The Medial Epicondyle-Ulnar Nerve Relation With Various Elbow Positions in Healthy Children

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Background: The position of the ulnar nerve relative to the medial epicondyle in healthy children was determined with a high-resolution ultrasonography with elbow flexion, forearm pronation, and supination maneuvers which are commonly employed during reduction of the supracondylar humerus fractures.

Methods: Healthy children aged between 4 and 12 years were enrolled in this study. Both elbows of the children were evaluated with a high-resolution sonography device with gradual flexion of the elbow, whereas the forearm is alternately in pronation and supination. The medial epicondyle-ulnar nerve distance was measured with the various positions of the elbow and the forearm. One-way analysis of variance was used to analyze the differences of medial epicondyle-ulnar nerve distance at different elbow flexion angles and forearm supination-pronation positions. Paried *t* test was used to compare the differences between the age and sex of the children.

Results: Twelve female and 26 male children (76 elbows) with a mean age of 8.36 years were included in the study. Ulnar nerve was translated anteriorly through the medial epicondyle with increasing elbow flexion. The mean medial epicondyle-ulnar nerve distance that was 3.7 mm in an extended elbow decreased to 1.1 mm with full elbow flexion. The difference was statistically significant ($P < 0.0001$). Presence of the forearm in either supination or pronation did not produce a statistically significant difference. The age and sex of the children did not produce a statistically significance difference in medial epicondyle-ulnar nerve distance.

Conclusions: Flexion of the elbow brings the ulnar nerve to a close proximity to the medial epicondyle independent of forearm pronation and supination in healthy children. The decrement of the medial epicondyle-ulnar nerve distance up to 1.1 mm in a fully flexed elbow might be a factor that endangers the nerve during medial pinning in supracondylar humerus fractures.

Level of Evidence: Level I—diagnostic studies.

Key Words: supracondylar fracture, ulnar nerve, medial epicondyle

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Supracondylar fractures of the humerus are one of the most common fractures of the childhood. Closed reduction and percutaneous fixation with a Kirschner (K) wire is a commonly preferred method for the treatment of displaced fractures. Cross pinning, in which 1 pin is inserted at the lateral epicondyle and another at the medial epicondyle is a well-known method and has a proven construct strength. However, iatrogenic ulnar nerve injury, which is due to the close proximity of the nerve to the insertion of the medial pin has been known to occur in 1% to 5% of the patients, is considered to be one of the significant complications of this technique.[1] Closed reduction with fixation by only lateral pins,[2,3] or medial pinning after visualizing of the ulnar nerve through a small incision[3,4] have been advocated to decrease the risk of injury.

Ulnar nerve is located posterior to the medial epicondyle. After passing through the 2 heads of flexor carpi ulnaris, it enters to the flexor compartment of the forearm. Anterior subluxation of the ulnar nerve during reduction maneuvers is one of the proposed rationale for medial pin injury.[5,6] On the basis of clinical examination by palpation on 1000 healthy individuals with 2000 elbows, Childress[7] reported 162 cases (16.2%) of anterior displacement of ulnar nerve with elbow flexion. Zaltz et al[8] performed a similar study on 164 healthy children and reported 33 (10%) ulnar nerve dislocation anteriorly during elbow flexion.

In the past few years, high-resolution ultrasonography of peripheral nerves has increased in importance.[9] By this technology, it is possible to examine the ulnar nerve anatomy and nonossified epiphysis in detail without invasion and radiation.[9–11] In this study, high-resolution ultrasonography was used to evaluate the position of the ulnar nerve relative to the medial epicondyle with elbow flexion, forearm pronation, and forearm supination maneuvers which are commonly employed during reduction of the supracondylar humerus fractures.

PATIENTS AND METHODS

Children admitted to the orthopedic outpatient clinic other than an upper extremity problem aged between 4 and 12 years were enrolled in this study. Children having a history of elbow trauma, congenital skeletal deformity, and upper extremity deformity was excluded.

This study was approved the Institutional Review Board of the Marmara University Hospital.

Examination of the range of motion of the wrists, elbows, and shoulders of all of the children were carried

out by a single orthopedic surgeon (M.B.). Ultrasonographic examination was carried by a radiology specialist having an experience in musculoskeletal sonography using a Mindray model M5 (Shenzen, China), high-resolution ultrasonography device. Sonographic examination was carried while the child is in a supine and comfortable position. The shoulder of the examined limb was placed at 45 degrees of abduction and externally rotated to 90 degrees.[12] Sonographic examination of the ulnar nerve was carried out with the elbow alternately in full pronation and supination while the elbow in extension, 30, 60, 90 degrees, and full flexion. Specially designed angle-adjustment orthotics, with a open medial side, were used for the right and left upper extremity to standardize the elbow position (Fig. 1).

The ulnar nerve was first examined in parallel on longitudinal images identified using the palpable bony landmarks of the cubital tunnel of the extended elbow. The dynamics of the nerve were then assessed on transvers images strictly perpendicular to the axis of the nerve at the cubital tunnel. The distances between the tip of the medial epicondyle and the ulnar nerve (ME-U) of the transverse images where the nerve is closest to the tip of medial epicondyle were marked and measured in the various positions of the elbow. The tip of the medial epicondyle was selected as the reference point as it is clinically easy to palpate, and it is the point where palpation is carried out during the surgery and the medial pin is usually inserted.

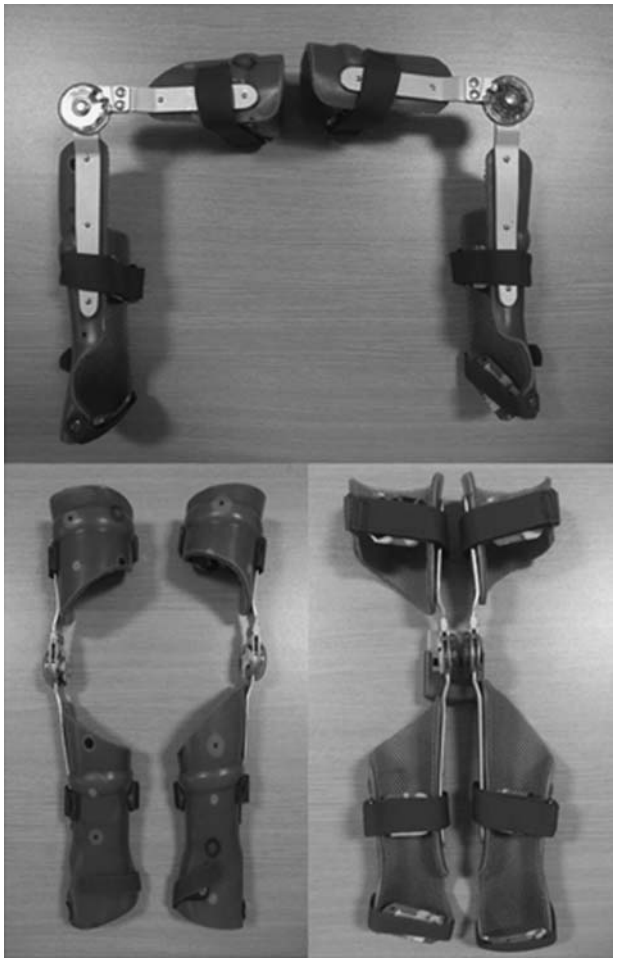

FIGURE 1. Specially designed angle-adjustment orthotics, with a open medial side were used for the right and left upper extremity to standardize the elbow position.

One-way analysis of variance was used to analyze the differences of medial epicondyle-ulnar nerve distance at various elbow positions. Paried t test was used to compare the differences between the age and sex of the children. Student Newman-Kauls multiple comparisons test was used to compare the right and left sides at both supination and pronation with elbow position. Statistical significance was set at $P < 0.0001$.

RESULTS

Twelve female and 26 male children (76 elbows) with a mean age of 8.36 years were included in the study. The right side was dominant in 81.6% and left side was in 18.4%. No ethnic variability was present in the groups.

In all of the cases, when the elbow is in extension, the ulnar nerve was adjacent to the sulcus nervi ulnaris. However, the ulnar nerve was translated anteriorly through the medial epicondyle with increasing elbow flexion (Figs. 2A–E). In only 1 case, the ulnar nerve completely dislocated anterior to the medial epicondyle with full flexion.

When the forearm was in full pronation, the ME-U distance decreased significantly with increasing elbow flexion. While the ME-U distance was 3.7 mm when the elbow was in extension, it decreased to 3.1, 2.7, 2, and 1.1 mm in 30, 60, 90 degrees, and in full flexion, respectively. The statistically significant difference was present with all elbow positions ($P < 0.0001$) (Table 1).

The results were similar when the forearm was in full supination. The ME-U distance was 3.7 mm when the elbow was in extension, it decreased to 3.3, 2.9, 2.2, and 1.2 mm in 30, 60, 90 degrees, and in full flexion, respectively. The statistically significant difference was present with all elbow positions ($P < 0.0001$) (Table 2).

Presence of the forearm in either pronation or supination did not produce a statistically significant difference in ME-U distance with elbow flexion (Fig 3).

The age and sex of the children did not have a correlation with the ME-U distance changes with elbow positions. In addition, there was no statistically significant difference regarding side to side and dominance.

DISCUSSION

Iatrogenic ulnar nerve injury is one of the dreadful complications of percutaneous fixation of the supracondylar humerus fractures in children. The ulnar nerve lies in the cubital tunnel between the medial epicondyle and the olecranon. This position renders the nerve vulnerable during medial pin placement. The proposed causes of iatrogenic ulnar nerve injury have been reported to be direct penetration of the nerve or its sheath by the

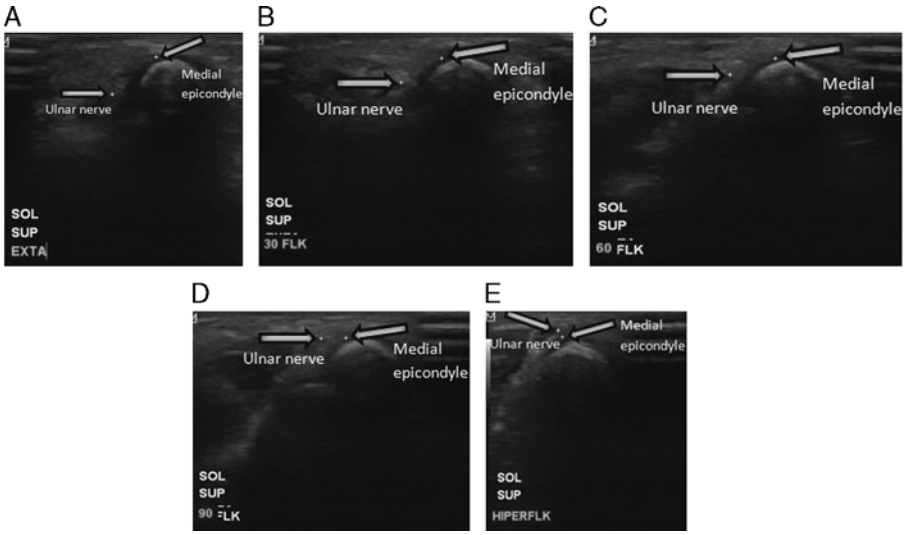

FIGURE 2. A, Ultrasonographic image of the left elbow in supination-extension. The medial epicondyle and the ulnar nerve (ME-U) distance is 5.5 mm. B, Ultrasonographic image of the left elbow in supination—30 degrees of flexion. ME-U distance is 4.7 mm. C, Ultrasonographic image of the left elbow in supination—60 degrees of flexion. ME-U distance is 4.3 mm. D, Ultrasonographic image of the left elbow in supination—90 degrees of flexion. ME-U distance is 2.4 mm. E, Ultrasonographic image of the left elbow in supination—full flexion. ME-U distance is 0.8 mm.

medial pin, iatrogenic constriction of the cubital tunnel by the medial pin while the elbow in flexion, medial pin injury to an unstable ulnar nerve which subluxates or dislocates anteriorly when the elbow is in flexion.[3,5,6,13–16]

The dynamics of the ulnar nerve in conjunction with elbow flexion takes a special consideration in the literature as a leading cause of iatrogenic ulnar nerve injury. In adults, by palpation, Childress[17] reported 16% anterior subluxation and dislocation of the ulnar nerve and similarly Astenhurst[18] found 22% hypermobility of the ulnar nerve in adults. By clinical examination, Zaltz et al[6] found 97% of ulnar nerve instability in children having a ligamentous laxity which was proposed as a risk factor for the injury of ulnar nerve with medial pinning in hyperflexion. Ozcelik et al[13] reported 18 cases of iatrogenic ulnar nerve injury in 90 supracondylar humerus fractures where cross pinning was performed in elbow hyperflexion. Eidelman et al[19] reported no ulnar nerve complication by reducing and fixing the fracture through lateral pinning first in hyperflexion, than when inserted in the medial wire from the medial epicondyle when the elbow was fully extended. Although the mentioned studies proposed the ulnar nerve mobility with elbow flexion as a rationale for iatrogenic ulnar nerve injury, they are ineffectual to establish an objective relation.

Closed reduction of the extension type of the supracondylar fracture is performed with flexion of the elbow up to full flexion for the maximum amount of stability. Besides full flexion of the elbow, supination and pronation of the forearm are the 2 maneuvers that are used for fracture reduction. The direction of displacement of the distal fracture fragment determines the position of the forearm. The forearm is held in pronation for posteromedial fractures and supination for posterolateral fractures.[20,21] To be informed about the position of the ulnar nerve in the cubital tunnel with the aforementioned reduction maneuvers is crucial to prevent an iatrogenic nerve injury during medial pinning.

In the current study, the position of the ulnar nerve relative to the medial epicondyle was determined with various positions of the elbow and forearm that simulated the reduction maneuvers. The ME-U distance was found to decrease with increasing amount of elbow flexion. The alteration in the ME-U distance was independent of forearm pronation and supination. However, our findings with the decrement of ME-U distance with elbow flexion is consistent

TABLE 1. ME-U Distances According to the Flexion Degrees in Full Pronation (the Distances are Described in Millimeters)

Groups	No. Elbows	Mean Value	SD	Median
Extension	76	3.78	0.1187	3.80
30-degree flexion	76	3.15	0.1041	3.20
60-degree flexion	76	2.68	0.1031	2.80
90-degree flexion	76	1.93	0.0935	1.75
Full flexion	76	1.16	0.0682	1.00

ME-U indicates medial epicondyle and the ulnar nerve.

TABLE 2. ME-U Distances According to the Flexion Degrees in Full Supination (the Distances are Described in Millimeters)

Groups	No. Elbows	Mean Value	SD	Median
Extension	76	3.76	0.1319	4.00
30-degree flexion	76	3.32	0.1153	3.50
60-degree flexion	76	2.93	0.1031	3.05
90-degree flexion	76	2.22	0.1059	2.20
Full flexion	76	1.24	0.0765	1.00

ME-U indicates medial epicondyle and the ulnar nerve.

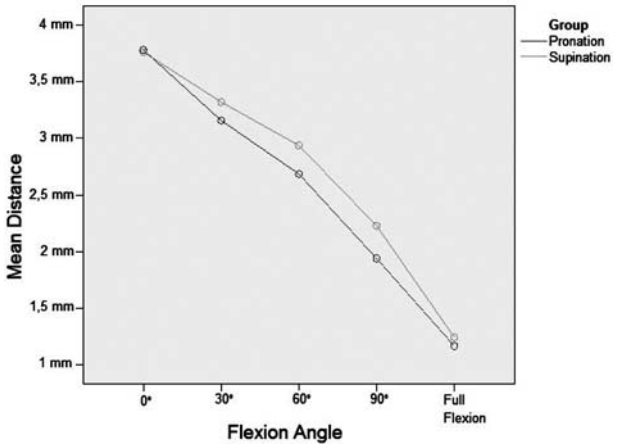

FIGURE 3. Comparison of the mean medial epicondyle and the ulnar nerve (ME-U) distances in pronation and supination with elbow flexion angles.

with Shen et al,[12] whose study lacked the effect of forearm pronation and supination on the distance. Although supination and pronation of the forearm did not produce a significant effect on ME-U distance in the current study, this finding is important as forearm pronation and supination are the other crucial maneuvers besides elbow flexion that might have effected the position of the ulnar nerve.

The gradual decrease in ME-U distance with elbow flexion eventually reached up to 1.1 mm in 120 degrees of elbow flexion. The approximation of the ulnar nerve to the medial epicondyle to such extent in 120 degrees of flexion endangers the nerve during medial pinning through the tip of medial epicondyle. However, considering the diameter of the K-wire used for pinning which is usually 1.8 to 2.0 mm, it can be considered that not only 120 degrees of flexion, but also 90 degrees of elbow flexion that decreased the ME-U distance up to 2.0 mm would threaten the ulnar nerve while medial pinning thorough the tip of medial epicondyle. This is compatible with Kuo and Widmann[20] who in clinical practice advised medial fixation when the elbow is at 50 to 70 degrees of flexion to prevent ulnar nerve injury.

In conclusion, flexion of the elbow brings the ulnar nerve to a close proximity to the medial epicondyle independent of forearm pronation and supination in children aged between 4 and 12 years. Sonography permits dynamic observation of the ulnar nerve. The nerve can be intraoperatively localized accurately with sonography before introduction of the medial pin to prevent injury. However, clinical studies are required to verify the accuracy of the sonography in a fractured elbow.

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