J Shoulder Elbow Surg (2020) 29, 2339–2346

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ELBOW

The impact of pre-existing ulnar nerve instability on the surgical treatment of cubital tunnel syndrome: a systematic review

DesRaj M. Clark, MD[a,*], Andres S. Piscoya, MD[a], John C. Dunn, MD[b], Leon J. Nesti, MD, PhD[a]

[a]*Department of Orthopedic Surgery, Walter Reed National Military Medical Center, Bethesda, MD, USA*
[b]*Department of Orthopedic Surgery, William Beaumont Army Medical Center, El Paso, TX, USA*

Background: The decision to perform nerve transposition (NT) or in situ decompression (SD) during surgical treatment of cubital tunnel syndrome is often based on nerve subluxation through elbow motion. This review assesses what impact nerve instability has on study design and reported outcomes.
Methods: A search was performed with Boolean operators: "ulnar nerve" OR "cubital tunnel" AND "decompression" OR "transposition" on PubMed, Clinical Key, and CINAHL to identify primary studies comparing NT and SD that report pre-existing nerve instability. Primary outcome was the effect of instability on study design. Secondary outcomes were nerve instability, patient-reported scores, and complications.
Results: Five studies met criteria after screening 134 articles. In 3 studies, nerve instability dictated treatment. Prospective randomization was maintained in 1 study. Included cases totaled 464 SD and 304 NT. The complication rate was 8.6% overall, 4.3% for SD and 21.1% for NT. Bishop scores were 56.9% excellent and 37.3% good for stable nerves and 62.0% excellent and 29.3% good for unstable nerves.
Conclusions: Very few studies report ulnar nerve instability, and study design is biased by ulnar nerve subluxation. Outcomes showed similar symptomatic improvement for both decompressed and transposed groups with higher complication rates for the transposed group.
Level of evidence: Level IV; Systematic Review

Keywords: Ulnar nerve; subluxation; cubital tunnel; decompression

Entrapment of the ulnar nerve at the elbow, or cubital tunnel syndrome (CuTS), is the second most common neuropathy of the upper extremity. Although typically treated conservatively, recalcitrant cases are treated surgically, involving ulnar nerve transposition (NT) or an in situ decompression (SD). The decision to transpose is often based on stability or subluxation of nerve in elbow flexion.[5,29] Prospective, comparative studies weighing decompression vs. transposition have shown equivalent results, each with their associated risks and benefits.[4,7] Proponents of SD are supported by meta-analyses that have shown no difference in outcomes between techniques with a difference in complication rates.[16,22,24,29] However, the stability of the ulnar nerve is not always addressed as a factor. As a result, advocates of

No institutional review board approval was required for this systematic review.

*Reprint requests: DesRaj M. Clark, MD, Department of Orthopedic Surgery, Walter Reed National Military Medical Center, 8901 Rockville Pike, Building 19, Bethesda, MD 20889, USA.

E-mail address: rajclark.uva@gmail.com (D.M. Clark).

1058-2746/$ - see front matter Published by Elsevier Inc. on behalf of Journal of Shoulder and Elbow Surgery Board of Trustees.
https://doi.org/10.1016/j.jse.2020.05.028

NT argue that ulnar neuropathy is a dynamic process resulting in both compression and traction that is only addressed by a transposition.[10,19] Comparing the results of NT or SD in the specific setting of stable or unstable nerves would provide important insight to how each surgical option addresses the different pathologies.

Our study represents a systematic review of CuTS exclusively limited to studies that recorded preoperative or intraoperative ulnar nerve instability, the impact of nerve subluxation on surgical intervention and study design, and the effects on outcomes. It is hypothesized that the literature characterizing pre-existing ulnar nerve instability in the setting of CuTS is limited, and many outcome studies do not report pre-existing instability. In addition, it is expected that preoperative instability affects study design by way of clinical management given the dogmatic nature of the SD vs. NT debate. If possible, subgroup analysis from included studies will provide insight on how SD and NT perform depending on the stability of the ulnar nerve.

Materials and methods

Literature review

This study was performed following the PRISMA guidelines without external funding or a previously registered protocol. A literature search of PubMed, Clinical Key, and CINAHL was performed with the following search terms and Boolean operators: "ulnar nerve" OR "cubital tunnel" AND "decompression" OR "transposition" with filters for English Language, between the years of 1999 and 2019, and full text articles. Two independent reviewers (DMC and ASP) assessed the titles and abstracts separately for relevancy. Abstracts that suggested inclusion in this review were saved for full manuscript review. Inclusion and exclusion criteria were then applied to select articles for analysis. The GRADE (Grading of Recommendations Assessment, Development and Evaluation Working Group) criteria are a quality assessment template used to evaluate the quality of methods in study analysis.[2] Using this template, the quality of the selected studies was then reviewed.

Eligibility

Inclusion criteria were (1) primary studies, (2) patients diagnosed with idiopathic CuTS, (3) reported data for pre-existing subluxation, and (4) skeletally mature patients. Exclusion criteria were (1) endoscopic decompression, (2) medial epicondylectomy, (3) revision surgery, and (4) treatment of polyneuropathies. Primary outcome was the effect of instability on study design. Secondary outcomes were rate of nerve instability, patient-reported scores, and complications.

Data extraction and analysis

Qualified studies that met criteria were examined, and the 2 reviewers extracted all relevant data including study sample size, sex, mean age, average follow-up, intervention (SD vs. NT), how ulnar nerve stability was assessed and reported, rate of nerve instability, how the presence or absence of nerve instability affected treatment or experimental group, and outcomes. The primary outcome was the effect of instability on study design. Secondary outcomes were rate of nerve instability, patient-reported scores, clinical improvement, and complications.

Demographic data, primary outcome measures, and secondary outcome measures from comparable studies were pooled for all patients. Rates and ratios were converted to percentages when applicable for comparison. Demographic variables, surgical variables, and outcomes were pooled and weighted averages were obtained when possible. Complications and reoperations were similarly recorded.

Results

Ulnar nerve instability

The literature search resulted in 645 unique results of which 134 articles were reviewed for inclusion. Five studies met inclusion for this systematic review (Fig. 1). Of these studies, 2 were retrospective reviews.[14,17] One was a prospective cohort.[15] Two were prospective randomized studies (Table I).[3,11] In 2 of the studies, one retrospective and one prospective, the presence of ulnar nerve instability did not direct patients into an SD or NT treatment group.[3,14] In another 2 of the studies, assessment of the nerves' stability, defined by palpable subluxation on preoperative examination or subluxation during elbow range of motion intraoperatively, dictated treatment with either SD or NT. Unstable nerves undergo NT.[15,17] In the final included study, patients with unstable nerves on preoperative examination were excluded from randomization, but still had outcomes reported after undergoing NT.[11] The overall rate of ulnar nerve instability identified in included studies was 16.9% (Table II).

Surgical outcomes

In total, 768 cases were included, of which 464 were SD and 304 were NT. The NT group was composed of 169 subcutaneous transpositions, 48 submuscular transpositions, 7 intramuscular transpositions, and 76 unspecified transpositions. The average age was 46.8 years and the mean length of follow-up was 33.7 months (Table I). The total complication rate for all included studies was 8.6%, with subgroup analysis for procedure type showing a complication rate of 4.3% for SD when reported and a rate of 21.1% for NT when reported. Within the SD group, complications for the unstable or stable nerve subgroups were not definitively reported. Of the patient-reported outcome scoring systems reported across all studies, only the Bishop score was reported in multiple studies. Bishop scores for total stable nerves showed 56.9% scoring

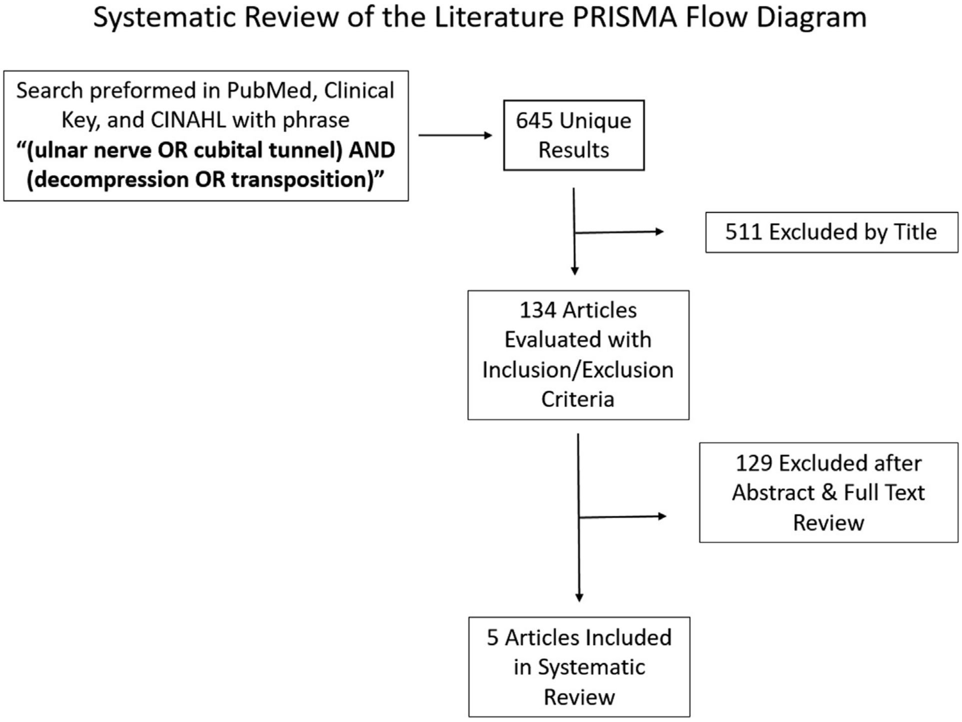

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram indicating the search method and article attrition during the systematic review process.

Table I Study demographics for included studies

Author, year	Journal	Study design	Sample size (n)	Gender (M/F)	Mean age (yr)	Treatment (SD/NT)	Mean follow-up (mo)
Henn, 2016[14]	*J Hand Surg Am*	Retrospective review	76	M: 31, F: 36	22.1	SD: 30, NT: 46	67.2
Matzon, 2016[17]	*J Hand Surg Am*	Retrospective review	363	M: 215, F: 148	53.7	SD: 287, NT: 76	n/a
Kang, 2015[15]	*J Orthop Surg Res*	Prospective cohort	107	M: 69, F: 38	36.6	SD: 37, NT: 70	32.2
Bartels, 2005[3]	*Neurosurgery*	Prospective, randomized, controlled trial	152	M: 94, F: 58	47.2	SD: 75, NT: 77	12
Gervasio, 2005[11]	*Neurosurgery*	Prospective, randomized study	70	M: 48, F: 22	52.6	SD: 35, NT: 35	47
Totals and weighted averages			768	M: 457 (60.0%)	46.8	SD: 464, NT: 304	33.7

M, male; *F*, female; *SD*, simple decompression; *NT*, nerve transposition.

excellent and 37.3% scoring good. Bishop scores for total unstable nerves showed 62.0% scoring excellent and 29.3% scoring good. Subgroup analysis with respect to stable or unstable nerves was possible in the study from Gervasio et al.[11] Patients with unstable nerves who underwent SD reported a mean Bishop score of Good, and those with unstable nerves who underwent NT reported a mean score of Good.[11] Conversely, subgroup analysis was also possible from the data presented by Bartels et al.[3] Ten patients (50%) with unstable nerves who underwent SD were evaluated to have "Excellent Recovery" by the Medical Research Council Grading system, and 13 patients (59%) with unstable nerves who underwent NT were evaluated to have "Excellent Recovery" by the Medical Research Council Grading system. Disabilities of the Arm, Shoulder and Hand score and visual analog scale satisfaction–reported outcomes also showed significant improvement after surgery in one study.[14] Outcomes collected from patient history and physical examination were not reported across multiple studies but did show significant findings regarding symptomatic improvement between stable and unstable nerves and male sex and younger age as risk factors for nerve instability (Table III).[14,17]

Table II Ulnar nerve instability assessment and impact on treatment or study design

Author, year	Sample size (n)	Assessment of pre-existing nerve instability	Rate of ulnar nerve instability	Impact of nerve instability on study/clinical decision
Henn, 2016[14]	76	Preoperative examination or intraoperative evaluation	34/76 (44.7%)	Patients with instability were kept in their treatment groups. Patients with stable nerves: SD: 28, NT: 14 Patients with unstable nerves: SD: 2, NT: 32
Matzon, 2016[17]	363	Preoperative examination	29/363 (8.0%)	Patients with instability underwent NT. Patients with instability after full decompression also underwent NT.
Kang, 2015[15]	107	Intraoperative assessment	Total: 23/107 (21.5%) Group A: 10/51 (19.6%) Group B: 13/56 (23.2%)	Group A: Underwent SD or NT based on stability assessment. Group B: all underwent NT.
Bartels, 2005[3]	152	Intraoperative assessment	Total: 42/152 (27.6%) SD group: 20/75 (26.7%) NT group: 22/77 (28.6%)	Patients with instability maintained randomization into treatment groups for simple SD or NT.
Gervasio, 2005[11]	70	Preoperative examination	2/70 (2.8%)	Patients with instability were excluded from randomization and underwent NT.
Totals	768		130/768 (16.9%)	

SD, simple decompression; *NT*, nerve transposition.

Discussion

With respect to the initial hypotheses, this systematic review revealed a very limited number of studies in which ulnar nerve stability was reported as part of the CuTS treatment algorithm. Furthermore, when nerve instability was taken into account, it often influenced study design and treatment decisions, introducing a source of bias. Unfortunately, results in the included studies were not uniformly reported in a manner that allowed for analysis of outcomes comparing SD and NT in well-defined subgroups based on the stability of the ulnar nerve.

Pre-existing ulnar nerve instability and its impact on surgical decisions and study design were of particular interest because recent studies have shown no difference in outcomes between SD and NT, but a glaring limitation in the study design has been lack of documented ulnar nerve stability assessment.[16,22,24,29] In the 3 prospective trials that met inclusion criteria for this review, only 1 maintained randomization into either SD or NT treatment groups.[3] The remaining 2 prospective studies appear inconclusive in this aspect because nerve instability leads to NT rather than randomization to either treatment option.[3,11,15] Bartels et al[3] maintained treatment randomization after assessing for nerve stability and found similar outcomes in both treatment groups with the NT group having a significantly higher incidence of complication (Table III). This may be the soundest evidence that transposing unstable ulnar nerves should be reconsidered, and it also reflects what has been borne out in prior meta-analyses regarding symptomatic improvement and complications stemming from SD and NT options.

The second objective of this review was to extract available data for both stable and unstable nerve subgroups in order to see what additional conclusions could be drawn and to compare those previous studies. The pooled patient-reported outcomes and complication rates from this systematic review showed improvement in both SD and NT groups and a higher complication rate for the NT group compared with the SD groups. Although these findings agree with recent meta-analyses, SD and NT may not always be compared equally in all patients. In this review, the overall rate of preoperative nerve instability was found to be around 16%, and a large proportion was indicated for NT solely based on stability.

Trends in treatment have shifted over time and currently favor following the algorithm that stable nerves undergo SD and unstable nerves undergo NT.[1,8,25,28] The evidence guiding that ulnar nerves undergo NT rather than SD has been subject to debate with authors arguing that ulnar nerve subluxation is physiological in around 16% of the population and questioning whether transposition should be done as a primary procedure.[1,13] Both radiographic and historical anatomic studies have shown the presence of ulnar nerve instability in asymptomatic or patients with negative electromyelograms.[21,26] Alternatively, even without frank subluxation, a process or anatomic variant limiting the excursion of the nerve during normal range of motion at the wrist or elbow may also contribute to neuropathy.[23,27] Although NT may alleviate nerve strain and pressure to a

Table III Reported outcomes and complications for included studies and pooled data

Author, year	Sample size (n)	Treatment (SD/NT)	Mean follow-up (mo)	Patient-reported outcome scores	Outcomes from history and physical examination	Complications
Henn, 2016[14]	76	SD: 30 (39.5%), NT: 46 (60.5%)	67.2	39 patients reached for follow-up questionnaires. QuickDASH (mean): Unstable: 6.3 Stable: 18.6 *P* value: .03 VAS (mean): Unstable: 1.6 Stable: 3.5 *P* value: .32 VAS satisfaction (mean): Unstable: 8.7 Stable: 5.9 *P* value: .01	39 patients reached for follow-up questionnaires. Return to sport (mean, mo): Unstable: 6.3 Stable: 5.7 *P* value: .72 Any residual symptoms: Unstable: 43% Stable: 93% *P* value: .001	Total: 10/76 (13.2%) SD: 7/30 (23.3%) NT: 3/46 (6.5%) 8 patients required revision surgery; 6 of the revisions occurred in patients with stable nerves who underwent simple decompression.
Matzon, 2016[17]	363	SD: 287 (79.1%), NT: 76 (20.9%)	n/a	NR	Risk factors for nerve instability: Male sex: odds ratio 2.92 (95% CI: 1.22-6.97, *P* value: .016) Younger age: odds ratio 0.96/yr (95% CI: 0.94-0.98, *P* value: .001) Low BMI: not clinically significant (*P* value: .57)	SD: 3/287 (1.0%) 3 patients with recurrent symptoms revised to nerve transposition
Kang, 2015[15]	107	SD: 37 (34.6%), NT: 70 (65.4%)	32.2	DASH mean at final follow-up: Group A: 11.0 Group B: 10.8 *P* value: .919 Bishop score: Group A: Excellent 29, Good 19, Fair 3 Group B: Excellent 35, Good 16, Fair 5 *P* value: .580	Grip strength at final follow-up (kg): Group A: 31.9 Group B: 31.8 *P* value: .931 Pinch strength at final follow-up (kg): Group A: 4.1 Group B: 4.0 *P* value: .777	Total: 9/107 (8.4%) Group A: 1/51 (2.0%) Group B: 8/56 (14.3%)

(*continued on next page*)

Table III Reported outcomes and complications for included studies and pooled data (*continued*)

Author, year	Sample size (n)	Treatment (SD/NT)	Mean follow-up (mo)	Patient-reported outcome scores	Outcomes from history and physical examination	Complications
					Two-point discrimination at final follow-up (mm): Group A: 3.2 Group B: 3.1 *P* value: .560	
Bartels, 2005[3]	152	SD: 75 (49.3%), NT: 77 (50.7%)	12	Medical research council grading at final follow-up: Total unstable nerves: 23/42 grade 1 Unstable nerve SD: 10/20 grade 1 Unstable nerve NT: 13/22 grade 1 Total SD: 36/73 grade 1, 13/73 grade 2 Total NT: 46/74 grade 1, 8/74 grade 2 SF-36: general improvement McGill Pain Questionnaire: general improvement	NR	Total: 30/152 (19.7%) SD: 7/75 (9.3%) NT: 23/77 (29.9%)
Gervasio, 2005[11]	70	SD: 35 (50.0%), NT: 35 (50.0%)	47	Bishop score for included patients: SD: 6.91 NT: 6.85 *P* value: .658 Bishop score for excluded patients: 1 Excellent, 1 Good	NR	Total minor complications: 14/70 (20%) Total major complications: 0 (0.0%) None reported for excluded patients
Totals and weighted averages	768	SD: 464 (60.4%), NT: 304 (39.6%)	33.7	Only Bishop score was reported across multiple studies Bishop score (stable nerves) Excellent: 56.9%, Good: 37.3% Bishop score (unstable nerves) Excellent: 62.0%, Good: 29.3%	No single metric was reported across multiple studies	Total: 66/768 (8.6%) SD: 17/392 (4.3%) NT: 26/123 (21.1%)

SD, simple decompression; *NT*, nerve transposition; *QuickDASH*, Disabilities of the Arm, Shoulder and Hand score; *VAS*, visual analog scale; *CI*, confidence interval; *BMI*, body mass index; *NR*, not reported.

greater extent than SD, both procedures would improve strain on the nerve during motion of the upper extremity.[6,9,12,18,20] So in this context, treating ulnar nerve subluxation with NT rather than SD may not be necessary. The subluxation found during evaluation could be physiological, and compression during excursion could be addressed with the safer procedure. Therefore, given the higher complication rates seen after NT compared with SD, it is critical to evaluate which patients truly need NT before undertaking a higher-risk procedure.

This study has several limitations. A true meta-analysis of the data gathered was not feasible because of the limited papers available in the literature recording ulnar nerve instability. Of the few included studies that did assess and report nerve stability, inconsistent metrics were reported making it difficult to aggregate data (Table III). Another limitation is that an average minimum follow-up time was not implemented in the search algorithm in order to include more studies, which was a tradeoff aimed to add to the value of our findings. Study quality was also variable. Two of the included papers were retrospective reviews, which carried the inherent limitations of retrospective reviews. Two prospective trials changed their management based on ulnar nerve stability examination, which introduces selection bias.

Conclusions

Despite recent randomized controlled trials and meta-analyses, the surgical management of CuTS remains controversial. This systematic review of primary studies that record and report ulnar nerve stability when treating CuTS provides an additional perspective in the debate between NT and SD for surgical treatment of ulnar nerve compression. Assessment of nerve stability does changes management and affects bias in studies, but without substantial support from available studies. For future studies, reporting nerve instability and including subgroup analysis of outcomes for patients with pre-existing subluxation will provide new data for evaluating how nerve instability should impact treatment decisions.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Adkinson JM, Zhong L, Aliu O, Chung CK. Surgical treatment of cubital tunnel syndrome: trends and the influence of patient and surgeon characteristics. J Hand Surg Am 2015;40:1824-31. https://doi.org/10.1016/j.jhsa.2015.05.009
2. Atkins D, Eccles M, Flottorp S, Guyatt GH, Henry D, Hill S, et al. Systems for grading the quality of evidence and the strength of recommendations I: critical appraisal of existing approaches The GRADE Working Group. BMC Health Serv Res 2004;4:38. https://doi.org/10.1186/1472-6963-4-38
3. Bartels RH, Verhagen WI, van der Wilt GJ, Meulstee J, van Rossum LG, Grotenhuis JA. Prospective randomized controlled study comparing simple decompression versus anterior subcutaneous transposition for idiopathic neuropathy of the ulnar nerve at the elbow: part 1. Neurosurgery 2005;56:522-30. https://doi.org/10.1227/01.neu.0000154131.01167.03
4. Biggs M, Curtis JA. Randomized, prospective study comparing ulnar neurolysis in situ with submuscular transposition. Neurosurgery 2006;58:296-304. https://doi.org/10.1227/01.NEU.0000194847.04143.A1
5. Dellon AL. Review of treatment results for ulnar nerve entrapment at the elbow. J Hand Surg Am 1989;14:688-700.
6. Dellon AL, Chang E, Coert JH, Campbell K. Intraneural ulnar pressure changes related to operative techniques for cubital tunnel decompression. J Hand Surg Am 1994;19:923-30.
7. Dunn JC, Goddard R, Eckhoff MD, Waterman BR, Nesti LJ, Kilcoyne KG. Retrospective, nonrandomized analysis of subcutaneous anterior transposition versus in situ decompression of the ulnar nerve of military service members. J Shoulder Elbow Surg 2019;28:751-6. https://doi.org/10.1016/j.jse.2018.12.005
8. Eberlin KR, Marjoua Y, Jupiter JB. Compressive neuropathy of the ulnar nerve: a perspective on history and current controversies. J Hand Surg Am 2017;42:464-9. https://doi.org/10.1016/j.jhsa.2017.03.027
9. Foran I, Vaz K, Sikora-Klak J, Ward SR, Hentzen ER, Shah SB. Regional ulnar nerve strain following decompression and anterior subcutaneous transposition in patients with cubital tunnel syndrome. J Hand Surg Am 2016;41:e343-50. https://doi.org/10.1016/j.jhsa.2016.07.095
10. 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.
11. Gervasio O, Gambardella G, Zaccone C, Branca D. Simple decompression versus anterior submuscular transposition of the ulnar nerve in severe cubital tunnel syndrome: a prospective randomized study. Neurosurgery 2005;56:108-17. https://doi.org/10.1227/01.neu.0000145854.38234.81
12. Grewal R, Varitimidis SE, Vardakas DG, Fu FH, Sotereanos DG. Ulnar nerve elongation and excursion in the cubital tunnel after decompression and anterior transposition. J Hand Surg Br 2000;25:457-60.
13. Heithoff SJ. Cubital tunnel syndrome does not require transposition of the ulnar nerve. J Hand Surg Am 1999;24:898-905.
14. Henn CM, Patel A, Wall LB, Goldfarb CA. Outcomes following cubital tunnel surgery in young patients: the importance of nerve mobility. J Hand Surg Am 2016;41:e1-7. https://doi.org/10.1016/j.jhsa.2016.01.014
15. Kang HJ, Koh IH, Chun YM, Oh WT, Chung KH, Choi YR. Ulnar nerve stability-based surgery for cubital tunnel syndrome via a small incision: a comparison with classic anterior nerve transposition. J Orthop Surg Res 2015;10:121. https://doi.org/10.1186/s13018-015-0267-8
16. 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. https://doi.org/10.1016/j.jhsa.2008.03.006

17. Matzon JL, Lutsky KF, Hoffler CE, Kim N, Maltenfort M, Beredjiklian PK. Risk factors for ulnar nerve instability resulting in transposition in patients with cubital tunnel syndrome. J Hand Surg Am 2016;41:180-3. https://doi.org/10.1016/j.jhsa.2015.11.014
18. Mitchell J, Dunn JC, Kusnezov N, Bader J, Ipsen DF, Forthman CL, et al. The effect of operative technique on ulnar nerve strain following surgery for cubital tunnel syndrome. Hand (NY) 2015;10:707-11. https://doi.org/10.1007/s11552-015-9770-y
19. Nabhan A, Ahlhelm F, Kelm J, Reith W, Schwerdtfeger K, Steudel WI. Simple decompression or subcutaneous anterior transposition of the ulnar nerve for cubital tunnel syndrome. J Hand Surg Br 2005;30:521-4. https://doi.org/10.1016/j.jhsb.2005.05.011
20. Ochi K, Horiuchi Y, Nakamura T, Sato K, Arino H, Koyanagi T. Ulnar nerve strain at the elbow in patients with cubital tunnel syndrome: effect of simple decompression. J Hand Surg Eur Vol 2013;38:474-80. https://doi.org/10.1177/1753193412465234
21. Ozturk E, Sonmez G, Colak A, Sildiroglu HO, Mutlu H, Senol MG, et al. Sonographic appearances of the normal ulnar nerve in the cubital tunnel. J Clin Ultrasound 2008;36:325-9. https://doi.org/10.1002/jcu.20486
22. Ren YM, Zhou XH, Qiao HY, Wei ZJ, Fan BY, Lin W, et al. Open versus endoscopic in situ decompression in cubital tunnel syndrome: a systematic review and meta-analysis. Int J Surg 2016;35:104-10. https://doi.org/10.1016/j.ijsu.2016.09.012
23. Richard MJ, Messmer C, Wray WH, Garrigues GE, Goldner RD, Ruch DS. Management of subluxating ulnar nerve at the elbow. Orthopedics 2010;33:672. https://doi.org/10.3928/01477447-20100722-04
24. Said J, Van Nest D, Foltz C, Ilyas AM. Ulnar nerve in situ decompression versus transposition for idiopathic cubital tunnel syndrome: an updated meta-analysis. J Hand Microsurg 2019;11:18-27. https://doi.org/10.1055/s-0038-1670928
25. Staples JR, Calfee R. Cubital tunnel syndrome: current concepts. J Am Acad Orthop Surg 2017;25:e215-24. https://doi.org/10.5435/JAAOS-D-15-00261
26. Tai TW, Kuo LC, Chen WC, Wang LH, Chao SY, Huang CN, et al. Anterior translation and morphologic changes of the ulnar nerve at the elbow in adolescent baseball players. Ultrasound Med Biol 2014;40: 45-52. https://doi.org/10.1016/j.ultrasmedbio.2013.07.016
27. 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.
28. Yahya A, Malarkey AR, Eschbaugh RL, Bamberger HB. Trends in the surgical treatment for cubital tunnel syndrome: a survey of members of the American Society for Surgery of the Hand. Hand (NY) 2018;13: 516-21. https://doi.org/10.1177/1558944717725377
29. Zlowodzki M, Chan S, Bhandari M, Kalliainen L, Schubert W. Anterior transposition compared with simple decompression for treatment of cubital tunnel syndrome. A meta-analysis of randomized, controlled trials. J Bone Joint Surg Am 2007;89:2591-8. https://doi.org/10.2106/JBJS.G.00183