Arthroscopic localization of the ulnar nerve behind the medial capsule is unreliable

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A R T I C L E   I N F O

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Purpose: Ulnar nerve injury is the most common neurologic complication of elbow arthroscopy. The purpose of this cadaveric study was to quantify the ability of surgeons to locate the ulnar nerve behind the posteromedial capsule during elbow arthroscopy using sole arthroscopic vision.

Methods: Twenty-one surgeons were asked to pin the ulnar nerve at the medial gutter and the posteromedial compartment using arthroscopic visualization of the medial capsule only. Pinning of the ulnar nerve was performed from extra-articular. Then, the cadaveric specimens were dissected and the shortest distances between the pins and ulnar nerve measured.

Results: Median pin-to-nerve distances at the medial gutter and posteromedial compartment were 0 mm (interquartile range [IQR], 0–3 mm) and 2 mm (IQR, 0–6 mm), respectively. The ulnar nerve was pinned by 11/21 surgeons (52%) at the medial gutter, and 7/21 surgeons (33%) at the posteromedial compartment. Three of 21 surgeons (14%) pinned the ulnar nerve at both the medial gutter and the posteromedial compartment. Surgeon’s experience and operation volume did not affect these outcomes (P > .05).

Conclusions: Surgeons’ ability to locate the ulnar nerve behind the posteromedial capsule using sole arthroscopic visualization, without external palpation, is poor. We recommend to proceed carefully when performing arthroscopic procedures in the posteromedial elbow, and identify and mobilize the ulnar nerve prior to any posteromedial capsular procedures.

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No institutional review board approval is required for cadaveric studies at our institution. The cadaveric specimens used in this study were derived from bodies that entered the department of anatomy, University of Utrecht, through a donation program. From these persons written consent was obtained during life that allowed the use of their entire bodies for educational and research purposes. The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Arthroscopic arthroscopy for an expanding range of indications. Cadaveric studies contributed to this gradual rise, because they have improved our understanding of elbow anatomy, leading to safer elbow arthroscopy techniques.1,9,12,28 One of the most common, and potentially devastating, complications during elbow arthroscopy is nerve injury with a reported incidence between 0% and 10%.4,5,7,10,19,21,22,24,25 The most frequently injured nerve around the elbow is the ulnar nerve (38%–42%).5,26

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injury during capsular procedures, as the nerve-to-capsule distance remains the same. Further limiting the safe work zone for surgeons to treat postero- medial elbow pathology is the inability to arthroscopically locate the ulnar nerve and the lack of anatomic references (e.g., medial epicondyle) inside the joint from which the location of the ulnar nerve could be derived.

Knowledge concerning the location of the ulnar nerve behind the medial capsule is essential in order to safely perform arthroscopic postero- medial capsular and bony procedures. Therefore, the purpose of this cadaveric study was to quantify the ability of surgeons to locate the ulnar nerve behind the medial capsule during elbow arthroscopy. The study hypothesis is that the ulnar nerve can be located precisely by at least 75% of surgeons based on arthroscopic visualization only.

Materials and methods

A cadaveric study was performed aiming to quantify the ability of surgeons to locate the ulnar nerve behind the medial capsule using sole arthroscopic vision. Twenty-one fresh-frozen cadaver upper limbs were included. The specimens were evaluated for signs of previous surgery, deformity, extensive scarring, or contracture that could possibly alter the native course of the ulnar nerve. None of the specimens had a (sub)luxating or transposed ulnar nerve. The cadaver arms were mounted onto an arm holder mimicking the lateral decubitus position with the elbow in 90° flexion and the forearm hanging free with only gravity force.

This study was performed after an hour-long arthroscopic training session in order to create an arthroscopic setting that increases the surgeons’ dependency on the use of arthroscopic vision to locate the ulnar nerve. The soft tissue swelling that occurs during elbow arthroscopy limits surgeons’ ability to estimate the course of the ulnar nerve based on external landmarks.

Subsequently, surgeons participating in a Dutch elbow course were recruited and asked to pin the ulnar nerve at 2 locations, the posteromedial compartment and the medial gutter based on arthroscopic visualization of the medial capsule only (Fig. 1). The posteromedial compartment was defined as the joint space between the trochlea, olecranon, and the posteromedial capsule, and the medial gutter was defined as the joint space between the medial border of the trochlea and adjacent medial capsule. Each surgeon was assigned 1 elbow specimen.

First, surgeons navigated into the posterior compartment and established a view of the medial elbow capsule. The posteromedial capsule was to be kept intact at all times. For arthroscopic visualization of the medial capsule, a 30°-angle 4-mm arthroscope was used via either a direct posterior or proximal posterolateral portal, depending on the surgeon’s preference. Surgeons were free to adjust their arthroscope position as they considered this necessary. Posterior viewing portals were already established during the training session by each corresponding surgeon; the direct posterior portal in the midline 3 cm proximal to the olecranon, and the posterolateral portal 2 cm proximal to the olecranon tip, just posterior and superior to the lateral epicondyle (Fig. 1).

Then, each surgeon had 1 attempt to pin the ulnar nerve at the posteromedial compartment and at the medial gutter from outside-in using a 20-gauge needle (Fig. 2). Surgeons were instructed not to palpate the elbow for anatomic references.

After each specimen was pinned twice, all specimens were dissected using a standard open medial approach to expose the cubital tunnel. The ulnar nerve was identified, taking care not to move the pins. The shortest distances between the pins and ulnar nerve at the medial gutter and the posteromedial compartment were measured twice by two independent investigators using a ruler in millimeters. The average of both measurements was used for analysis.

Statistical analysis

Data analysis was performed using Stata, version 14.0 (StataCorp LP, College Station, TX, USA). Continuous variables are reported as mean and standard deviation (SD) or median and interquartile range, depending on the normality of the data. A Shapiro-Wilk test was performed to assess normality of the data. In addition, pin-to-nerve distances were dichotomized to hits (pin-to-nerve distance of 0 mm) and misses (pin-to-nerve distance >0 mm) to provide proportions of hits.

Associations of surgeon’s experience with performing elbow arthroscopy (<5 years of experience; ≥5 years of experience) and operation volume (<10 elbow arthroscopies performed in the past...
12 months; >10 elbow arthroscopies performed in the past 12 months) in relation to the pin-to-nerve distance and proportion of hits were analyzed. Depending on normality of the data, a Student t test or Mann-Whitney U test was used to assess the association for the pin-to-nerve distance. A Fisher exact test was used to assess the associations for the proportion of hits. A P value of <.05 was considered significant.

Twenty-one surgeons were recruited during a Dutch elbow course (Table I). All surgeons were successful in placing both pins. The median distance between the pins and the ulnar nerve was 0 mm (interquartile range, 0-3; range, 0-10) at the medial gutter and 2 mm (interquartile range, 0-6; range, 0-13) at the posteromedial compartment. Eleven of 21 surgeons (52%) hit the ulnar nerve at the medial gutter, and 7 surgeons (33%) hit the ulnar nerve at the posteromedial compartment. Three of 21 surgeons (14%) were able to hit the ulnar nerve at both the medial gutter and the posteromedial compartment (Fig. 3).

No difference was found in the proportions of hits or pin-to-nerve distance at the medial gutter or posteromedial compartment between surgeons with less than 5 years of experience and 5 or more years of experience. Similarly, no difference was found between surgeons who performed fewer than 10 arthroscopies in the past 12 months and 10 or more arthroscopies in the past 12 months (Table II).

No problems were encountered during the pin placement, dissection, or measurements of the pin-to-nerve distances.

**Discussion**

The main finding of this study is that surgeons are not able to locate the ulnar nerve using sole arthroscopic visualization, without external palpation. In a setting simulating an already initiated arthroscopic procedure, surgeons showed poor accuracy in locating the ulnar nerve behind the medial capsule in the medial gutter (11/21, 52%) and in the posteromedial compartment (7/21, 33%). Overall, only 3 of 21 (14%) surgeons located the ulnar nerve at both the medial gutter and the posteromedial compartment (Fig. 3), and pin-to-nerve distances ranged up to 13 mm. Accordingly, our hypothesis that more than 75% of surgeons would be able to locate the ulnar nerve is rejected.

The most frequently injured nerve in the elbow during arthroscopy is the ulnar nerve (38%-42%), with other nerves at risk being the superficial radial (22%-33%), posterior interosseous (8%-19%), median (0%-10%), anterior interosseous (5%-8%), and median (5%-8%), lateral, and posterior antebrachial cutaneous nerves.4,16 The ulnar nerve may be injured from outside-in by direct trauma due to placement of anteromedial or posteromedial portals.3,18 Previous cadaveric studies have shown that joint distension, elbow flexion, and use of proximal instead of distal anteromedial portals increases the nerve-to-portal distance and as such reduce the risk of outside-in ulnar nerve injury.3,18 In addition, based on the external palpability of the ulnar nerve, Sahajpal et al23 and Park et al21 could develop algorithms for safe anteromedial portal placement and thus reducing the risk of extra-articular ulnar nerve injury. Recently, Hilgersom et al13 showed that the ulnar nerve can only be palpated accurately proximal of the medial epicondyle once soft tissue swelling has occurred during elbow arthroscopy, emphasizing the preference for use of a proximal over a distal anteromedial portal during later stages of elbow arthroscopy.

In contrast, no studies have been published investigating measures to reduce the risk of inside-out ulnar nerve injury or strategies to safely perform arthroscopic procedures in the posteromedial compartment. Inside-out injury of the ulnar nerve may occur when using suction or motorized instruments close to the medial capsule as the nerve lies almost directly behind it with an average nerve-to-capsule distance of 0-3 mm.1,7,11,12,18 Standard measures as elbow flexion and joint distension do not reduce the chance of inside-out ulnar nerve injury as the nerve-to-capsule distance remains the same.16 This limits the safe work zone for surgeons to arthroscopically treat posteromedial elbow pathology. In order to investigate the possibilities to safely perform arthroscopic procedures in the posteromedial elbow, this cadaveric study was performed with the purpose to quantify the ability of surgeons to locate the ulnar nerve behind the posteromedial capsule using sole arthroscopic vision.

Protecting the ulnar nerve comes first when performing arthroscopic procedures in the posteromedial elbow. Current results show that surgeons have poor ability to locate the ulnar nerve behind the posteromedial capsule using sole arthroscopic visualization with pin-to-nerve distances up to 13 mm. Based on these results, we advise surgeons to proceed cautiously when performing arthroscopic posteromedial elbow procedures. In bony procedures, such as resecting posteromedial osteophytes, the ulnar nerve can be protected by keeping motorized instruments away from the medial capsule, preferably using hooded instruments facing away from the medial capsule and using retractors to keep the capsule...
away from the instruments.\textsuperscript{14} To safely perform capsular procedures, such as a posterior capsulectomy, it is of utmost importance to know the exact course of the ulnar nerve behind the medial capsule. We recommend to identify and isolate the ulnar nerve prior to any arthroscopic posteromedial capsular procedures, using an open approach.

### Table I

| Surgeon | Expertise | Gender | Age (yr) | Experience (yr) | Number of elbow arthroscopies (past 12 mo) |
|---------|-----------|--------|----------|-----------------|---------------------------------------------|
| 1       | Resident  | Female | 35       | 0.5            | 25                                          |
| 2       | Fellow    | Male   | 35       | 0.8            | 6                                           |
| 3       | Surgeon   | Male   | 51       | 5              | 3                                            |
| 4       | Resident  | Male   | 33       | 1              | 15                                          |
| 5       | Surgeon   | Male   | 40       | 6              | 2                                            |
| 6       | Surgeon   | Male   | 42       | 1              | 40                                          |
| 7       | Surgeon   | Male   | 44       | 10             | 20                                          |
| 8       | Surgeon   | Male   | 39       | 5              | 100                                         |
| 9       | Surgeon   | Male   | 50       | 15             | 10                                          |
| 10      | Surgeon   | Male   | 39       | 3              | 2                                            |
| 11      | Surgeon   | Female | 48       | 16             | 30                                          |
| 12      | Surgeon   | Male   | 41       | 2              | 5                                            |
| 13      | Resident  | Male   | 31       | 0.4            | 0                                            |
| 14      | Surgeon   | Male   | 34       | 1              | 1                                            |
| 15      | Resident  | Female | 31       | 0.5            | 10                                          |
| 16      | Surgeon   | Male   | 39       | 4              | 5                                            |
| 17      | Surgeon   | Male   | 34       | 3              | 3                                            |
| 18      | Fellow    | Male   | 36       | 0.5            | 2                                            |
| 19      | Surgeon   | Male   | 44       | 6              | 120                                         |
| 20      | Surgeon   | Male   | 38       | 3              | 10                                          |
| 21      | Surgeon   | Male   | 38       | 6              | 10                                          |
| Median  |           |        | 39       | 3              | 10                                          |
| Interquartile range | | | 35–42 | 1–6 | 3–20 |
| Range   |           |        | 31–51   | 0.4–16         | 0–120                                       |

**Figure 3** The upper 2 circle diagrams represent the proportions of surgeons who transfixed the ulnar nerve at the medial gutter and posteromedial compartment, respectively. The lower circle diagram shows the proportion of surgeons who transfixed the ulnar nerve at both locations.
This study has several limitations. First, pinning of the ulnar nerve was performed by placing needles using an outside-in technique. It would have been optimal to place these needles from intra-articular, but placing large enough needles with the ability to properly control them inside the joint is difficult. Second, cadaveric specimens are usually stiffer than living patients possibly influencing the course and course variation of the ulnar nerve. However, as this study cannot be performed on live patients without the risk of ulnar nerve damage, cadaveric specimens are the next best option. Third, one can reason that this study would be more realistic if surgeons were allowed to palpate for the ulnar nerve as this is (or should be) standard practice before starting elbow arthroscopy. However, we did not allow participants to palpate for the ulnar nerve as this could easily bias the accuracy of locating the ulnar nerve using arthroscopic visualization only. According to previous research regarding the palpability of the ulnar nerve, it would be easy for the surgeons, although involuntarily, to rely more on their palpation than their arthroscopic visualization when trying to pin the ulnar nerve from outside-in.\(^1\) Last, because no previous studies have used sole arthroscopic vision to locate the ulnar nerve, the sample size of this study was based on previous publications regarding anatomic dissections of peripheral nerves around the elbow. A recent systematic review by Cushing et al.\(^2\) investigating the safety of anteromedial portals with regard to nearby neurovascular structures included successfully conducted cadaveric studies with sample sizes ranging from 5–20 cadaveric specimens. In addition, several other open, arthroscopic, and image-controlled cadaveric studies have been completed successfully using relatively small sample sizes.\(^2,5,12,26\) Based on these experiences, a minimum of five cadaveric specimens was considered as suitable to conduct this study. The number of elbow specimens available at the course determined the sample size to a final number of 21.

The strengths of the current study lay in the readily large number of surgeons and cadaveric upper limbs included. In addition, because of the varying levels of experience among the surgeons, the results may represent a larger group of surgeons. The latter is strengthened by the fact that surgeon’s experience did not influence pin-to-nerve distance or proportion of hits in this study. This study is of clinical importance because we quantified the ability of surgeons to arthroscopically locate the ulnar nerve behind the medial capsule and found it to be poor, thus emphasizing the danger of posteromedial arthroscopic procedures, especially capsular procedures. This corresponds with the current tendency to avoid posteromedial procedures.\(^1\) Our take-home message: the ulnar nerve cannot be accurately located behind the medial capsule using sole arthroscopic vision; therefore, we recommend to proceed carefully when performing arthroscopic procedures in the posteromedial elbow and identify and mobilize the ulnar nerve prior to any posteromedial capsular procedures (Fig. 4).

Conclusions

Surgeons’ ability to locate the ulnar nerve using sole arthroscopic visualization is poor at both the medial gutter (11/21, 52%) and the posteromedial compartment (7/21, 33%). Overall, only 3 of 21 surgeons (14%) were able to locate the ulnar nerve at both the medial gutter and the posteromedial compartment. Therefore, we recommend to proceed carefully when performing arthroscopic procedures in the posteromedial elbow and identify and mobilize the ulnar nerve before any posteromedial capsular procedures.

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References

1. Adolfsson L. Arthroscopy of the elbow joint: a cadaveric study of portal placement. J Shoulder Elbow Surg 1994;3:53–61.
2. Arrigoni P, Cucchi D, Guerra E, Marinelli A, Menon A, Randelli PS, et al. Distance of the posterior interosseous nerve from the radial head during elbow...
arthroscopy: an anatomical study. Joints 2017;5:147–51. https://doi.org/10.1055-s-0037-1605388.
3. Cushing T, Finley Z, O'Brien MJ, Savoie FH 3rd, Myers I, Medvedev G. Safety of anteromedial portals in elbow arthroscopy: a systematic review of cadaveric studies. Arthroscopy 2019;35:2164–72. https://doi.org/10.1016/j.arthro.2019.02.046.
4. Desai MJ, Mithani SK, Lodha SJ, Richard MJ, Leversedge FJ, Ruch DS. Major peripheral nerve injuries after elbow arthroscopy. Arthroscopy 2016;32:999–1002.e8. https://doi.org/10.1016/j.arthro.2015.11.023.
5. Dodson CC, Nio SJ, Williams RJ 3rd, Altchek DW. Elbow arthroscopy. J Am Acad Orthop Surg 2008;16:574–85. https://doi.org/10.1093/jaaos/16.9.574.e1.
6. Dumonski ML, Arciero RA, Mazzocca AD. Ulnar nerve palsy after elbow arthroscopy. Arthroscopy 2006;22:577.e1–3. https://doi.org/10.1016/j.arthro.2005.12.049.
7. Elfeddali R, Schreuder MH, Eygendaal D. Arthroscopic elbow surgery, is it safe? J Shoulder Elbow Surg 2013;22:647–52. https://doi.org/10.1016/j.jse.2013.01.032.
8. Gay DM, Raphael BS, Weiland AJ. Revision arthroscopic contracture release in the elbow resulting in an ulnar nerve transection: a case report. J Bone Joint Surg Am 2010;92:1246–9. https://doi.org/10.2106/JBJS.L00555.
9. Hackl M, Lappen S, Burkhart KJ, Leschinger T, Scala M, Muller LP, et al. Elbow positioning and joint insufflation substantially influence median and radial nerve locations. Clin Orthop Relat Res 2015;473:3627–34. https://doi.org/10.1007/s11999-015-4442-3.
10. Hackl M, Wegmann K, Lappen S, Helf C, Burkhart KJ, Muller LP. The course of the posterior interosseous nerve in relation to the proximal radius: is there a reliable landmark? Injury 2015;46:587–92. https://doi.org/10.1016/j.injury.2015.01.028.
11. Hahn M, Grossman JA. Ulnar nerve laceration as a result of elbow arthroscopy. J Hand Surg Br 1998;23:109.
12. Hilgersom NF, Oh LS, Flipsen M, Eggenaald D, van den Bekerom MP. Tips to avoid nerve injury in elbow arthroscopy. World J Orthop 2017;8:99–106. https://doi.org/10.5312/wjo.v8.i2.99.
13. Hilgersom NFJ, Cucchi D, Luceri F, van den Bekerom MJP, Oh LS, Arrigoni P, et al. Locating the ulnar nerve during elbow arthroscopy using palpation is only accurate proximal to the medial epicondyle. Knee Surg Sports Traumatol Arthrosc 2019;27:3254–60. https://doi.org/10.1007/s00167-018-5108-y.
14. Hilgersom NFJ, van Deuzen DFP, Gerritsma CJE, van der Heide HJJ, Malesey MJAJ, Eggenaald D, et al. Nerve injuries do occur in elbow arthroscopy. Knee Surg Sports Traumatol Arthrosc 2018;26:318–24. https://doi.org/10.1007/s00167-017-4719-z.
15. Jinnah AH, Luo TD, Wiesler ER, Li Z, Poehling GG, Tsuoy C, et al. Peripheral nerve injury after elbow arthroscopy: an analysis of risk factors. Arthroscopy 2018;34:1447–52. https://doi.org/10.1016/j.arthro.2017.12.004.
16. Kelly EW, Morrey BF, O'Driscoll SW. Complications of elbow arthroscopy. J Bone Joint Surg Am 2001;83:25–34. https://doi.org/10.1302/0301-620X.33A11.106.
17. Marti D, Spross C, Jost B. The first 100 elbow arthroscopies of one surgeon: analysis of complications. J Shoulder Elbow Surg 2013;22:567–73. https://doi.org/10.1016/j.jse.2012.12.001.
18. Miller CD, Jobe CM, Wright MH. Neuroanatomy in elbow arthroscopy. J Shoulder Elbow Surg 1995;4:168–74.
19. Nelson GN, Wu T, Galatz LM, Yamaguchi K, Keener JD. Elbow arthroscopy: early complications and associated risk factors. J Shoulder Elbow Surg 2014;23:273–8. https://doi.org/10.1016/j.jse.2013.09.026.
20. Omid R, Hamid N, Keener JD, Galatz LM, Yamaguchi K. Relation of the radial nerve to the anterior capsule of the elbow: anatomy with correlation to arthroscopy. Arthroscopy 2012;28:1800–4. https://doi.org/10.1016/j.arthro.2012.05.896.
21. Park SE, Bachman DR, O'Driscoll SW. The safety of using proximal anteromedial portals in elbow arthroscopy with prior ulnar nerve transposition. Arthroscopy 2016;32:1003–9. https://doi.org/10.1016/j.arthro.2015.12.043.
22. Reddy AS, Kvitne RS, Yocum LA, Elatrache NS, Glousman RE, Jobe FW. Arthroscopy of the elbow: a long-term clinical review. Arthroscopy 2008;16:588–94.
23. Sahajpal DT, Blonna D, O’Driscoll SW. Anteromedial elbow arthroscopy portals in patients with prior ulnar nerve transposition or subluxation. Arthroscopy 2010;26:1045–52. https://doi.org/10.1016/j.arthro.2008.12.029.
24. Savoie FH 3rd. Editorial commentary: Danger zone: the posteromedial elbow: don’t go looking for trouble and it won’t find you! Arthroscopic management of the arthritis elbow. Arthroscopy 2017;33:1512–3. https://doi.org/10.1016/j.arthro.2017.05.003.
25. Schneider T, Hoffstetter I, Fink B, Jerosch J. Long-term results of elbow arthroscopy in 67 patients. Acta Orthop Belg 1994;60:378–83.
26. Thon S, Gold P, Rush I, O’Brien MJ, Savoie FH 3rd. Modified anterolateral portals in elbow arthroscopy: a cadaveric study on safety. Arthroscopy 2017;33:1981–5. https://doi.org/10.1016/j.arthro.2017.06.012.
27. Vavken P, Muller AM, Camathias C. First 50 pediatric and adolescent elbow arthroscopies: analysis of indications and complications. J Pediatr Orthop 2016;36:400–4. https://doi.org/10.1097/BPO.0000000000000461.
28. Yeoh KM, King GJ, Faber KJ, Glazebrook MA, Athwal GS. Evidence-based indications for elbow arthroscopy. Arthroscopy 2012;28:272–82. https://doi.org/10.1016/j.arthro.2011.10.007.