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Research article

Revisiting the anatomy and biomechanics of the anconeus muscle and its role in elbow stability

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ABSTRACT

Background: Recent studies have designated the anconeus muscle as an option for use as a pedicled flap for covering soft tissue defects about the elbow, with reported minimal risk of morbidity. This has raised the question as to the importance of the anconeus muscle and as to whether this is truly an accessory muscle that can be sacrificed, or whether the anconeus muscle significantly contributes to elbow and forearm stability? This study revisits the anatomy and biomechanics of the anconeus muscle and aims to investigate the neuromuscular compartments of the anconeus muscle and to determine the changes in the muscle length, fibre length and moment arm over a range of elbow flexion angles for each compartment.
Methods: An anatomical study on 8 human cadavers (51–77 years of age) was done and a 2-dimensional kinematic elbow model developed to determine changes in the muscle length and moment arm of the muscle related to changes in elbow flexion angles.
Findings: The muscle was modelled with two possible lines of action, one along the posterior and another on the anterior edge of the muscle as they had different muscle fibre lengths (posterior: average of 32 mm, anterior: average of 20 mm). The anterior edge also had an aponeurosis which was 70% of its length. From 0 to 120° elbow flexion, the length of the posterior and anterior edges increased with a maximum change recorded at 90° elbow flexion (31.7 ± 1.0 mm and 65.3 ± 1.4 mm, respectively). The moment arm is 14-mm at 0° flexion, but between the posterior and anterior edges it decreases at different rates with increasing elbow flexion angle. Beyond 80°, the anterior edge behaves as an elbow flexor, while the posterior edge remains an elbow extensor. The study demonstrates that the anconeus muscle has two neuromuscular compartments each with distinct intramuscular innervations and muscle fibre lengths.
Interpretation: The posterior and deep aspect of the muscle functions as an elbow extensor decreasing in influence with increasing elbow flexion angle. The anterior superficial aspect which is adjacent and parallel to the lateral collateral ligaments, would most likely work in unison to provide constraint to the posterolateral stability of the elbow.

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1. Introduction

The anconeus muscle is usually described as a triangular-shaped skeletal muscle with its origin just posterior to the lateral epicondyle of the humerus, and the muscle fibres fanning out to a broad insertion spanning the posterolateral surface of ulna (Gray et al., 2005; Morrey, 1985; Rosse et al., 1997). Functionally, the anconeus muscle is reported as a weak accessory extensor to the triceps brachii. Some have added that it contributes to the posterolateral stability of the elbow during forearm rotation (Basmajian and De Luca, 1985; Gleason et al., 1985; Morrey and An, 1985; Morrey et al., 1991).

Yet interestingly, recent studies have described the anconeus muscle as an option for a pedicled flap for covering soft tissue defects about the elbow, with reported minimal risk of morbidity (Hwang et al., 2004; Nishida et al., 2009; Schmidt et al., 1999). This indeed raises the question as to the importance of the anconeus muscle. Is it an accessory muscle that can be sacrificed or does the anconeus muscle significantly contribute to elbow and forearm stability?

Although the stability of the elbow and forearm has been well documented, only a few studies have investigated the posterolateral stability at the elbow. Most data show that the lateral collateral ligament complex, comprising of the posterior capsular ligament, the lateral collateral ligaments and the annular ligaments; constrain the elbow, albeit passively (Cohen and Hastings, 1997; Morrey et al., 1991; O'Driscoll et al., 1991; Olsen

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et al., 1998; Takigawa et al., 2005). In the absence or disruption of this complex, the subluxation of the humeroulnar joint has been demonstrated simulating posterolateral instability of the elbow as seen clinically in some reported cases (Hannouche and Begue, 1999; Imatani et al., 1999). Both studies (Hannouche and Begue, 1999; Imatani et al., 1999) further question whether the anconeus muscle would likewise contribute to stabilisation of the elbow to varying degrees dependent on elbow flexion positions. Given that the anconeus muscle has a close anatomical relationship to the lateral collateral ligamentous complex (Molinier et al., 2011) this investigation revisits the anatomy of the anconeus muscle in human cadavers and the contributory role of the anconeus muscle as a possible active lateral stabiliser of the elbow. The study aimed at determining the anatomy and morphology of the neuromuscular compartments of the anconeus muscle and hypothesized that the two neuromuscular compartments have changes in their isometric muscle length, fibre length and respective moment arms over a range of degrees of elbow flexion.

2. Methods

2.1. Anatomy

Eight freshly-frozen human cadaveric upper limbs with no known history of injury or pathology were disarticulated at the glenohumeral joint. Of these, six were right and 2 were left upper limbs. These cadavers, donated for anatomical education and research to the Department of Orthopaedic Surgery, National University of Singapore were from 6 males of Asian descent and a mean age of 65 years-old (range, 51–77). The specimens were thawed for 24-h at room temperature before the dissection of the tissues was done. In all specimens, the skin and soft tissue were first removed exposing the skeletal muscles around the elbow. The various steps of the dissection were photo-documented (Fig. 1). Measurements of the length of the forearm, and the size and orientation of the anconeus muscle in situ were taken, with the elbow at 90° flexion and forearm in neutral. The lateral epicondyle was used as the reference point. The length of the forearm was taken as the length measured from the olecranon to the distal ulnar styloid.

In two upper limb specimens, the anconeus muscle was removed with its peripheral nerve branch to examine the intramuscular innervation and their relationship to the muscle fibres and the tendon-like tissue, using the Sihler's in-toto staining as described previously (Lim et al., 2004; Liu et al., 1997). The purpose was to investigate the neuromuscular compartments within the muscle (English et al., 1993; Weeks and English, 1985).

2.2. Biomechanics

Markers were placed on one specimen, to identify the origin (U) and insertion footprints of the muscle (A, P) on the ulna and for the purpose of developing a 2-D kinematic model to investigate the changes in the length of the muscle (Fig. 2). This model was based on the line of action being either along the posterior or anterior edge of the muscle. Markers were also placed at various bony landmarkers to establish a local 2-D coordinate system for humerus and ulna. The humerus was fixed to a frame, and the forearm was passively flexed from 0 to 120° range of elbow flexion with the forearm in neutral rotation. The origin of the humeral coordinate system was the lateral epicondyle (O), with the longitudinal axis of the humerus taken as the humeral y-axis. The origin of the ulnar coordinate system was at the posterior-end of the footprint insertion of

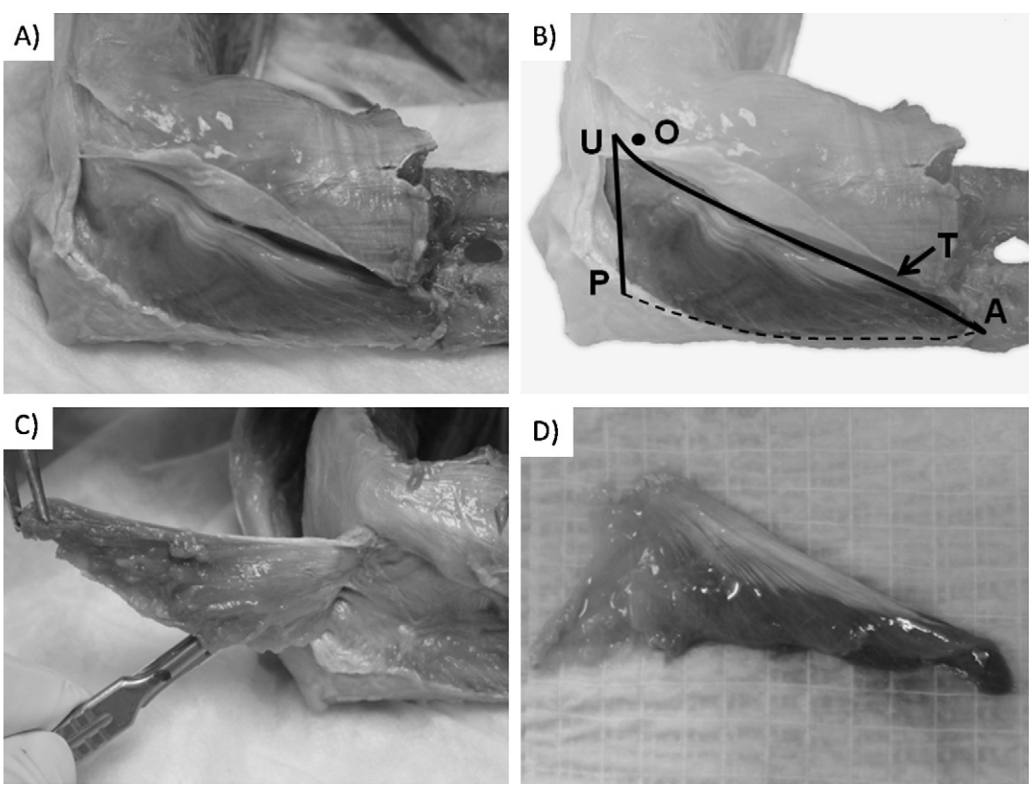

Fig. 1. (A) Dissection of the lateral side of the elbow after removing the skin and surrounding fascia and soft tissue and exposing the anconeus muscle in situ. (B) Isometric measurements of the muscle (*note*: UP – posterior edge, UA – anterior edge, UT – length of the aponeurosis, PA – isometric length of insertion to the posterolateral aspect of the ulna, and the distance between the muscle origin, U, with respect to the lateral epicondyle, O) were recorded with the elbow flexed at 90°). (C) The muscle was subsequently lifted exposing the region deep to the anconeus muscle and (D) released at its origin.

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