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

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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.

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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; 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.2,3,22,23 However, these reports were based
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. 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 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 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.

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 ME to the medial edge of the TH and a parallel line tangential to the bottom of the ulnar nerve groove. OL, olecranon.

![Ulnar nerve groove measurement](image)

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.
relationships between the DBR and the dynamic parameters of the ulnar nerve. We set statistical significance at $P < .05$.

### Results

**Dynamic analysis of ulnar nerve**

The dynamics of the ulnar nerve during elbow flexion are summarized in Table I. The location of the nerve at $30^\circ$, $60^\circ$, $90^\circ$, and $120^\circ$ of flexion was $7 \pm 2$, $9 \pm 2$, $10 \pm 3$, and $14 \pm 4$ mm from the TH, respectively. The location of the ulnar nerve was significantly more medial in the cubital tunnel at $120^\circ$ than at $30^\circ$, $60^\circ$, or $90^\circ$ (all $P < .001$) and at $90^\circ$ than at $30^\circ$ ($P < .001$).

The FR of the ulnar nerve at $60^\circ$, $90^\circ$, and $120^\circ$ of flexion was $8\% \pm 9\%$, $19\% \pm 12\%$, and $34\% \pm 11\%$, respectively. The FR was significantly greater at $90^\circ$ of flexion than at $60^\circ$ ($P < .001$) and significantly greater at $120^\circ$ than at $60^\circ$ or $90^\circ$ (all $P < .001$).

The medial shift at $60^\circ$, $90^\circ$, and $120^\circ$ was $2 \pm 1$, $3 \pm 2$, and $7 \pm 4$ mm, respectively. In 4 of the 40 elbows, which were not in the same individuals, the nerve moved over the medial epicondyle and dislocated from the ulnar nerve groove at $120^\circ$ of elbow flexion. The medial shift was significantly greater at $120^\circ$ of flexion than at $60^\circ$ and $90^\circ$ (all $P < .001$), but we found no significant medial shift at $90^\circ$ of flexion.

**Morphologic assessment of the ulnar nerve groove**

The mean ulnar nerve groove breadth was $16$ mm (range, $12-19$ mm), the mean ulnar nerve groove depth was $5$ mm (range, $7-3$ mm), and the mean DBR was $0.32$ (range, $0.22-0.48$).

**Relationships between the DBR and the dynamics of the ulnar nerve**

We found a significant negative correlation between the DBR and the FR at $120^\circ$ of flexion ($r = -0.43$, $P = .005$; Fig. 2), but found no correlation at $60^\circ$ and $90^\circ$ of flexion. We found no significant correlation between the DBR and the nerve location or between the DBR and the medial shift at any of the angles studied.

**Reliability of measurements**

The intraobserver reliability was $0.98$ (almost perfect) for the location of the ulnar nerve and $0.97$ (almost perfect) for the SAD. It was less reliable for the DBR, although at $0.83$, was still considered almost perfect.

### Discussion

Ozturk et al$^{21}$ studied nerve movement in the ulnar nerve groove in asymptomatic individuals using ultrasonography and found dislocation of the ulnar nerve in $8.5\%$ of individuals. Okamoto et al$^{19}$ used ultrasonography to classify medial movement of the ulnar nerve and found dislocation in $20\%$ of asymptomatic individuals. We found dislocation of the ulnar nerve in $4$ of the $40$ elbows, which is comparable to previously reported findings.

Investigators in several previous studies of healthy human volunteers used ultrasonography to measure normal gliding of the nerve trunk during joint motion.$^{5,8,9,27}$ We used ultrasonography to measure transverse movement of the ulnar nerve and found significant medial movement of the nerve within the cubital tunnel between $90^\circ$ and $120^\circ$ of flexion. Therefore, flexion of the elbow greater than $90^\circ$ is likely to result in friction between the nerve and surrounding tissues. Even in healthy individuals, flexion of the elbow of more than $90^\circ$, such as during sports activities, may cause the ulnar nerve to slide excessively in the nerve groove. This translation of the nerve may lead to repetitive strain injury of the nerve and cause friction between the
nerve and surrounding tissues, resulting in neuropathy\textsuperscript{26} or neuritis.\textsuperscript{2}

Gelberman et al\textsuperscript{6} studied morphologic changes in the ulnar nerve in 20 cadaveric elbows and found that elbow flexion caused a decrease in the cross-sectional area of the nerve. Using a pressure transducer, they found that the internal pressure of the ulnar nerve in the cubital tunnel was significantly greater than the external pressure on the ulnar nerve when the elbow was flexed more than 90°. James et al\textsuperscript{11} used 3-dimensional digitization technology to examine morphologic changes of the ulnar nerve during elbow flexion in 11 cadaveric elbows. The cross-sectional area of the cubital tunnel decreased and the nerve was compressed when the elbow was flexed greater than 90°. However, the dynamics of the ulnar nerve may not be the same in vivo as in cadavers. Okamoto et al\textsuperscript{19} used ultrasonography to study 200 elbows of healthy individuals and found that the ulnar nerve was flatter during elbow flexion than during extension. We found that the ulnar nerve flattened gradually during elbow flexion, even in healthy individuals, and that this flattening was significant when the elbow was flexed more than 90°. These findings suggest that deep flexion of the elbow can cause ulnar nerve traction and compression in the cubital tunnel in healthy individuals, leading to flattening of the nerve.

Minami\textsuperscript{15} examined the relationship between the angle of inclination of the ulnar nerve groove and ulnar nerve dislocation in radiographic images of 2800 elbows without arthrosis and found a sharp inclination angle was associated with nerve dislocation.

To the best of our knowledge, no previous studies have quantified the transverse distance of ulnar nerve movement and nerve flattening in relation to the shape of the ulnar nerve groove. We examined the relationship between the shape of the ulnar nerve groove and the ulnar nerve location, medial shift, and flattening according to various angles of elbow flexion. Although we found no correlation between the DBR and the location or medial shift, the DBR was correlated with nerve flattening at 120° of elbow flexion. In healthy individuals, we found that elbows with a shallow ulnar nerve groove had a flattened ulnar nerve at 120° of elbow flexion. Because the ulnar nerve moves medially and is sandwiched between the epicondyle and the cubital tunnel retinaculum in deep elbow flexion, significant flattening of the nerve in a shallower groove may indicate compression of the nerve, suggesting that a shallow groove is a predisposing factor for ulnar nerve compression in deep elbow flexion.

Our study is limited by the small sample size. Despite this limitation and the lack of a power analysis, we have documented several significant findings and have provided additional information related to normal morphology and kinetics of the ulnar nerve using in vivo human volunteers. Further analysis of larger cohorts may reveal age and sex differences in dynamics of the nerve and morphology of the groove.

Another limitation concerns the reliability of ultrasound measurements. Reliability testing showed that intraobserver and interobserver agreements of the measurements were almost perfect. However, the reliability of the measurements for the shape of the ulnar nerve groove was relatively low. This may be because partial volume effects of the ultrasound image affected the reliability of observed osseous configuration, and the measurement results were therefore influenced by variation of each observer.

Finally, because our participants were asymptomatic volunteers, we acknowledge that this study did not measure the pathologic movement of the nerve in cubital tunnel syndrome. To further clarify the pathology of entrapment neuropathy at the elbow, future studies are warranted to analyze the dynamics of the ulnar nerve in individuals with cubital tunnel syndrome compared with findings in healthy individuals.

Conclusions

We used ultrasonography to measure the location, medial shift, and flattening of the ulnar nerve in the groove in healthy individuals. We confirmed significant flattening and medial shift of the ulnar nerve in the cubital tunnel when the elbow was flexed at 120°. Also, a shallower groove was associated with greater flattening of the nerve at 120° of flexion.

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References


