Surgical Anatomy of the Triceps Brachii Tendon

Anatomical Study and Clinical Correlation

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Background: The triceps tendon has been described as a single unit with contribution from each of the 3 heads of the muscle. An observation at the time of surgical repair of a triceps tendon injury led to an anatomical study to further define the anatomy of this tendon as it inserts on the olecranon.

Hypothesis: The medial head of the triceps has a tendon that is distinct from, and deep to, the common tendon of the long and lateral heads.

Study Design: Descriptive laboratory study and case report.

Methods: Eight cadaveric elbows were dissected to examine the triceps tendon. None of the specimens had any evidence of prior injury or surgery to the elbow. All specimens were fresh-frozen and stored at –4°C until they were thawed for use. Skin and subcutaneous tissue were removed, and the tendon of each head of the triceps was explored from the muscle to its bony insertion.

Results: In all 8 specimens, on gross inspection, the medial head had a separate insertion deep to the common insertion of the lateral and long heads. The muscle of the medial head extended further distally than did the long and lateral heads. The medial head was muscular to its deep insertion, with a small amount of tendon blended with the muscle distally. Histologic analysis demonstrated that the tendon of the medial head and that of the other 2 heads are confluent distally at their olecranon insertion.

Conclusion: The medial head of the triceps has a tendon that is distinct from, and deep to, the common tendon of the long and lateral heads on gross inspection. Histologic studies show the insertion of these 2 tendons is confluent.

Clinical Relevance: This anatomy has important implications for surgical repair of these tendon injuries. Rupture of the deep triceps insertion alone can occur and lead to weakness of elbow extension with the elbow flexed beyond 90°. Triceps strength should be tested with the elbow fully flexed when injury to the tendinous insertion is suspected.

Keywords: triceps; tendon; insertion; anatomy

The triceps tendon has been described as a single unit with contributions from the medial, lateral, and long heads of the muscle.[6] During the course of performing a triceps tendon repair, we noted a specific deep tendon separate from the more superficial tendon. This observation stimulated us to perform an anatomical study to define the triceps tendon in greater detail. The purpose of this study is to better define the triceps brachii tendon and its insertion and discuss the clinical implications of our findings.

CASE STUDY

A 22-year-old, right-hand-dominant man involved in weight training was evaluated for right arm weakness of 3 months' duration. The patient had the onset of right elbow pain when he struck the face of an opponent with his elbow while playing basketball. The exact mechanism of injury was not clear. Immediately after this accident, he developed elbow pain and weakness that progressed during the next few months. The patient was otherwise healthy, and he denied the use of anabolic steroids.[8] Furthermore, there were no secondary signs

or other evidence of steroid use such as acne, increased vascularity, or mood swings.

The patient was referred to the senior author (R. F. W.) 3 months after the injury. Physical examination revealed full elbow flexion and extension. He had normal triceps strength with the elbow near full extension; however, he was profoundly weak when trying to extend his elbow in the arc from full flexion to 90° of flexion. The patient did not have pain with resisted motion. Magnetic resonance imaging (MRI) revealed a partial tear of the triceps tendon at its insertion (Figure 1). Electrodiagnostic studies including nerve conduction studies showed normal results.

Four months after the injury, the patient remained very weak; therefore, we did not believe he would improve with nonoperative management. He underwent surgical reattachment of the right triceps tendon insertion through a midline posterior incision 4 months after the injury. At the time of surgery, the superficial appearance of the tendon was normal. The tendon was then split longitudinally to identify the injury diagnosed on MRI. Beneath the split created in the superficial tendon, a distinct deep tendon insertion was identified. The deep tendon insertion was degenerative and retracted 1 cm proximal to the olecranon. The degenerative portion was resected, and the deep tendon was reattached to the olecranon using 2 metal suture anchors. The ulnar nerve was not transposed.

The patient's elbow initially was splinted in 60° of flexion. Range of motion exercises were started 10 days after surgery. At 3 months postoperatively, the patient had full flexion and extension, with no notable deficit to extension strength with the arm in flexion. The patient returned to weight lifting. Cybex dynamometer results performed at 5 months postoperatively showed an improvement over preoperative function in peak torque of 50%, 57% in total work, and 66% in mean power as compared with presurgical testing. His right triceps showed a deficit of 13% in peak torque, 17% in total work, and 17% in mean power, compared with the normal side. There was no significant variation in triceps strength through the range of motion with manual testing. At 6 months postoperatively, he noted no subjective strength difference and was satisfied with the result. At 2 years, he had returned to all activities, including weight lifting, and reported no weakness or limitations. The patient felt that he had complete return of strength to his operated arm.

ANATOMICAL AND HISTOLOGIC ANALYSIS

Materials and Methods

Eight cadaveric elbows were dissected to examine the insertion of the triceps. None of the specimens had any evidence of prior injury or surgery to the elbow. All specimens were fresh-frozen and stored at –4°C until they were thawed for use. Each specimen was dissected through a direct posterior approach. Skin and subcutaneous tissue were removed. The triceps tendon insertion was dissected free posteriorly. The superficial and lateral heads of the muscle were dissected from the deep medial head, which was in turn dissected from the humerus. These muscles were followed to their tendon
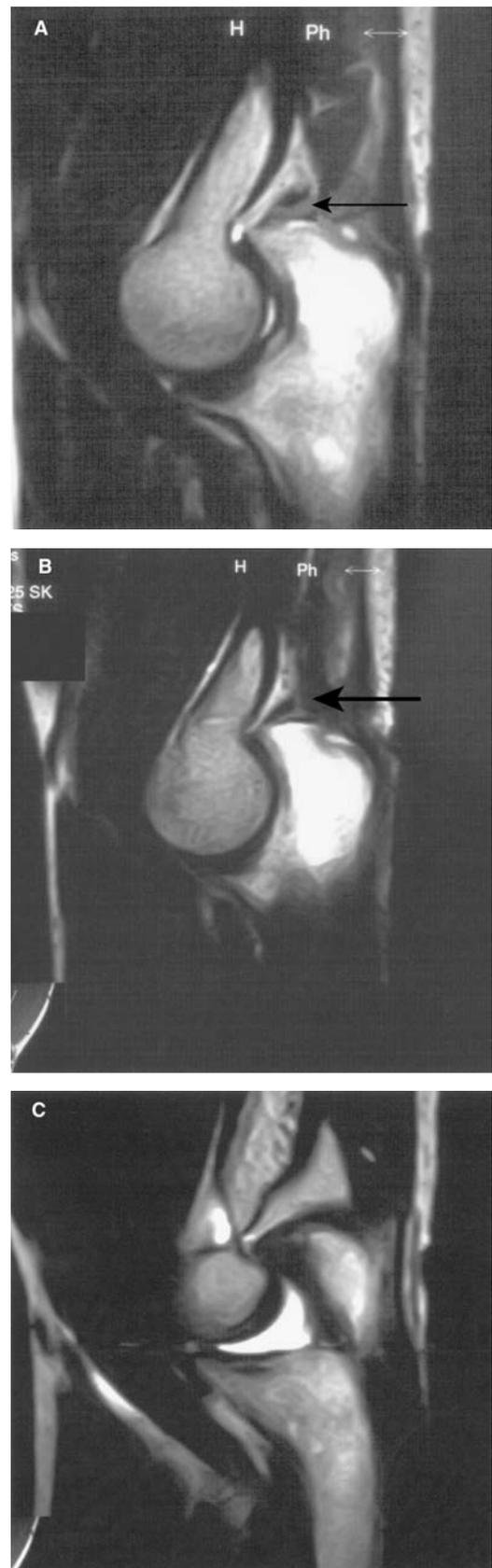

Figure 1. Sagittal MRI views of the elbow demonstrating triceps insertion injury (arrows). A, lateral sagittal cut; B, central sagittal cut; C, medial sagittal cut.

distally, to determine whether there existed distinct superficial and deep tendons.

Three additional fresh-frozen cadaveric specimens were dissected to the level of the triceps insertion. Longitudinal sections were taken across the olecranon at the level of the triceps insertion. The sections were then fixed and examined microscopically.

Results

Eight specimens were dissected to determine the anatomy of the triceps insertion. Subsequently, to further delineate the insertional anatomy, an additional 3 specimens were used for histologic analysis of the insertion.

In all 8 specimens, the medial head had a separate insertion deep to the common insertion of the lateral and long heads (Figures 2-4). The muscle of the medial head extended distally, and the deep insertion was muscular to its insertion, with a small amount of tendon blended with the muscle distally (Figure 2). There was invariably a thin fascial layer separating the 2 muscle layers (ie, separating the long and lateral heads from the deeper medial head) as they extended to their insertions. This fascial plane was very clearly defined, and dissection was easily accomplished. The tissue plane was easily found, and it was not made by the dissector. This plane extended down to the insertion, necessitating histologic analysis to determine whether the insertion was separate. Proximally, the interval extended to the proximal humerus.

On gross inspection, the tendon of the medial head of the triceps was smaller and deep to the long and lateral heads. The deep tendon was readily identifiable after longitudinally dividing the overlying conjoined tendons of the long and lateral heads of the triceps. However, on histologic analysis, no separation between the deep and superficial tendons was demonstrable at their insertion on the olecranon. The distinction between the 2 tendons that were identified in the dissections was not seen on the microscopic sections, indicating that the tendons unite as they insert to bone.

DISCUSSION

Review of the literature revealed only 1 case report of a partial tear of the triceps muscle involving only the medial head.[1] A 36-year-old woman with end-stage renal disease who was on corticosteroids was evaluated after falling on her extended arm while skiing. Her physical examination was notable for triceps strength of 3+, with no mention of variable strength through the range of motion. Magnetic resonance imaging confirmed the diagnosis and indicated a tear localized to the tendon of the medial head. She was treated nonoperatively with a posterior splint and returned to full strength and range of motion after 6 months.

The triceps muscle derives its name from a tripartite origin consisting of long, lateral, and medial heads. As described by Gray,[5] the long head arises from the infraglenoid tuberosity of the scapula. The lateral head has 3 sites of origin, including the humerus between the teres minor insertion and the proximal part of the radial groove, the lateral border of the humerus, and the lateral intermuscular
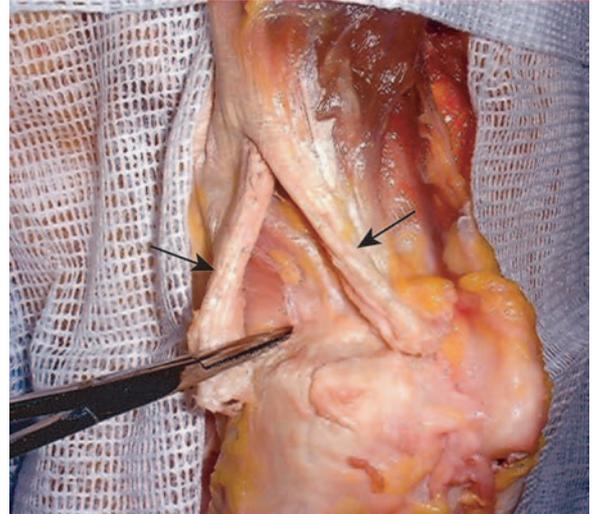

Figure 2. Posterior view of the elbow with the humerus above and the ulna below. The superficial triceps insertion is split longitudinally (dark arrows) and partially detached from the insertion on the olecranon. The metal instrument is in contact with the deep insertion of the triceps, which is not detached from its insertion on the olecranon.
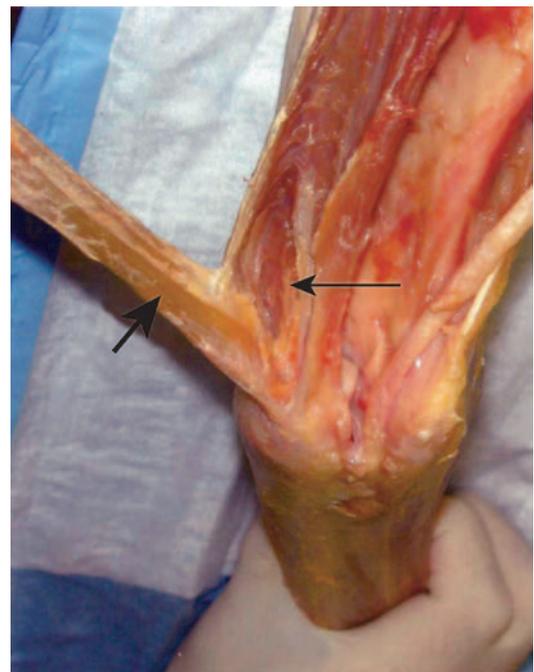

Figure 3. Posterior view of the elbow with the humerus above and the ulna below (ulna held by surgeon's hand). The superficial tendon is dissected free from the specimen (thick black arrow). The deep insertion and medial head are clearly found below the superficial tendon and are muscular at the level of the distal humerus (thin black arrow).

septum. The medial (deep) head arises from the posterior humerus distal to the spiral groove.

The triceps mechanism consists of 2 components, the triceps proper—that portion inserting on the olecranon—and
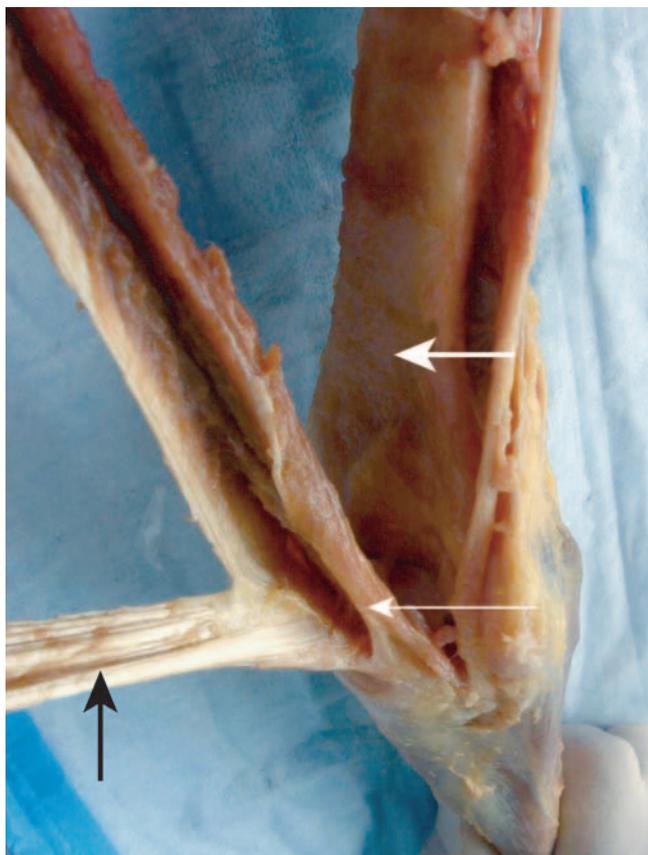
Figure 4. Posterior view of the elbow with the humerus above and the ulna below. The medial head of the triceps and deep insertion are now also dissected free from the humerus. The superficial tendon insertion is illustrated with the black arrow, the medial head and deep insertion with the thin white arrow, and the humerus with the thick white arrow.

the triceps expansion, which inserts on the posterior crest of the ulna medially, the fascia of the extensor carpi ulnaris origin laterally, the antebrachial fascia distally, and the aconeus insertion deeply.[3] Although the triceps proper appears to be able to compensate for injury to the triceps expansion (eg, sacrificing the triceps expansion in the classic intra-articular olecranon osteotomy exposure[9]), the triceps expansion is unable to compensate fully for injury to the triceps proper as in triceps avulsion injuries.[2]

In their study of cadaveric specimens, Gerbeaux et al[4] investigated the lever arm of the triceps muscle. Using the long head of the triceps as their model, they showed that the value of the lever arm of the triceps ranged from a maximum around 0.5 radians (45°) to a minimum for an angle of about 2 radians (180°). This finding suggests that the triceps has its greatest lever arm when the elbow is fully flexed. It is notable that although this experiment fixed the triceps, the scapular insertion of the long head of the triceps provides for another degree of freedom, producing a potentially more dynamic system in vivo.

Although the length of the triceps lever arm would suggest that it would have its greatest strength in flexion, separation

of individual sarcomeric units substantially weakens the triceps when it is stretched.[5] For this reason, the triceps has its greatest power when the elbow is near full extension.[5]

LeBozec et al[7] showed that the mechanical energy of each of the heads is equivalent and that their electromyograms are perfectly correlated. Thus, it can be assumed that the muscle heads change in a proportional fashion. This finding indicates that for a given elbow angle, the activity of any one of the muscles is representative of the activity of the group as a whole. Biomechanically, this factor suggests that the shape of the force-length relationship is the same for each head of the triceps.

The mechanism of injury was likely a direct blow to the area or a forceful eccentric contraction. Weakness after tendon injury is generally noted near the point of maximum shortening of the muscle (ie, the last few degrees of knee extension will be lacking in a partial quadriceps tear, resulting in an extension lag). Patients with triceps tendon tears are generally weak near terminal extension or are unable to actively extend the elbow.[10] In contrast, our patient noted his weakness only when he attempted resisted extension with his elbow flexed past 90° of flexion. This weakness was not demonstrable with the arm in midflexion or near full extension. Such isolated weakness when initiating extension from a position of full flexion is a finding previously unreported in the literature.

As a weight lifter, he had a highly developed musculature and a 300-lb 1-repetition maximum in the bench press. In such a setting, it was remarkable that he had such profound loss of extension strength with the elbow flexed but not in the near-extended position. Isolated repair of the deep insertion of the triceps essentially eliminated his preoperative weakness.

There are 2 possible explanations for the relative weakness in flexion. One possibility is that the medial head has a mechanical advantage with the elbow flexed because it requires a greater degree of flexion to achieve optimum stretch. Our dissections showed that the medial head's origin extends distally as far as the level of the joint capsule. It is possible that as the muscle moves from flexion to extension, the medial head is unable to maintain optimum stretch to provide torque as the elbow nears the extended position.

Another possibility is that the medial head is preferentially activated with the elbow in the flexed position. Previous electromyographic studies have indicated that the 3 heads are activated equally through the range of motion. These studies were limited by small sample size, and some studies have suggested that the medial head might be preferentially activated during unopposed extension.[11] An individual pattern of preferential medial head activation with the elbow in the flexed position might account for this previously unreported presentation.

Given the rare nature of this injury and the inferior results reported with late repair,[2] a high index of suspicion should be maintained when evaluating a patient for this injury. In particular, clinicians should consider evaluating triceps strength with the elbow fully flexed. This type of physical examination maneuver is particularly important for strength athletes who are suspected of having an injury to the triceps tendon.

The anatomy of the deep and superficial triceps tendons must be appreciated in cases in which there is a rupture of only 1 of the 2 tendons. Although only 8 specimens were used, we believe this amount was acceptable in view of the consistency of the findings. In an isolated rupture of the deep tendon, the injury may not be apparent at the initial surgical exposure. The deep tendon from the medial head can be easily exposed by longitudinally dividing the superficial tendon. Magnetic resonance imaging may play an important role in the preoperative evaluation of such patients. This anatomy has not been previously described and has important implications for surgical repair of these injuries.

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