bone Joint Surg Br 1972;54(4):729–34.
[23] Ford LT, DeBender J. Tendon rupture after local steroid injection. South Med J 1979;72(7): 827–30.
[24] Middleton WD, Reinus WR, Totty WG, Melson GL, Murphy WA. US of the biceps tendon apparatus. Radiology 1985;157(1):211–5.
[25] Michna H. Tendon injuries induced by exercise and anabolic steroids in experimental mice. Int Orthop 1987;11:157–62.
[26] Visuri T, Lindholm H. Bilateral distal biceps tendon avulsions with use of anabolic steroids. Med Sci Sports Exerc 1994;26(8):941–4.
[27] Morgenthaler M, Weber M. Eine pathologische ruptur der distalen bizepssehne nach langjahriger androgen substitution [Pathological rupture of the distal biceps tendon after long-term androgen substitution]. Z Orthop Ihre Grenzgeb 1999;137(4):368–70.
[28] Ramsey ML. Distal biceps tendon injuries: diagnosis and management. J Am Acad Orthop Surg 1999;7(3):199–207.
[29] Karanjia ND, Stiles PJ. Cubital bursitis. J Bone Joint Surg Br 1988;70(5):832–3.
[30] Rokito AS, McLaughlin JA, Gallagher MA, Zuckerman JD. Partial rupture of the distal biceps tendon. J Shoulder Elbow Surg 1996;5(1):73–5.
[31] Fritz RC, Steinbach LS. Magnetic resonance imaging of the musculoskeletal system: part 3. the elbow. Clin Orthop 1996;324:321–39.
[32] Hang DW, Bach Jr BR, Bojchuk J. Repair of chronic distal biceps brachii tendon rupture using free autogenous semitendinosus tendon. Clin Orthop 1996;(323):188–91.
[33] Morrey BF, Askew LJ, An KN, Dobyns JH. Rupture of the distal tendon of the biceps brachii. A biomechanical study. J Bone Joint Surg Am 1985;67(3):418–21.
[34] Aldridge JW, Bruno RJ, Strauch RJ, Rosenwasser MP. Management of acute and chronic biceps tendon rupture. Hand Clin 2000;16(3):497–503.
[35] Carroll R, Hamilton L. Rupture of the biceps brachii. J Bone Joint Surg Am 1967;49:1016.
[36] Pearl ML, Bessos K, Wong K. Strength deficits related to distal biceps tendon rupture and repair. A case report. Am J Sports Med 1998;26(2):295–6.
[37] Agins HJ, Chess JL, Hoekstra DV, Teitge RA. Rupture of the distal insertion of the biceps brachii tendon. Clin Orthop 1988;(234):34–8.
[38] Baker BE, Bierwagen D. Rupture of the distal tendon of the biceps brachii. Operative versus non-operative treatment. J Bone Joint Surg Am 1985;67(3):414–7.
[39] Norman WH. Repair of avulsion of insertion of biceps brachii tendon. Clin Orthop 1985; (193):189–94.
[40] Bell RH, Wiley WB, Noble JS, Kuczynski DJ. Repair of distal biceps brachii tendon ruptures. J Shoulder Elbow Surg 2000;9(3):223–6.
[41] Kelly EW, Morrey BF, O'Driscoll SW. Complications of repair of the distal biceps tendon with the modified two-incision technique. J Bone Joint Surg Am 2000;82-A(11):1575–81.
[42] Morrey BF. Injury of the flexors of the elbow: biceps in tendon injury. In: Morrey BF, editor. The elbow and its disorders. 3rd editon. Philadelphia: W.B. Saunders Co.; 2000. p. 468–78.

[43] Levy HJ, Mashoof AA, Morgan D. Repair of chronic ruptures of the distal biceps tendon using flexor carpi radialis tendon graft. Am J Sports Med 2000;28(4):538–40.

[44] Rettig AC. Traumatic elbow injuries in the athlete. Orthop Clin North Am 2002;33(3):509–22.

[45] Acquaviva J. Rupture du tendon inferieur du biceps brachial droit a son insertion sur la tuberosite bicipitale: Tenosuture success operatoire. Mars Med 1898;35:570.

[46] Boyd HB, Anderson LB. A method for reinsertion of the distal biceps brachii tendon. J Bone Joint Surg Am 1961;7:1041–3.

[47] Failla JM, Amadio PC, Morrey BF, Beckenbaugh RD. Proximal radioulnar synostosis after repair of distal biceps brachii rupture by the two-incision technique. Report of four cases. Clin Orthop 1990;(253):133–6.

[48] Davison BL, Engber WD, Tigert LJ. Long term evaluation of repaired distal biceps brachii tendon ruptures. Clin Orthop 1996;(333):186–91.

[49] Moosmayer S, Odinsson A, Holm I. Distal biceps tendon rupture operated on with the Boyd-Anderson technique: follow-up of 9 patients with isokinetic examination after 1 year. Acta Orthop Scand 2000;71(4):399–402.

[50] Sotereanos DG, Pierce TD, Varitimidis SE. A simplified method for repair of distal biceps tendon ruptures. J Shoulder Elbow Surg 2000;9(3):227–33.

[51] Bain GI, Prem H, Heptinstall RJ, Verhellen R, Paix D. Repair of distal biceps tendon rupture: a new technique using the Endobutton. J Shoulder Elbow Surg 2000;9(2):120–6.

[52] Berlet GC, Johnson JA, Milne AD, Patterson SD, King GJ. Distal biceps brachii tendon repair. An in vitro biomechanical study of tendon reattachment. Am J Sports Med 1998;26(3):428–32.

[53] Barnes SJ, Coleman SG, Gilpin D. Repair of avulsed insertion of biceps. A new technique in four cases. J Bone Joint Surg Br 1993;75(6):938–9.

[54] Lintner S, Fischer T. Repair of the distal biceps tendon using suture anchors and an anterior approach. Clin Orthop 1996;(322):116–9.

[55] Johnson DC, Allen AA. Biceps and triceps tendon injury. In: Altchek DW, Andrews JR, editors. The athlete's elbow. Philadelphia: Lippincott Williams & Willkins; 2001. p. 105–20.

[56] Nielsen K. Partial rupture of the distal biceps brachii tendon. A case report. Acta Orthop Scand 1987;58(3):287–8.

[57] Kragh Jr JF, Basamania CJ. Surgical repair of acute traumatic closed transection of the biceps brachii. J Bone Joint Surg Am 2002;84-A(6):992–8.

[58] Hovelius L, Josefsson G. Rupture of the distal biceps tendon. Report of five cases. Acta Orthop Scand 1977;48(3):280–2.

[59] Louis DS, Hankin FM, Eckenrode JF, Smith PA, Wojtys EM. Distal biceps brachii tendon avulsion. A simplified method of operative repair. Am J Sports Med 1986;14(3):234–6.

[60] Le Huec JC, Moinard M, Liquois F, Zipoli B, Chauveaux D, Le Rebeller A. Distal rupture of the tendon of biceps brachii. Evaluation by MRI and the results of repair. J Bone Joint Surg Br 1996;78(5):767–70.

[61] Leighton MM, Bush-Joseph CA, Bach Jr BR. Distal biceps brachii repair. Results in dominant and nondominant extremities. Clin Orthop 1995;317:114–21.

[62] Pereira DS, Kvitne RS, Liang M, Giacobetti FB, Ebramzadeh E. Surgical repair of distal biceps tendon ruptures: a biomechanical comparison of two techniques. Am J Sports Med 2002; 30(3):432–6.

[63] El-Hawary R, Macdermid JC, Faber KJ, Patterson SD, King GJ. Distal biceps tendon repair: comparison of surgical techniques. J Hand Surg [Am] 2003;28(3):496–502.

[64] Johnson DC, Johnson TS, Cavanaugh J, Noonan D, Weiland AJ, Allen AA. Comparison of 1-incision technique versus 2-incision technique for repair of acute distal biceps tendon ruptures. Paper presented at American Orthopaedic Society for Sports Medicine Speciality Day—American Academy of Orthopaedic Surgery. New Orleans, LA, February 8, 2003.

[65] Lin KH, Leslie BM. Surgical repair of distal biceps tendon rupture complicated by median nerve entrapment. A case report. J Bone Joint Surg Am 2001;83-A(5):741–3.

[66] Katzman BM, Caligiuri DA, Klein DM, Gorup JM. Delayed onset of posterior interosseous nerve palsy after distal biceps tendon repair. J Shoulder Elbow Surg 1997;6(4):393–5.

[67] Strauch RJ, Michelson H, Rosenwasser MP. Repair of rupture of the distal tendon of the biceps brachii. Review of the literature and report of three cases treated with a single anterior incision and suture anchors. Am J Orthop 1997;26(2):151–6.
[68] Conwell HE. Ruptures and tears of muscles and tendons. Am J Surg 1937;35:22–33.
[69] Clayton ML, Thirupathi RG. Rupture of the triceps tendon with olecranon bursitis. A case report with a new method of repair. Clin Orthop 1984;(184):183–5.
[70] Morrey BF. Rupture of the triceps tendon. In: Morrey BF, editor. The elbow and its disorders. 3rd edition. Philadelphia: WB Saunders Co.; 2000. p. 479–84.
[71] Strauch RJ. Biceps and triceps injuries of the elbow. Orthop Clin North Am 1999;30:95–107.
[72] Viegas SF. Avulsion of the triceps tendon. Orthop Rev 1990;19:533–6.
[73] Wagner JR, Cooney WP. Rupture of the triceps muscle at the musculotendinous junction: a case report. J Hand Surg [Am] 1997;22:341–3.
[74] Aso K, Torisu T. Muscle belly tear of the triceps. Am J Sports Med 1984;12:485–7.
[75] Bach Jr BR, Warren RF, Wickiewicz TL. Triceps rupture: a case report and literature review. Am J Sports Med 1987;15:285–9.
[76] Tarsney FF. Rupture and avulsion of the triceps. Clin Orthop 1972;83:177–83.
[77] Farrar 3rd EL, Lippert 3rd FG. Avulsion of the triceps tendon. Clin Orthop 1981;161:242–6.
[78] Herrick RT, Herrick S. Ruptured triceps in a powerlifter presenting as cubital tunnel syndrome: a case report. Am J Sports Med 1987;15:514–6.
[79] Sherman OH, Snyder SJ, Fox JM. Triceps tendon avulsion in a professional body builder: a case report. Am J Sports Med 1984;12:328–9.
[80] Sollender JL, Rayan GM, Barden GA. Triceps tendon rupture in weightlifters. J Shoulder Elbow Surg 1998;7:151–3.
[81] Bos CFA, Nelissen RG, Bloem JL. Incomplete rupture of the tendon triceps brachii. Int Orthop 1994;18:273–5.
[82] Pina A, Garcia I, Sabater M. Traumatic avulsion of the triceps brachii. J Orthop Trauma 2002; 16(4):273–6.
[83] Levy M, Fishel RE, Stern GM. Triceps tendon avulsion with or without fracture of the radial head—a rare injury? J Trauma 1978;18(9):677–9.
[84] Kaempffe FA, Lerner RM. Ultrasound diagnosis of triceps tendon rupture. A report of 2 cases. Clin Orthop 1996;(332):138–42.
[85] Inhofe PD, Moneim MS. Late presentation of triceps rupture. A case report and review of the literature. Am J Orthop 1996;25:790–2.
[86] Anderson RL. Traumatic rupture of the triceps tendon. J Trauma 1979;19(2):134.
[87] Bennett BS. Triceps tendon ruptures. J Bone Joint Surg Am 1961;44:741.