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SCIENTIFIC ARTICLE

Triceps brachii tendon: anatomic-MR imaging study in cadavers with histologic correlation

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Abstract
Objective The purpose of this cadaveric study was to describe the normal MR anatomy of the triceps brachii tendon (TBT) insertion, to correlate the findings with those seen in anatomic sections and histopathologic analysis, and to review triceps tendon injuries.
Materials and methods Twelve cadaveric elbows were used according to institution guidelines. T1-weighted spin-echo MR images were acquired in three planes. Findings on MR imaging were correlated with those derived from anatomic and histologic study.
Results On MR images, the TBT had a bipartite appearance as it inserted on olecranon in all specimens. The insertion of the medial head was deeper than that of the long and lateral heads and was mainly muscular at its insertion, with a small amount of the tendon blending with the muscle distally, necessitating histologic analysis to determine if there was tendon blending with the muscle at the site of insertion and if the medial head inserted together with the common tendon or as a single unit. At histopathologic analysis, the three heads of the triceps tendon had a common insertion on the olecranon. The bipartite aspect of the tendon that was identified in the MR images was not seen by histologic study, indicating that there was a union of the medial and common tendons just before they inserted into bone.
Conclusion TBT has a bipartite appearance on MR images and inserts on olecranon as a single unit.

Keywords Triceps brachii tendon · MRI · Anatomy · Injuries

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Introduction

The triceps brachii muscle is part of the posterior group of the elbow muscles and according to Gray is formed by three heads (long, lateral, and medial), hence, its name. The origin of each head is different and the tendon descends to insert on the upper surface of the olecranon process of the ulna [1].

MR imaging studies of the triceps brachii tendon have raised the hypothesis that the medial head has a distinct and deeper insertion than the common tendon (long and lateral heads) on olecranon. This anatomy may have important implications for the diagnosis and surgical repair of triceps tendon injuries [2]. A more detailed description of the anatomy of the tendinous attachments of the triceps muscle in the olecranon is needed.

The purpose of this cadaveric study was to describe the normal MR anatomy of the triceps brachii tendon insertion, to correlate the findings with those seen in anatomic sections and histopathologic analysis, and to review triceps tendon injuries.

Materials and methods

Cadavers and specimen preparation

Twelve elbows from twelve fresh cadavers (six women and six men; eight right elbows and four left elbows) derived from persons with an advanced age at the time of death (age range at death, 62–96 years; mean age of death, 81 years) were imaged according to institution guidelines. The specimens were taken from arms cut through the proximal portion of the humerus. Frontal and lateral radiographs were performed in all elbows to exclude traumatic or advanced degenerative disorders. None of the specimens had any evidence of surgery to the elbow. The specimens were deep frozen at −40 °C (Forma Bio-Freezer; Forma Scientific, Marietta, Ohio).

MR imaging

All specimens were allowed to thaw for 24 h at room temperature prior to MR imaging. Standard MR imaging studies were obtained by using a 1.5 T unit (GE). A surface flexible coil was employed. The elbow was placed supine in the center of the gantry. Sagittal, coronal, and axial T1-weighted spin-echo MR images (475/12, 2.5 mm section thickness, 0.5 intersection space, 13 × 13 cm field of view, 256 × 224 matrix) were obtained (Figs. 1 and 5).

Anatomic inspection

After imaging, all cadaveric specimens were deep frozen at −40C, in the same position used for MR scanning, for at least 24 h. After that, the specimens were cut with a band saw into 2.5 mm thick sections corresponding to the thickness of the images along one of the imaging planes: sagittal (n=6), coronal (n=3), and axial (n=3). Digital photographs were taken with the specimen thawed (Figs. 2, 3 and 4).

MR imaging–anatomic correlation and analysis

The MR images were correlated with the macroscopic anatomical sections by means of consensus among two musculoskeletal radiologists (C.L.S.P.B., D.P.). On the basis of MR image analysis results, the observers reached a consensus regarding the insertional anatomy of the triceps muscle in the olecranon.

Histopathologic analysis of the triceps brachii tendon

After anatomic inspection, histopathologic analysis of the triceps tendon at the site of its insertion was performed. From twelve specimens, nine selected slices were analyzed at light microscopy by an experienced orthopedic pathologist (P.H.). The characteristics of the triceps tendon were reported.

Results

Imaging–anatomic correlation and analysis

On MR images, the triceps brachii tendon had a bipartite appearance as it inserted in the olecranon in all twelve specimens. The medial head appeared to have a separate insertion from the common tendon (long and lateral heads). The insertion of the medial head was deeper than that of the common tendon and was mainly muscular at its insertion, with a small amount of the tendon blending with the muscle distally.

The muscle of the medial head extended further distally than the muscles of the long and lateral heads, necessitating microscopic sections and histologic analysis to determine if there was tendon blending with the muscle at the site of insertion and if the medial head inserted together with the common tendon or as a separate unit.

The tendinous insertions were best seen in the sagittal plane, and evaluation in the axial plane was difficult.

Histopathologic analysis

At histopathologic analysis, the three heads of the triceps tendon had a common insertion on the olecranon, with no demonstrable division into separate tendons. The bipartite aspect of the tendon that was identified in the MR images was not seen by microscopic study, indicating that there was a union of the medial and common tendons just before they inserted in to bone.

Histologic study showed that only fibrocartilage separated the tendinous fibers from the bone and no demonstrable muscle was found attached to the bone at the insertion site. In six specimens, a small amount of muscle

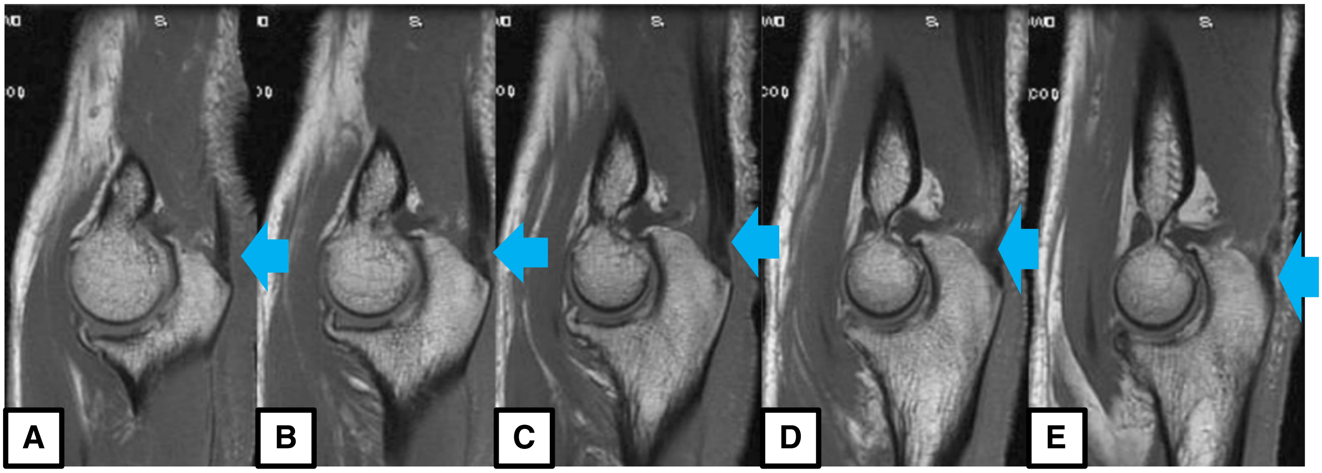

Fig. 1 **a**,**b**,**c**,**d**,**e** Sagittal T1-weighted spin-echo MR images of the elbow demonstrating the triceps brachii tendon and its insertion on olecranon (*arrows*). **a**,**b** medial sagittal cut; **c**–**d** medial–central sagittal cut; **e** central–lateral sagittal cut

(about 5% of the tendon's circumference) was found very close (from 1 mm to 3 mm) to the insertion site of the medial head of the muscle into the bone.

Discussion

The triceps brachii muscle was described by Gray to be formed by three heads (long, lateral, and medial heads). The origin of each head is different: the long head arises by a flattened tendon from the infraglenoid tuberosity of the scapula. The lateral head arises from the posterior surface of the shaft of the humerus, between the insertion of the teres minor muscle and the upper part of the groove for the radial nerve, from the lateral border of the humerus, and from the lateral intermuscular septum. The medial head arises from the posterior surface of the shaft of the humerus, below the groove for the radial nerve [1].

Variations of the triceps brachii muscle are rare. Frabrizio et al. [4] reported a fourth head of the triceps brachii muscle arising from the proximal posteromedial aspect of the humeral shaft, distal to the glenohumeral joint. This head was lying in close proximity to the ulnar groove and the neurovascular bundle, containing the radial nerve and deep brachial artery. This close relationship may be responsible for the snapping elbow and compression of the neurovascular bundle. Tubbs et al. [5] reported an additional attachment site of the medial head. This fourth head originated from the posterior aspect of the surgical neck of the humerus. In our study, none of the cases demonstrated any variation in the origin of the triceps brachii muscle.

Fig. 2 Photograph of the macroscopic sagittal sectioning of the elbow (medial–central cut) demonstrating the insertion of the triceps brachii tendon on olecranon (*arrow*)

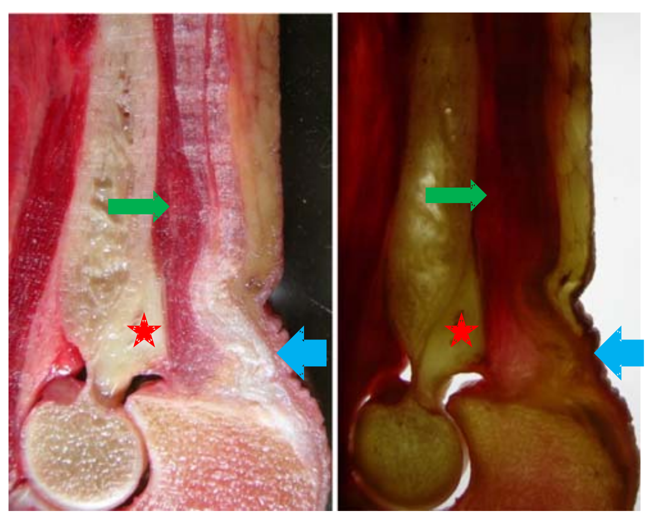

Fig. 3 Photograph of the macroscopic sagittal sectioning of the elbow (medial–central cut) demonstrating the triceps brachii muscle (*green arrows*) and Tendon (*blue arrows*). Posterior fat pad (*red stars*). Different photography techniques of the same sample

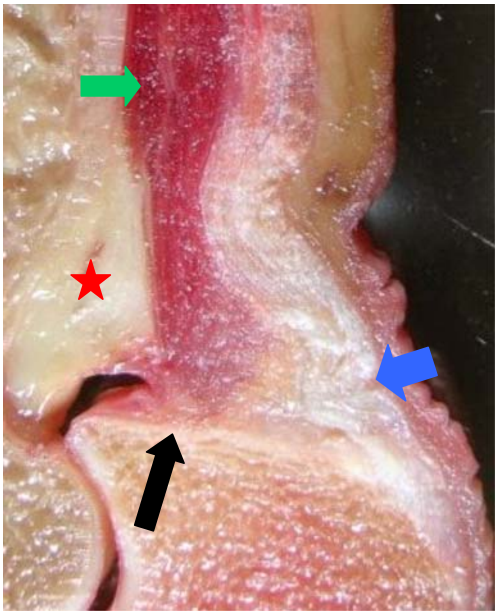

Fig. 4 Photograph of the macroscopic sagittal sectioning of the elbow (medial–central cut) demonstrating the medial head of the triceps (*black arrow*) and its apparently distinct and deeper insertion than the common tendon in the olecranon. Triceps brachii muscle (*green arrow*) and tendon (*blue arrow*). Posterior fat pad (*red star*)

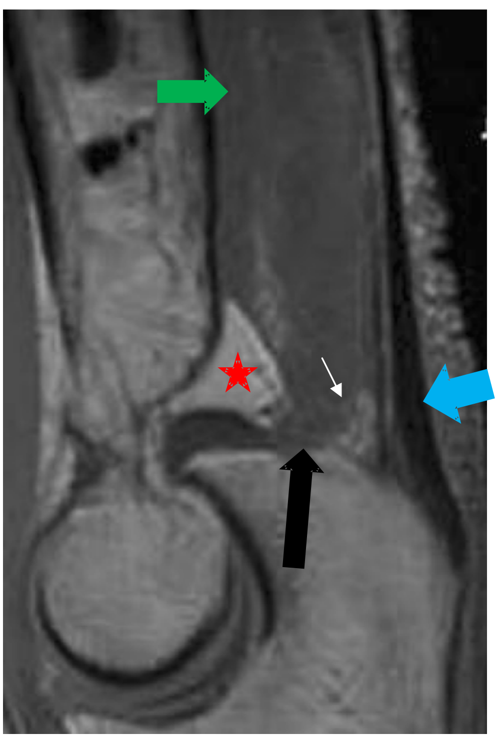

Fig. 5 Sagittal T1-weighted spin-echo MR image of the elbow (medial–central cut) demonstrating the medial head of the triceps (*black arrow*) and its apparently distinct and deeper insertion than the common tendon in the olecranon. Triceps brachii muscle (*green arrow*) and tendon (*blue arrow*). Posterior fat pad (*red star*). Focal fatty atrophy of the muscle (*white arrow*)

The triceps brachii muscle is the major extensor muscle of the forearm, and is the direct antagonist to the biceps brachii and brachialis muscles [1].

The triceps tendon inserts on the upper surface of the olecranon process of the ulna. The triceps tendon expansion inserts on the posterior crest of the ulna medially, fascia of the origin of the extensor carpi ulnaris muscle laterally, the antebrachial fascia distally, and the anconeus muscle deeply [1, 2].

MR imaging and anatomic study performed in our cadavers demonstrated a bipartite appearance (deep and superficial, muscular and tendinous) of the triceps tendon insertion in all specimens. The medial head appeared to have a separate insertion from the common tendon (long and lateral heads).

The insertion of the medial head was deeper than that of the common tendon and was mainly muscular at its insertion, with a small amount of the tendon blending with the muscle distally. The muscle of the medial head extended further distally than the muscles of the long and lateral heads, so the myotendinous junction of the medial head was in the distal third of the triceps, very close to the insertion site on the olecranon.

Although the triceps muscle has a tripartite origin (long, lateral, and medial heads) and a bipartite aspect (deep and superficial, muscular and tendinous) at its insertion when examined by MR imaging, histologic analysis showed that the triceps tendon inserts as a single unit in the olecranon. This observation is in agreement with that in previous studies [2, 6]. A possible explanation for the mismatch between results derived from MR imaging and histology is that the myotendinous junction of the medial head and the union of the medial head and common tendon occur just a few millimeters proximal to the tendinous insertion in the olecranon, a finding confirmed by our microscopic analysis. Also, because our cadaveric specimens were derived from persons who were elderly at the time of death it is possible that focal atrophy of the distal portion of the triceps muscle may lead to a bipartite appearance in T1-weighted MR images (Fig. 5). In young persons without muscular atrophy, the triceps insertion may not show apparent separate insertion for different divisions of the triceps.

The anatomy of the deep and superficial triceps tendons is relevant to clinical MR imaging studies of the injured elbow because deep or superficial ruptures of the tendon alone can occur and lead to weakness of the extensor mechanism. Madsen et al. [2] reported a case of a rupture of the medial head of the triceps insertion alone in a 22-year-old male weightlifter with isolated weakness when initiating elbow extension from a position of full flexion. These investigators emphasized that clinicians should also evaluate triceps muscle strength with the elbow fully flexed, particularly in athletes. De Waal Malefijt et al. [3] also reported a partial tear of the triceps muscle involving only the medial head in a 36-year-old woman with end-stage renal disease who was on corticosteroids. Rupture of the medial head alone has importance for surgical repair because in the presence of an isolated rupture of the deep tendon, the injury may not be apparent at the time of initial surgical exposure. The deep tendon, which is derived from the medial head, can be easily exposed by longitudinally dividing the superficial tendon [2].

Rupture of the triceps tendon is rare. It usually occurs from a direct blow or a deceleration force applied to the arm while the triceps muscle is contracted, usually during a fall on an out-stretched hand. Sports that rely on repetitive elbow extension, such as bowling, pitching, and weightlifting, can also produce triceps tendon disruption [7, 8]. The risk factors also include renal insufficiency, hyperparathyroidism, Marfan's syndrome, osteogenesis imperfecta tarda, olecranon bursitis, local corticoid injection, and systemic anabolic steroid, and corticosteroid use [9–12].

Most tears of the triceps tendon occur at the insertion site of the tendon into the olecranon of the proximal ulna [13, 14]. Intrasubstance tears and tears at the musculotendinous junction have been reported but are rare [15, 16]. Persons with triceps tendon rupture usually present with pain and swelling in the posterior aspect of the elbow. On physical examination, most patients have tenderness over the olecranon process and show significant weakness near terminal extension of the forearm or are unable to actively extend the elbow [9].

MR imaging allows differentiation between partial and complete rupture of the triceps tendon and determination of the amount of retraction of a completely torn tendon. The triceps tendon is best visualized in sagittal MR images. Partial rupture of the triceps tendon is characterized by a small fluid-filled defect within the distal triceps tendon with edema in the surrounding subcutaneous tissue. The central portion of the tendon is generally affected in cases of partial tears. Complete rupture of the triceps tendon is characterized by a large fluid-filled gap between the distal triceps tendon and the olecranon with a large amount of edema in the adjacent subcutaneous tissue. The distal edges of the torn triceps tendon are frayed and have heterogeneous signal intensity. A variable amount of retraction of the distal triceps tendon is usually present [9, 17, 18]. Complete tears are more frequent than partial tears. Children and adults are affected.

Our study had some limitations, including the small number of specimens (twelve) and the advanced age of our specimens which could increase the likelihood of degenerative changes of the tendons, making some details difficult to be seen at MR images. Furthermore, only T1-weighted MR imaging sequences were performed, clinical data were lacking, there was no independent interpretation of the MR images and there was a single pathological specimen reader.

However, we believe that the main goal of this investigation was achieved which was to describe qualitative data about the MR imaging insertional anatomy of the triceps brachii tendon.

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