Relation of the Radial Nerve to the Anterior Capsule of the Elbow: Anatomy With Correlation to Arthroscopy

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Purpose: To determine the location and proximity of the radial nerve to the anterior capsule and to delineate and describe the anatomy of the brachialis as it relates to the radial nerve and anterior capsule. **Methods:** Arthroscopy was performed on 24 cadavers using only a standard anteromedial portal. A Beath pin was placed laterally, entering the joint at the most lateral edge of the radiocapitellar joint space, and a suture was placed through the pin and into the joint for reference during the dissection. The second phase was to perform open anatomic dissections. **Results:** We found that in all specimens the radial nerve coursed longitudinally medial to the capitellum. The brachialis muscle was found to lie between the radial nerve and the joint capsule at the joint line and all proximal levels. Only at the most distal aspect of the joint line (corresponding to the level of the radial neck) did the nerve run in direct contact with the capsule in 11 specimens (55%). The brachialis muscle thickness was 4 mm or greater at the joint line and at all proximal measurement points. **Conclusions:** We found that the radial nerve is more medially located than previously thought. At the level of the radiocapitellar joint line, the radial nerve runs medial to the capitellum. The brachialis muscle lies between the radial nerve and the joint capsule at the level of the joint line and proximally. **Clinical Relevance:** Arthroscopic capsular release laterally should be performed at the level of the joint line or above. The most dangerous area for capsular resection is distally over the radial head/neck, where 50% of our specimens had no brachialis protecting the nerve.

Advances in elbow arthroscopy have led to the expansion of surgical indications.[1] However, elbow arthroscopy is not without complications, and significant risks exist because of the close proximity of surrounding neurovascular structures. Several previous studies have shown the close proximity of the portals used during elbow arthroscopy to the neurovascular structures.[2-8] Given the significant risk of iatrogenic injury to the neurovascular structures, elbow arthroscopy was not initially indicated for capsular release; however, arthroscopy is now commonly used for this procedure, as well as osteocapsular arthroplasty of the elbow.[9] Few studies have attempted to delineate the relation of the radial nerve and the brachialis muscle to the elbow capsule as it pertains to elbow arthroscopy.[6,10,11] Recently, a study attempted to more clearly define the relation of the anterior capsule to the neurovascular structures. Although the authors were unable to measure the distance between the capsule and the neurovascular structures, they did determine that the radial nerve division occurred distal to the level of the radial neck.[11]

The purpose of this study was to define the relation of the radial nerve to the anterior capsule. When one is performing arthroscopic capsular release, there still remains controversy about where the capsular release

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should begin.[9,11,12] Prior anatomic studies have shown that starting more proximally can be safer in terms of neurovascular structures. In addition, it is clear that the closest neurovascular structure to the anterior joint capsule is the radial nerve; however, the course of the nerve in relation to the capsule has been poorly defined. Knowledge of the relation between the radial nerve and capsule would be useful to define a relative "safe zone" for capsular release. The primary objective of this study was, therefore, to determine the location and proximity of the radial nerve to the anterior capsule. A secondary objective was to delineate and describe the anatomy of the brachialis as it relates to the radial nerve and anterior capsule. Ultimately, our goal was to define a safe zone for arthroscopic anterior capsular excision of the elbow. Our hypothesis was that the radial nerve would be more medially located than previously assumed.

METHODS

Twenty-four fresh-frozen cadaveric upper extremity specimens spanning from the disarticulated glenohumeral joint to the hand were obtained from the department of anatomy at our institution. Four cadaveric arms were excluded because of fluid extravasation during the arthroscopy causing distortion of the anatomy. None of the specimens used in the study had evidence of prior surgery or injury to the elbow. There was also no evidence of significant osteoarthritis or capsular contracture in any elbow studied. The mean age of the cadavers was 75.6 years (range, 51 to 95 years). There were 7 male and 3 female specimens and 10 right and left extremities (matched pairs).

The first phase of the study entailed transfixing the elbow with a 2.5-mm Steinmann pin across the ulnohumeral joint in 90° of flexion. The elbow joint was next insufflated with 15 to 25 mL of normal saline solution at the lateral "soft spot" between the capitellum, radial head, and olecranon until slight resistance was felt. An arthroscopy was then performed by use of only a standard anteromedial portal (no lateral portals were made). This portal was placed 1 to 2 cm anterior and 2 cm proximal to the medial epicondyle. The pump pressure was set to 30 mm Hg. Once the radiocapitellar joint line was visualized, a Beath pin was placed laterally, entering the joint at the most lateral edge of the radiocapitellar joint space. A suture was placed through the pin and into the joint for reference during the dissection. The suture was secured outside the elbow with a clamp to prevent migration during the dissection. The suture represents the most lateral aspect of the joint capsule that can be accessed with the arthroscope in the anterior compartment of the elbow at the level of the radiocapitellar joint line.

The second phase was to perform open anatomic dissections. The elbow was in 90° of flexion (as previously transfixed) and the forearm in neutral rotation with the humerus being stabilized upright in a vertical position. Before dissection, the joint was reinsufflated with 15 to 20 mL of normal saline solution to better define the capsule and to simulate arthroscopic conditions. The skin and subcutaneous fat were dissected from the specimens, exposing the underlying brachial and antebrachial fascia. Dissection was carefully performed over the interval corresponding to the brachialis and brachioradialis by identifying the brachioradialis in the forearm and working proximally. The radial nerve was identified between the brachialis and brachioradialis, and all soft tissues lateral to the radial nerve were removed. The medial and deep surfaces of the radial nerve were not dissected to preserve the relation to the brachialis. The fatty tissue surrounding the nerve was removed on the lateral aspect to allow for accurate measurements to nerve tissue. All the arthroscopic and open dissections were performed in a standardized fashion.

All measurements were performed with a handheld sliding digital caliper (General Tools & Instruments, New York, NY) calibrated to 0.01 mm. Measurements were performed by a single observer. The distance from the radial nerve to a perpendicular line (vertically from proximal to distal) referenced from the previously placed suture at 4 locations was measured: 1 cm distal to the suture, at the joint line, and 1 and 2 cm proximal to the suture. Measurements were then made from the lateral aspect of the nerve to the lateral aspect of the brachialis at the same 4 points (Fig 1). The thickness of the brachialis was also measured at the same 4 points. Once all measurements were obtained, we placed an 18-gauge needle through the radial nerve into the distal humerus, keeping the axis of the needle in line with the forearm (thus keeping the needle perpendicular to the joint surface). This allowed measurement of the location of the nerve relative to the bony architecture.

RESULTS

The results are summarized in Table 1. In all specimens the radial nerve coursed longitudinally medial to the capitellum (Fig 2). The brachialis muscle was found to lie between the radial nerve and the joint capsule at the joint line and all proximal levels (Fig 3).

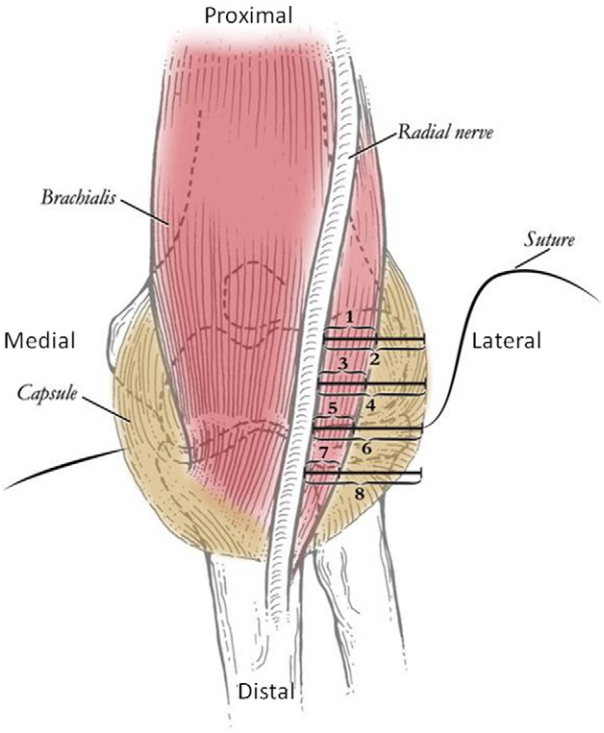

Figure 1. Suture placement and location for measurements. All measurements are based on the location of the suture that represents the most lateral aspect of the capsule that can be visualized arthroscopically. Also shown is how the suture-to-nerve and nerve-to-muscle distances are measured.

Only at the most distal aspect of the joint line (corresponding to the level of the radial neck) did the nerve run in direct contact with the capsule in 11 specimens. The brachialis muscle thickness was 4 mm or greater at the joint line and at all proximal measurement points.

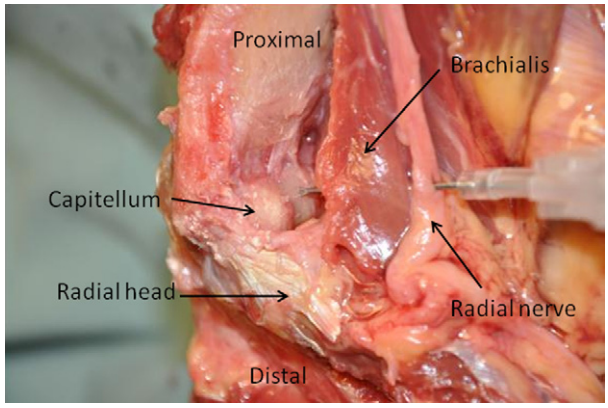

Figure 2. Relation of radial nerve to capitellum. The needle is medial to the capitellum. We found the radial nerve to be medial to the capitellum in all specimens.

At the level of the radiocapitellar joint line, the distance from the lateral-most aspect of the joint (depicted by the suture) to the radial nerve was at least 20.8 mm (Fig 1). Proximally, as well as distally, this distance narrowed, because of the tapered shape of the capsular insertion and the natural flare of the distal humerus, and it was found to be at least 11.6 mm. The nerve-to-capsule distance (referenced form the vertical line) was narrowest 1 cm distal to the joint and was as close as 11.6 mm. In all specimens the radial nerve was located medial to the lateral edge of the brachialis muscle at the level of the joint (mean, 10.4 mm) and 1 cm proximal (mean, 16.3 mm) and 2 cm proximal (mean, 19.0 mm) to the joint line. The mean distance from the lateral edge of the muscle to the nerve decreased to 2.2 mm and at the level 1 cm distal to the joint line, and 10 specimens did not have any brachia-

Table 1. *Results (N = 20)*

	1 cm Distal	At Joint Line	1 cm Proximal	2 cm Proximal
Suture to nerve (Fig 1)	8	6	4	2
Mean ± SD (mm)	23.49 ± 5.16	27.94 ± 2.84	26.80 ± 5.19	25.63 ± 4.99
95% CI (mm)	23.49 ± 2.26	27.94 ± 1.24	26.80 ± 2.27	25.63 ± 2.18
Range (mm)	12.12-36.30	20.83-32.78	11.60-33.85	14.84-33.80
Nerve to lateral edge of muscle (Fig 1)	7	5	3	1
Mean ± SD (mm)	2.15 ± 3.49	10.39 ± 3.59	16.31 ± 6.35	18.97 ± 6.82
95% CI (mm)	2.15 ± 1.53	10.39 ± 1.57	16.31 ± 2.78	18.97 ± 2.99
Range (mm)	0-10.43	3.46-18.10	6.36-28.98	4.62-27.74
Brachialis thickness (Fig 1)				
Mean ± SD (mm)	3.38 ± 5.27	8.06 ± 3.05	5.54 ± 1.62	4.46 ± 1.20
95% CI (mm)	3.38 ± 2.31	8.06 ± 1.34	5.54 ± 0.71	4.46 ± 0.53
Range (mm)	0-18.03	4.04-15.72	4.29-9.10	4.10-8.13

Abbreviation: CI, confidence interval.

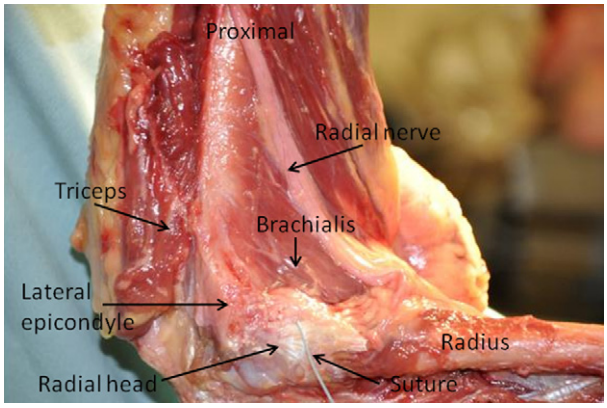

FIGURE 3. The suture was placed arthroscopically and marks the most lateral aspect of the radiocapitellar joint line visualized arthroscopically. The amount of brachialis lateral to the radial nerve should be noted.

lis muscle between the radial nerve and the capsule at this level.

DISCUSSION

This study shows that the radial nerve lies more medial than previously thought. In all specimens the nerve crossed the joint at the medial aspect of the capitellum. The brachialis muscle lies between the radial nerve and the capsule at the level of and proximal to the joint line. The thickness of the brachialis ranged from 0 to 18 mm depending on the location, but a minimum of 4 mm of brachialis was found between the nerve and the capsule in all specimens at the joint line and proximally. However, the radial nerve was separated from the underlying capsule by only adipose tissue in 50% of our specimens at the level of the radial neck (1 cm distal to the joint line).

Our results suggest that during arthroscopic capsular release of the elbow, the radial nerve is relatively protected by the brachialis as long as the capsule is released proximal to the joint line. The only level of the joint that had direct contact between the capsule and the nerve was more distally, near the level of the radial neck. These findings are consistent with other studies that have shown the radial nerve to lie closer to the capsule more distally.[2,3,5,7,9,13] The posterior interosseous nerve (PIN) runs at the level of the radial neck, and any debridement performed at this level can cause damage to the nerve. Damage to the PIN has been reported on at least 4 different occasions in the literature, and in all instances the distal anterolateral portal was used (3 cm distal and 1 cm anterior to the lateral epicondyle).[14-17]

Arthroscopic elbow capsule release was associated with early reports of peripheral nerve injuries, but an improved safety profile was noted over time. Almost all radial nerve complications due to elbow arthroscopy reported in the literature were seen in patients in whom the distal anterolateral portal, originally described by Andrews and Carson[2] (3 cm distal and 1 cm anterior), was used.[4,15-18] In studies where more proximal portals were used, no reported instances of radial nerve palsies were seen.[3] The concept of placing the anterolateral portal more proximal than originally described to avoid the radial nerve was first emphasized by O'Driscoll and Morrey.[9] Since then, several studies have suggested that the radial nerve lies further away from the capsule the more proximal the location.[3,6,9,11] Most anatomic studies have focused on portal-to-nerve distances, and little attention has been paid to nerve-to-capsule relations.[6,10,11]

We were able to better define a lateral safe zone for arthroscopic capsular release/excision. Our specimens showed that approximately 20 mm of lateral capsule can be released before encountering the radial nerve at the level of the radiocapitellar joint. However, proximally, this safe zone can diminish to less than 12 mm, and distally, the nerve can lie directly on the capsule. Furthermore, at the joint line and proximally, the nerve is protected by the brachialis muscle, with a muscle-to-nerve mean width ranging from 10 to 19 mm and a minimal muscle thickness of 4 mm.

Although the radial nerve may lie closer to the joint line than the median or ulnar nerve, the brachialis separates the nerve from the capsule in all specimens. The important concept noted from our data is that the nerve is located further from the capsule proximal to the radial head and that brachialis is present between the nerve and capsule at the level of the joint line and proximally. Furthermore, the radial nerve seems to course longitudinally further medial (just medial to the capitellum) than previously recognized. We therefore recommend starting the capsular release just proximal to the joint line and staying proximal to the radial head. If resection or debridement is necessary near the radial head or neck, extreme caution must be taken not to damage the radial nerve (or PIN), because 50% of our specimens had no brachialis protecting the nerve.

An obvious limitation of the study is that nonarthritic or contracted elbows were used and the distances between the capsule and the nerve in a contracted elbow may be quite shorter. The relation of the radial nerve to the capsule may change with contrac-

ture; however, the relation of the brachialis to the radial nerve should not be changed. Other weaknesses are inherent in the dissection with potential changes of soft-tissue relations during measurements. We did, however, try to limit the motion by transfixing the humerus in 90° of flexion and keeping the forearm in the neutral position. We also positioned all the specimens vertically during the dissection to limit the effects of gravity. It must also be remembered that our dissections were performed with the forearm in neutral rotation, so our measurements could change in pronation and supination. There are several strengths to our study including the large number of specimens used. We also used arthroscopy to locate the region of capsule accessible so that our measurements were useful arthroscopically.

CONCLUSIONS

We found that the radial nerve is more medially located than previously thought. At the level of the radiocapitellar joint line, the radial nerve runs medial to the capitellum. The brachialis muscle lies between the radial nerve and the joint capsule at the level of the joint line and proximally.

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