ORIGINAL ARTICLE

Acta Orthop Traumatol Turc 2012;46(4):243-249
doi:10.3944/AOTT.2012.2836

Subcutaneous anterior transposition of the ulnar nerve in cubital tunnel syndrome

Nevzat Selim GÖKAY[1], A. Erdem BAGATUR[2]

[1]Department of Orthopedics and Traumatology, Faculty of Medicine, Namık Kemal University, Tekirdağ, Turkey;
[2]Department of Orthopedics and Traumatology, Medicana International İstanbul Hospital, İstanbul, Turkey

Objective: The aim of this study was to present the mid- to long-term results of subcutaneous anterior transposition of the ulnar nerve in the treatment of cubital tunnel syndrome.

Methods: The study retrospectively evaluated 33 patients (24 males, 9 females; mean age: 48 years; range: 26 to 59 years) who underwent subcutaneous transposition of the ulnar nerve. Mean follow-up period was 4 years 9 months (range: 2 years 6 months to 8 years). Modified McGowan's classification was used for preoperative scoring and the Wilson & Krout classification for postoperative clinical evaluation. Preoperatively 5 patients (15%) had Grade 1, 7 (21%) had Grade 2A, 9 (27%) had Grade 2B, and 12 (36%) had Grade 3 neuropathy.

Results: There were excellent results in 24 patients (73%), good in 7 (21%), fair in 1 (3%), and poor in one (3%). The patient with the poor result had developed neuropathy following a crush injury. There was a negative correlation between the preoperative McGowan grade and the postoperative Wilson & Krout score ($p<0.05$, $r=-0.43$). The success rate of the operation was significantly lower in patient groups as the time from symptom onset increased ($p<0.05$). There were no complications.

Conclusion: Subcutaneous anterior transposition of the ulnar nerve is an effective and reliable surgical method with a low complication rate for the treatment of cubital tunnel syndrome.

Key words: Anterior transposition; cubital tunnel syndrome; neuropathy; ulnar nerve.

Ulnar nerve entrapment at the elbow, known as cubital tunnel syndrome, is the second most frequent entrapment neuropathy following carpal tunnel syndrome.[1-5] Initially identified in 1878, the term 'cubital tunnel syndrome' was first used in 1958.[6] Despite the presence of bone problems (osteophytes, post-fracture cubitus valgus), soft tissue masses (ganglion, tumor), posttraumatic strictures of fascial structures and subluxation of the ulnar nerve on the medial epicondyle in some patients, no certain etiology can be determined in most of the cases and it is thus evaluated as idiopathic.[3,7] In most cases, the ulnar nerve is compressed by the Osborne's ligament at the immediate distal end of the medial epicondyle, between the fasciae of the humeral and ulnar heads of the flexor carpi ulnaris muscle.

Numbness in the ulnar nerve distribution is the most common finding in patients with cubital tunnel syndrome. Patients often report pain at the medial aspect of the elbow which radiates into the proximal forearm and

Correspondence: Nevzat Selim Gökay, MD. Bülbül Cad. Badem:13, Villa:1 No:59, 34538, Bahçeşehir, İstanbul, Turkey.
Tel: +90 212 - 669 52 80 e-mail: nevzatselim@yahoo.com

Submitted: February 10, 2012 **Accepted:** June 25, 2011

Available online at
www.aott.org.tr
doi:10.3944/AOTT.2012.2836
QR (Quick Response) Code:

behind the medial epicondyle, as well as weakness of intrinsic muscles and grip strength. In severe and prolonged instances, significant atrophy of the intrinsic musculature, especially the first dorsal interosseous muscle, may also occur.[7] The initial treatment of acute and subacute entrapment neuropathy is conservative. Rest and avoidance of elbow flexion and pressure on the nerve are usually sufficient; however, brace immobilization can be useful if symptoms persist. Surgical decompression of the ulnar nerve is indicated when nonoperative methods fail to relieve these symptoms and neurosensory and motor tests document progressive ulnar nerve dysfunction or a degree of nerve compression resulting in axonal loss.[1,8] Surgical treatment options are simple decompression (open or endoscopic), medial epicondylectomy with simple decompression, and anterior transposition (subcutaneous, intramuscular, submuscular). However, the selection of a surgical technique remains controversial. Subcutaneous anterior transposition of the ulnar nerve is a common surgical treatment with a relatively simple technique and high success and low complication rates.[1,5]

In this study, we retrospectively reviewed mid- and long-term results of patients with cubital tunnel syndrome who underwent subcutaneous anterior transposition of the ulnar nerve.

Patients and methods

Forty-six consecutive patients with cubital tunnel syndrome who underwent subcutaneous anterior transposition of the ulnar nerve were evaluated retrospectively. Nine patients with concomitant cervical radiculopathy, carpal tunnel syndrome, alcohol abuse, hypothyroidism, or chronic renal failure were excluded and four patients were lost to follow-up. The study included 33 patients (24 males, 9 females; mean age: 48 years; range: 26 to 59 years). The right side was involved in 21 patients and the left in 12. All operations were performed by a single surgeon.

The clinical diagnosis of cubital tunnel syndrome was based on history and physical examination findings and confirmed with electrodiagnostic test results. Sensory loss and numbness in the ulnar nerve distribution of the hand, especially the ulnar half of the ring finger and little finger, medial elbow pain, loss of fine motor skills, weakness of intrinsic muscles of the hand and grip strength, in particular atrophy of the first dorsal interosseous muscle, a positive Tinel's sign at the elbow, a positive elbow flexion test, and two-point discrimination were taken into consideration.

Electrodiagnostic tests included nerve conduction studies and needle EMG. A motor conduction velocity (MCV) of less than 47 m/s and a sensory conduction velocity (SCV) of less than 54 m/s were accepted as abnormal. Pathological findings on EMG included fibrillation activity, decreased recruitment, and abnormalities in the configuration of the motor unit action potential.[9]

All patients had conservative treatment for a minimum of 3 months before surgery. The mean period from the onset of symptoms to surgery was 11 (range: 6 to 36) months. Elbow radiographs were performed to rule out additional bone pathologies. Etiology was idiopathic in all patients with the exception of two in whom cubital tunnel syndrome was secondary to former trauma (cubitus valgus deformity due to a lateral condyle pseudarthrosis of the humerus and a crush injury of the elbow). The patient with the crush injury previously underwent two surgeries and ulnar nerve decompression without transposition.

Patients were classified into four grades according to the modified McGowan classification (Table 1).[10] Preoperatively, the mean value of MCV at the elbow segment was 35±9 m/s. The MCV at the forearm were within normal limits. EMG results were abnormal in 20 patients.

Three of the patients were operated under axillary block anesthesia, 12 under regional intravenous anesthesia and 18 under general anesthesia, all with pneumatic tourniquet hemostasis. Careful dissection was carried out to protect the medial antebrachial cutaneous nerve and the vascular structures of the ulnar nerve while releasing and transposing the nerve (Fig. 1). The medial intermuscular septum was resected in all patients. The nerve was lifted from its bed and transposed anterior to

Table 1. Modified McGowan classification[10] for preoperative grading of ulnar neuropathy at the elbow.

Grade	Description	No. of patients
1	Patients with subjective sensory symptoms, but without objective findings	5
2A	Patients with good intrinsic strength (4/5), without intrinsic atrophy	7
2B	Patients with fair intrinsic strength (3/5), with intrinsic atrophy	9
3	Patients with marked intrinsic atrophy and sensory disturbance	12

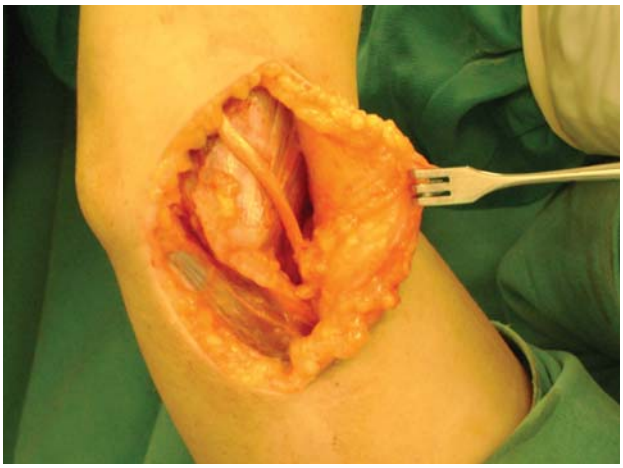

Fig. 1. Release and anterior transposition of the ulnar nerve. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

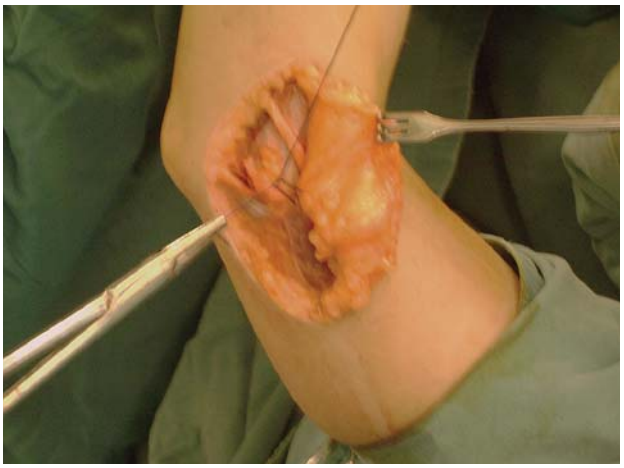

Fig. 2. Subcutaneous tissue is sutured to the medial epicondyle to prevent the nerve from returning to its groove. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

the medial epicondyle. A sling of subcutaneous tissue sutured to the fascia over the medial epicondyle was created to prevent the nerve from returning to its groove (Fig. 2). Apparent scarring of the nerve and adherence to surrounding tissues was observed in the patient with the crush injury. No subluxation of the ulnar nerve was present in any patient. The elbow was not immobilized postoperatively and immediate active range of motion exercises were encouraged to allow excursion of the ulnar nerve and prevent fibrosis in the surgical bed. No complications were observed.

Results were evaluated with the modified Wilson & Krout criteria (Table 2).[11] Spearman and chi-square tests were used in the statistical evaluation of the data. P values of less than 0.05 were considered statistically significant.

Results

The postoperative mean follow-up was 4 years 9 months (range: 2 years 6 months to 8 years). There were no early or late complications or recurrences.

Symptomatic improvement was obtained in all patients except one. Results based on the Wilson & Krout classification were excellent in 24 patients (73%), good in 7 (21%), fair in 1 (3%), and poor in 1 (3%) (Table 3). Only 2 (6%) of the patients had fair and poor results and both had a postoperative modified McGowan score of Grade 3. The patient with the poor result was the one who had undergone two previous surgeries due to neuropathy developed after a crush injury.

There was a negative correlation between the preoperative McGowan grade and the postoperative Wilson & Krout score ($p<0.05$, $r=-0.43$) (Table 3). The success rate of the operation was significantly lower in patient groups as the time from symptom onset increased ($p<0.05$) (Table 4).

Discussion

Ulnar nerve entrapment at the elbow, the cubital tunnel syndrome, is increasingly recognized as a source of upper-extremity sensory and motor symptoms. The treatment for nerve compression is the decompression of the nerve. No consensus exists in the literature regarding the optimal surgical treatment for cubital tunnel syndrome.[7,12-15] Surgical treatment options

Table 2. Modified Wilson & Krout criteria[11] for postoperative grading of ulnar neuropathy patients.

Grade	Description
Excellent	Minimal motor and sensory changes and no tenderness at the incision site
Good	Loss of symptoms but a regional sensitivity continued at intervals
Fair	Improved but persistent sensory or motor changes that are milder than the preoperative status
Poor	No improvement or worsened condition

Table 3. Statistical comparison of the clinical results according to the preoperative scorings of the patients.

Wilson & Krout evaluation	Preoperative McGowan grade				Total
	1	2A	2B	3	
Excellent	5	6	7	6	24
Good		1	2	4	7
Fair				1	1
Poor				1	1

p=0.01, r=-0.43

include open and endoscopic simple decompression, decompression with medial epicondylectomy and anterior transposition of the nerve (subcutaneous, intramuscular or submuscular).[1,5,13,15,16]

In simple decompression, all tissues constricting the ulnar nerve, mainly the Osborne's ligament, are released; however, the nerve is not separated from its bed in the bone tunnel. In medial epicondylectomy, in addition to simple decompression, the bone tunnel is expanded by removing a fragment of the bone from the medial epicondyle and thus the compression on the ulnar nerve is relieved. This procedure may result in more complications than simple decompression.[17]

The extrinsic pressure on the nerve can be removed through both of these methods, but the intraneural pressure remains unchanged. The basic idea behind ulnar nerve transposition is relieving the intraneural intrinsic pressure which occurs with the traction of the nerve during elbow flexion.[18] The ulnar nerve is subject to traction, friction and pressure with normal elbow motion. The cubital tunnel narrows during elbow flexion as Osborne's ligament stretches and the medial collateral ligament bulges beneath the nerve.[6,19] The cross-sectional oval shape of the cubital tunnel changes to a flattened ellipse during elbow flexion.[20] As the elbow is flexed, the cubital tunnel volume decreases by 55%, pressure within the tunnel increases sevenfold and rises to more than twentyfold when contraction of the flexor carpi ulnaris muscle is added.[21] With the elbow flexed 130 degrees, the intraneural pressure is 45% greater than the extraneural pressure within the tunnel and 63% greater than the extraneural pressure 4 cm proximal to the tunnel.[22,23]

The ulnar nerve moves and stretches during elbow movements. While normal excursion of the ulnar nerve is 16 mm around the elbow, it increases to 22 mm with the combined motion of the wrist, fingers, elbow, and shoulder.[24] The ulnar nerve elongates 4.7 mm with elbow flexion, increasing to 8 mm with abduction and external rotation of the shoulder. An average strain of 29% occurs with elbow flexion.[25] Strain may be a factor associated with a tension neuropathy, which in turn may lead to the development of cubital tunnel syndrome.

We believe that cubital tunnel syndrome should be handled as a traction neuropathy as well as a compression neuropathy. As in one of our cases, cubital tunnel syndrome occurring secondary to cubitus valgus, that is tardy ulnar nerve palsy, is a very good example for this traction type of neuropathy. With this perspective, it is obvious that simple decompression of the ulnar nerve or decompression with medial epicondylectomy will not provide complete and permanent relief, especially in severe cases.

Anterior transposition of the ulnar nerve, which relaxes the traction and strain on the nerve that leads to increased intraneural pressure with elbow flexion, will serve to treat the etiology. Simple decompression and decompression with medial epicondylectomy reduces

Table 4. Statistical comparison of the clinical results according to the symptom duration.

Wilson & Krout evaluation	Duration of the symptoms (months)			Total
	≤6	6 - 12	≥12	
Excellent	4	16	4	24
Good		1	6	7
Fair			1	1
Poor			1	1

p<0.05

the extrinsic pressure on the nerve, but does not change the traction effect. It is shown that simple decompression does not prevent the traction forces occurring on the nerve with elbow flexion.[26] Moreover, statistically significant instability of the ulnar nerve was found after simple decompression.[27,28]

Numerous comparison studies have been made to investigate the most appropriate technique in the surgical treatment of cubital tunnel syndrome and technical selection according to preoperative classification and clinical findings. Most of these studies used the classification system defined by McGowan[29] in 1950 which is based predominantly on the loss of motor function and does not include sensory changes. However, the majority of patients have mainly sensory complaints and motor function impairment occurs in advanced phases. McGowan's classification system was modified by Goldberg et al.[10] in 1989 and included sensory deficits as well as motor function impairment.

Although a literature review on the surgical treatment of cubital tunnel syndrome does not show a single procedure to be superior, there usually is a bias on patient selection. The use of the old version of the McGowan's classification system may also be misleading. While patients with mild to moderate symptoms with a short duration usually undergo simple decompression, patients with severe symptoms with a long duration usually undergo anterior transposition, with favorable results in both groups. In our series, the success of the operation in patients who had symptoms of a duration of less than 6 months was statistically higher than the others ($p<0.05$), which implies that the longer the onset of symptoms, the less the success of surgery (Table 4). Dellon[27] reported that patients with minimal nerve compression obtained excellent results with any surgical procedure. Simple decompression, however, was rarely successful in patients with moderate compression. The efficiency of in situ decompression and partial epicondylectomy were reported to be similar while anterior subcutaneous transposition lacked the efficiency of the other two methods.[7] However, the authors also stated that unequal distribution of the patients according to preoperative grading scale limited the solidity of their results, and anterior subcutaneous transposition proved to have comparable outcomes to partial epicondylectomy in severe cases. In a study by Hahn et al.,[13] in which the groups had a similar duration of symptoms, the clinical results of the ulnar nerve decompression with minimal medial epicondylectomy and anterior subcutaneous transposition of the ulnar nerve were similar in spite of the preoperative Dellon's grade at the final follow-up. However, they stated that there were statistical differences between the two groups in terms of the incision length and procedure-related morbidities in favor of the epicondylectomy group.

Mandelli and Baiguini[30] defined an algorithm based on biological properties (nerve morphology and amount of scar tissue around medial epicondyle), preoperative McGowan grade, and clinical parameters for the surgical treatment of cubital tunnel syndrome and attempted to define the most appropriate surgical technique for every patient. They treated 44 patients classified according to this algorithm with modified simple decompression, subcutaneous, and submuscular transposition and obtained successful results. The algorithm seems to be useful, although the number of patients was insufficient to draw a conclusion and the abovementioned disadvantages of simple decompression could not be eliminated even in mild cases.

Subcutaneous anterior transposition of the ulnar nerve is frequently performed as it is a simple procedure with a high success rate and very few complications. Morbidity due to subcutaneous transposition is clearly less when compared to submuscular or intramuscular procedures.[8] In a comparative study of submuscular and subcutaneous transposition of the ulnar nerve for cubital tunnel syndrome, sensory and motor recovery for patients with McGowan grades 2 and 3 were similar following submuscular and subcutaneous transposition techniques.[18] Furthermore, no immobilization is necessary after anterior subcutaneous transposition as no muscle or bone intervention is carried out. We did not use postoperative immobilization because early mobilization of the elbow permits early gliding of the ulnar nerve, which prevents the perineural fibrosis that occurs if mobilization is delayed to the second or third postoperative week.[8] It is shown that early mobilization also reduces the return-to-work period.[31]

Complications such as deterioration in ulnar nerve functions and painful neuroma development have been reported after anterior subcutaneous transposition.[13] Cubital tunnel surgery has an average 20% overall rate of failure, with up to 35% of patients having residual symptoms at the surgical site after surgery.[32] Failed surgery can be attributed to inadequate decompression, creation of iatrogenic compression, iatrogenic nerve injury, scar formation, kinking of the ulnar nerve or nerve subluxation. Iatrogenic compression can occur at the medial intermuscular septum with anterior transposition as a result of inadequate proximal and

distal mobilization of the nerve, as well as kinking of the nerve over an unreleased septum.[33] The medial intermuscular septum should be resected in all patients so that it does not become a proximal site of compression after anterior transposition.[5,33] Cutaneous neuromas are a common cause of continued pain after cubital tunnel surgery. The medial antebrachial cutaneous nerve may be injured or transacted during exposure of the ulnar nerve. Careful dissection at the time of the original surgery is key to preventing nerve injury. The deterioration in ulnar nerve functions is probably due to devascularization of the nerve.[33] We did not observe any of these complications in our patients. None of the patients developed ulnar nerve paralysis, subluxation, or flexion contracture of the elbow. Incisions should be in front of the medial epicondyle in order to protect medial antebrachial cutaneous nerve.[12]

We observed that the mid- and long-term results were excellent and good in patients who underwent subcutaneous anterior transposition of the ulnar nerve. No ulnar nerve paralysis developed and none of the patients showed deterioration of the ulnar nerve functions when compared to the preoperative period. Of the 33 patients, 31 had excellent and good results (94%), 1 had fair (3%), and one had poor result (3%). The patient with the poor result had a crush injury of the elbow and underwent simple decompression of the ulnar nerve twice and had scarring of the nerve, implying an intrinsic damage of the nerve. Caputo and Watson[34] reported 75% good to excellent results with secondary subcutaneous anterior transposition. Although these results are less favorable than those for the primary procedure, submuscular or subcutaneous anterior transposition provides most patients at least partial pain relief. This did not happen in our patient, perhaps because it was not a revision surgery after an idiopathic entrapment in which entrapment of the ulnar nerve, not scarring, would be expected.

In conclusion, the relatively poor results of anterior subcutaneous transposition in some studies can be attributed to the fact that this procedure is particularly preferred in chronic patients with a long duration and advanced disease with probable intrinsic nerve damage. Subcutaneous transposition of the ulnar nerve for the surgical treatment of cubital tunnel syndrome is a reliable and easy method with a low complication rate and should be preferred for its mechanical advantage in solving the nerve traction problem.

Conflicts of Interest: No conflicts declared.

References

1. Asamoto S, Böker DK, Jödicke A. Surgical treatment for ulnar nerve entrapment at the elbow. Neurol Med Chir 2005;45:240-5.
2. Brauer CA, Graham B. The surgical treatment of cubital tunnel syndrome: a decision analysis. J Hand Surg Eur Vol 2007; 32:654-62.
3. Erol B, Tetik C, Sirin E. The mid-term results of minimal medial epicondylectomy and decompression for cubital tunnel syndrome. Acta Orthop Traumatol Turc 2004;38:330-36.
4. Keiner D, Gaab MR, Schroeder HW, Oertel J. Comparison of the long-term results of anterior transposition of the ulnar nerve or simple decompression in the treatment of cubital tunnel syndrome – a prospective study. Acta Neurochir 2009; 151:311-6.
5. Palmer BA, Hughes TB. Cubital tunnel syndrome. J Hand Surg Am 2010;35:153-63.
6. Feindel W, Stratford J. The role of the cubital tunnel in tardy ulnar palsy. Can J Surg 1958;1:287-300.
7. Mitsionis GI, Manoudis GN, Paschos NK, Korompilias AV, Beris AE. Comparative study of surgical treatment of ulnar nerve compression at the elbow. J Shoulder Elbow Surg 2010;19:513-9.
8. Dellon AL, Coert JH. Results of the musculofascial lengthening technique for submuscular transposition of the ulnar nerve at the elbow. J Bone Joint Surg Am 2003;85-A:1314-20.
9. Practice parameter for electrodiagnostic studies in ulnar neuropathy at the elbow: summary statement. American Association of Electrodiagnostic Medicine, American Academy of Neurology, American Academy of Physical Medicine and Rehabilitation. Muscle Nerve 1999;22:408-11.
10. Goldberg BJ, Light TR, Blair SJ. Ulnar neuropathy at the elbow: results of medial epicondylectomy. J Hand Surg Am 1989;14:182-8.
11. Wilson DH, Krout R. Surgery of ulnar neuropathy at the elbow: 16 cases treated by decompression without transposition. Technical note. J Neurosurg 1973;38:780-5.
12. Abuelem T, Ehni BL. Minimalist cubital tunnel treatment. Neurosurgery 2009;65:A145-9.
13. Hahn SB, Choi YR, Kang HJ, Kang ES. Decompression of the ulnar nerve and minimal medial epicondylectomy with a small incision for cubital tunnel syndrome: comparison with anterior subcutaneous transposition of the nerve. J Plast Reconstr Aesthet Surg 2010;63:1150-5.
14. Lee SK, Sharma S, Silver BA, Kleinman G, Hausman MR. Submuscular versus subcutaneous anterior ulnar nerve transposition: a rat histologic study. J Hand Surg Am 2009;34: 1811-4.
15. Macadam SA, Gandhi R, Bezuhly M, Lefaivre KA. Simple decompression versus anterior subcutaneous and submuscular transposition of the ulnar nerve for cubital tunnel syndrome: a meta-analysis. J Hand Surg Am 2008;33:1314.e1-12.
16. Cobb TK. Endoscopic cubital tunnel syndrome. J Hand Surg Am 2010;35:1690-7.
17. Bednar MS, Blair SJ, Light TR. Complications of the treatment of cubital tunnel syndrome. Hand Clin 1994;10:83-92.
18. Charles YP, Coulet B, Rouzaud JC, Daures JP, Chammas M. Comparative clinical outcomes of submuscular and subcutaneous transposition of the ulnar nerve for cubital tunnel syndrome. J Hand Surg Am 2009;34:866-74.

19. Vanderpool DW, Chalmers J, Lamb DW, Whiston TB. Peripheral compression lesions of the ulnar nerve. J Bone Joint Surg Br 1968;50:792-803.
20. Apfelberg DB, Larson SJ. Dynamic anatomy of the ulnar nerve at the elbow. Plast Reconstr Surg 1973;51:79-81.
21. Werner CO, Ohlin P, Elmqvist D. Pressures recorded in ulnar neuropathy. Acta Orthop Scand 1985;56:404-6.
22. Gelberman RH, Yamaguchi K, Hollstien SB, Winn SS, Heidenreich FP Jr, Bindra RR, et al. Changes in interstitial pressure and cross-sectional area of the cubital tunnel and of the ulnar nerve with flexion of the elbow. An experimental study in human cadavera. J Bone Joint Surg Am 1998;80:492-501.
23. Patel VV, Heidenreich FP Jr, Bindra RR, Yamaguchi K, Gelberman RH. Morphologic changes in the ulnar nerve at the elbow with flexion and extension: a magnetic resonance imaging study with 3-dimensional reconstruction. J Shoulder Elbow Surg 1998;7:368-74.
24. Wilgis EF, Murphy R. The significance of longitudinal excursion in peripheral nerves. Hand Clin 1986;2:761-6.
25. Wright TW, Glowczewskie F Jr, Cowin D, Wheeler DL. Ulnar nerve excursion and strain at the elbow and wrist associated with upper extremity motion. J Hand Surg Am 2001; 26:655-62.
26. Catalano LW 3rd, Barron OA. Anterior subcutaneous transposition of the ulnar nerve. Hand Clin 2007;23:339-44.
27. Dellon AL. Review of treatment results for ulnar nerve entrapment at the elbow. J Hand Surg Am 1989;14:688-700.
28. Robertson C, Saratsiotis J. A review of compressive ulnar neuropathy at the elbow. J Manipulative Physiol Ther 2005; 28:345.
29. McGowan AJ. The results of transposition of the ulnar nerve for traumatic ulnar neuritis. J Bone Joint Surg Br 1950;32-B:293-301.
30. Mandelli C, Baiguini M. Ulnar nerve entrapment neuropathy at the elbow: decisional algorithm and surgical considerations. Neurocirugia (Astur) 2009;20:31-8.
31. Weirich SD, Gelberman RH, Best SA, Abrahamsson SO, Furcolo DC, Lins RE. Rehabilitation after subcutaneous transposition of the ulnar nerve: immediate versus delayed mobilization. J Shoulder Elbow Surg 1998;7:244-9.
32. Jackson LC, Hotchkiss RN. Cubital tunnel surgery. Complications and treatment of failures. Hand Clin 1996;12: 449-56.
33. Gellman H. Compression of the ulnar nerve at the elbow: cubital tunnel syndrome. Instr Course Lect 2008;57:187-97.
34. Caputo AE, Watson HK. Subcutaneous anterior transposition of the ulnar nerve for failed decompression of cubital tunnel syndrome. J Hand Surg Am 2000;25:544-51.