J Shoulder Elbow Surg (2014) 23, 933-937

ELSEVIER

JOURNAL OF SHOULDER AND ELBOW SURGERY

www.elsevier.com/locate/ymse

BASIC SCIENCE

Dynamic analysis of the ulnar nerve in the cubital tunnel using ultrasonography

Kenichi Nakano, MD, Keiichi Murata, MD, PhD, Shohei Omokawa, MD, PhD*, Yasuaki Nakanishi, MD, Takamasa Shimizu, MD, Tsutomu Kira, MD, Tadanobu Onishi, MD, Yasuhito Tanaka, MD, PhD

Department of Orthopaedic Surgery, Nara Medical University, Kashihara, Nara, Japan

Background: We investigated the dynamics of the ulnar nerve during elbow flexion and the relationships between these dynamics and the morphology of the ulnar nerve groove in healthy individuals.
Materials and methods: Twenty healthy volunteers (40 elbows) underwent ultrasonographic examination of the ulnar nerve at the elbow. We measured the breadth and depth of the ulnar nerve groove at 90° of elbow flexion and calculated the depth-to-breadth ratio. We recorded the distance from the trochlea of the humerus to the nerve and the short-axis diameter of the nerve at 30°, 60°, 90°, and 120° of elbow flexion. We calculated the medial shift and flattening of the ulnar nerve at each angle relative to 30° of flexion, compared the values among the different angles, and compared the depth-to-breadth ratio with the location, medial shift, and flattening ratio of the ulnar nerve.
Results: The medial shift was significantly greater at 120° than at other angles ($P < .001$). Flattening increased with increasing elbow flexion and was significantly different at 60°, 90°, and 120° (all $P < .001$). The flattening ratios were significantly correlated with the depth-to-breadth ratio at 120° ($r = -0.43$, $P = .005$).
Conclusions: The ulnar nerve moves medially and is flattened with the elbow flexed between 90° and 120°. When the ulnar nerve groove is shallow, high degrees of elbow flexion result in flattening of the ulnar nerve in the groove.
Level of evidence: Basic Science, Anatomy Study, Imaging.

Keywords: Ultrasonography; ulnar nerve; elbow; groove; dynamics; morphology

Cubital tunnel syndrome refers to entrapment of the ulnar nerve at the elbow and may be caused by various conditions, including compression, friction, and traction of the nerve.[1,6,10,17,19,20,24,26,28] Although it has been proposed that several perineural structures contribute to nerve compression,[10,17,20] the mechanism of onset of idiopathic cubital tunnel syndrome remains unclear.

Previous studies reported that several factors contribute to dislocation or subluxation of the ulnar nerve at the elbow, including absence,[17] hypoplasia,[2,17] or traumatic rupture of the tendinous arch or cubital tunnel retinaculum[7]; hypoplasia of the trochlea of the humerus (TH) or medial epicondyle of the humerus[14,16,25]; and dislocation of the medial head of the triceps brachii, with or without a cubitus varus deformity.[3,22,23] However, these reports were based

This study was approved by the Nara Medical University Institutional Review Board (Approval Number: 583).

*Reprint requests: Shohei Omokawa, MD, PhD, Department of Orthopaedic Surgery, Nara Medical University, 840 Shijo-cho, Kashihara, Nara 634-8522, Japan.

E-mail address: omokawa@naramed-u.ac.jp (S. Omokawa).

1058-2746/$ - see front matter © 2014 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2014.01.039

on qualitative observations of case series and did not consider quantitative factors contributing to nerve instability. Also, we found no studies evaluating the relationships between elbow flexion-related ulnar nerve instability and anatomic variations in the osseous configuration of the ulnar nerve groove.

Several previous studies reported the use of ultrasound to evaluate the dynamics of the ulnar nerve during elbow movement and the morphology of the ulnar nerve in healthy individuals.[4,12,18,19,21] Most studies observed the cross-sectional movement of the ulnar nerve in the cubital tunnel and found that the ulnar nerve moved medially during elbow flexion. A quantitative investigation[18] examining morphologic changes in the ulnar nerve during elbow movement found that flattening of the nerve increased during maximum elbow flexion compared with during extension. Erez et al[4] observed the ulnar nerve in the cubital tunnel of healthy pediatric patients and found a significant correlation between ligamentous laxity and ulnar nerve instability. However, all of the ultrasonographic measurements in adult volunteers were conducted at only 2 elbow flexion angles, and there are no known detailed observations of dynamic changes of the ulnar nerve with multiple degrees of elbow flexion angle. Information is also lacking with respect to the relationship between the shape of the ulnar nerve groove and the dynamics of the ulnar nerve.

We hypothesized that the ulnar nerve shifts medially and flattens in the cubital tunnel in accordance with the degree of elbow flexion and that the extent of the shifting and flattening of the nerve is correlated with the morphology of the ulnar nerve groove (ie, the ulnar nerve is unstable in elbows with a shallow sulcus).

Our purpose was to use ultrasonography to quantitatively measure the morphology of the ulnar nerve groove in normal elbow joints and the medial shift and flattening of the ulnar nerve during elbow flexion. We also examined the relationships between the configuration of the ulnar nerve groove and the dynamics of the ulnar nerve during elbow flexion.

Materials and methods

This prospective cross-sectional study investigated the dynamics of the ulnar nerve in the cubital tunnel using normal volunteers. The inclusion criterion was healthy asymptomatic volunteers aged between 20 and 49 years. We excluded participants with a history of injury, therapy, or surgery to the elbow. Twenty volunteers (10 men, 10 women), who were a mean age of 29 years (range, 21-47 years), met the criteria, and the 40 elbows were examined. We performed all ultrasound studies using a Hitachi HI VISION Avius ultrasound system with a 5- to 13-MHz linear-array transducer (Hitachi Medical Corp, Tokyo, Japan).

A board-certified orthopedic surgeon (K.N.), with more than 2 years of expertise with ultrasound evaluation in orthopedics, conducted all of the ultrasound observations. We placed each volunteer in the lateral recumbent position on an arm table, with the shoulder flexed at 90° and the forearm in neutral rotation. We used a custom-made acrylic board on which a goniometer was installed and placed the board on the arm table, with the upper limb fixed on the board with the elbow in different flexion angles during the ultrasound observation. We placed a probe oriented to maintain a 60° angle with the longitudinal axis of the humerus, and recorded images where the ulnar nerve groove was most clearly visualized. We recorded a single image at 30°, 60°, 90°, and 120° of elbow flexion, with the interposition of a water bag to avoid nerve compression by the probe.

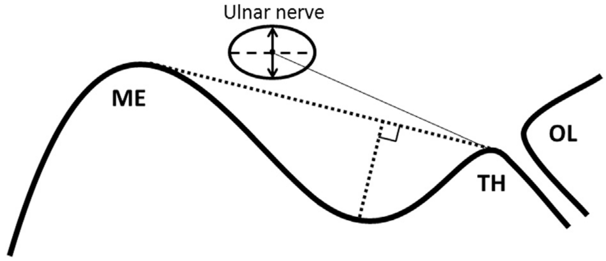

Figure 1 We defined the location of the ulnar nerve as the distance from the medial edge of the trochlea of the humerus (*TH*) to the center of the cross-section of the nerve and defined the short-axis diameter of the ulnar nerve as the shortest diameter of the cross-section of the nerve. We defined the breadth of the ulnar groove as the distance from the medial epicondyle (*ME*) of the humerus to the TH and the depth of the ulnar groove as the distance between a line from the tip of the ME to the medial edge of the TH and a parallel line tangential to the bottom of the ulnar nerve groove. *OL*, olecranon.

We made the following measurements on each recorded image: the location of the ulnar nerve, the short-axis diameter (SAD) of the cross-section of the ulnar nerve, and the breadth and depth of the ulnar nerve groove (Fig. 1). We defined the location of the ulnar nerve as the distance from the medial edge of the TH to the center of the cross-section of the nerve and defined the breadth of the ulnar nerve groove as the distance from the tip of the medial epicondyle to the medial edge of the TH. We defined the depth of the ulnar nerve groove as the distance between 2 lines: a line from the tip of the medial epicondyle to the medial edge of the TH and a parallel line tangential to the bottom of the nerve groove. Using the location of the ulnar nerve at 30° of flexion as the reference, we calculated the medial shift of the ulnar nerve at 60°, 90°, and 120°. Using the SAD at 30° of flexion as the reference, we calculated the flattening ratio (FR) of the ulnar nerve at 60°, 90°, and 120° and calculated the depth-to-breadth ratio (DBR) of the ulnar nerve groove as an indicator of the shape of the groove. A decreased DBR indicates a shallow groove. We then analyzed the relationships between the DBR and the location, medial shift, and FR of the nerve.

Three examiners (1 board-certified orthopedic surgeon and 2 board-certified hand surgeons) randomly assessed the ultrasonographic images of each of the 40 elbows at 90° of flexion. We calculated the interobserver and intraobserver reliabilities for the DBR, location of the ulnar nerve, and SAD. An intraclass correlation coefficient value of 0.00 to 0.20 was considered to represent slight agreement, 0.21 to 0.40 fair agreement, 0.41 to 0.60 moderate agreement, 0.61 to 0.80 substantial agreement, and $\geq$0.81 almost perfect agreement.[13]

We compared the differences in the location of the nerve, medial shift, and FR between groups using 1-way analysis of variance, with post hoc multiple comparisons tested using the Bonferroni test. We used the Spearman correlation analysis to examine the