Original Article

Multimodal ultrasound evaluation of asymptomatic ulnar nerve dislocation at the cubital tunnel

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Background: Ultrasonography has received broad acceptance as an effective peripheral nervous imaging examination. Shear wave elastography (SWE) can quantitatively assess the stiffness of nerves; however, little research has been conducted on elastography for ulnar nerve dislocation. The purpose of this study was thus to investigate the characteristics of multimodal ultrasound, including high-resolution ultrasonography and SWE, for asymptomatic ulnar nerve dislocation at cubital tunnel.

Methods: In this prospective cross-sectional study, 41 participants were recruited in Shandong Provincial Hospital Affiliated to Shandong First Medical University in July 2022. The inclusion criteria for participants were being in good health and being 18–60 years of age. Meanwhile, the exclusion criterion was a history of upper limb pain or fractures, peripheral neuropathy, or systemic or immunological diseases. Finally, 38 participants were enrolled. Two ultrasound doctors measured the maximum diameter, the maximum cross-sectional area (CSA), and the shear modulus of the ulnar nerve at the cubital tunnel independently. Another two ultrasound doctors determined whether dislocation was present during dynamic elbow flexion and extension and divided the elbows into a dislocation group and a control group. The descriptive statistics and independent sample *t*-test were used for data analysis, and intragroup correlation coefficient (ICC) was used to determine the consistency of evaluation between observers.

Results: Ulnar nerve dislocation was observed in 15.8% (12/76) of the ulnar nerves. There was no significant difference in the maximum diameter between the dislocation group (0.194±0.022 cm) and the control group (0.181±0.023 cm) (t=1.888; P=0.063). The CSA and SWE of the ulnar nerve were 0.064±0.009 cm^2 and 43.629±6.737 kPa in the dislocation group, respectively, and were 0.050±0.008 cm^2 and 31.293±7.858 kPa in the control group, respectively. There were significant differences between the two groups in terms of CSA (P<0.001) and SWE (P<0.001). The ICCs of the maximum diameter, CSA, and SWE values between observers were 0.970, 0.900, and 0.915, respectively.

Conclusions: Multimodal ultrasound consisting of high-resolution ultrasonography combined with elastography can comprehensively and quantitatively evaluate the morphological changes and mechanical properties of the dislocated ulnar nerve and monitor disease progress.

Keywords: Ulnar nerve dislocation; multimodal ultrasound; elastography

Submitted Mar 11, 2023. Accepted for publication Nov 20, 2023. Published online Jan 02, 2024.
doi: 10.21037/qims-23-301
View this article at: https://dx.doi.org/10.21037/qims-23-301

Introduction

The ulnar nerve passes through the cubital tunnel in the elbow. The arcuate ligament covering the tunnel forces the ulnar nerve to stretch in the cubital tunnel during elbow flexion, thus preventing dislocation. Childress (1) classified ulnar nerve instability (UNI) into subluxation (type A) and dislocation (type B) from the cubital tunnel. UNI can be completely asymptomatic and is present in a significant portion of the general population (2-5). The clinical implications of ulnar nerve dislocation are controversial. Some studies suggest it is not clinically meaningful, as cross-sectional area (CSA) and morphology changes of the dislocated ulnar nerve may be accompanied by normal electrodiagnostic examinations (6-8). However, other researches indicate that during elbow movement, the dislocated ulnar nerve can undergo transient deformation influenced by the humeral medial epicondyle. Repetitive abnormal dynamic compression related to elbow flexion may produce shear stress, resulting in frictional neuritis and contributing to further ulnar neuropathy at the elbow (7,9).

Ultrasonography has received broad acceptance as an effective peripheral nervous imaging examination (10,11). Pisapia *et al.* (8) found that ultrasonography can detect the morphologic changes of ulnar nerve dislocation earlier than can other imaging findings. The ultrasonic manifestations of ulnar neuropathy at the elbow include enlargement and swelling of the nerve, loss of normal fascicular pattern, increases in nerve CSA, and increased stiffness (12-14). Noticeably, ultrasonography can be used to dynamically observe the dislocation process and to assess the surrounding tissues (15).

Shear wave elastography (SWE), as a recently developed ultrasound technique, can quantitatively assess the stiffness of peripheral nerves (16). Significant increases in elastographic measurements may be caused by reduced fluid diffusion across the cellular membrane due to neuropathy (17).

The use of SWE in the diagnosis of ulnar nerve dislocation has not been extensively researched. We thus conducted a study to identify the characteristics of high-resolution ultrasonography and SWE in asymptomatic ulnar nerve dislocation at cubital tunnel. To this end, using high-resolution ultrasound, we measured the maximum diameter and CSA of the ulnar nerve at the cubital tunnel of an asymptomatic dislocation group and a control group and compared the stiffness of ulnar nerve between these groups using SWE. The aim of this study was to verify whether multimodal ultrasound techniques, specifically high-resolution ultrasonography combined with elastography, can evaluate morphological changes and mechanical properties of the dislocated ulnar nerve and monitor disease progress. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-301/rc).

Methods

Ethical approval for this prospective, cross-sectional study was obtained from the Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University (No. MR-37-23-023994). This study was conducted according to the principles outlined in the Declaration of Helsinki (as revised in 2013). In July 2022, 41 participants were recruited in Shandong Provincial Hospital Affiliated to Shandong First Medical University. One participant refused to continue due to time constraints. Inclusion criteria included being healthy and being 18–60 years of age; meanwhile, the exclusion criteria included a history of pain or numbness of the upper limbs, peripheral neuropathy, systemic disease or immunological disorders (diabetes mellitus, gout, rheumatoid arthritis, etc.), a history of upper limb fractures or surgery, and subluxation of the ulnar nerve from the cubital tunnel. Two participants were excluded due to having systemic disease. Finally, 76 ulnar nerves from 38 healthy adult participants aged 21–52 years (21 males and 17 females; mean age 34.8 years) were enrolled in the study. All participants provided signed informed consent.

Each participant was subjected to B-mode ultrasound and SWE, both of which were conducted with a Canon Aplio i800 ultrasound machine (Canon Medical Systems, Otawara, Japan) and an ultrasound solid gel pad. B-mode ultrasound examinations were performed using a L24 linear array transducer (i24LX8, Canon Medical Systems), and SWE was performed with an L18 linear array transducer (i18LX5, Canon Medical Systems).

Two senior musculoskeletal ultrasound doctors with more than 5 years of experience independently performed the examinations. Every participant was positioned in the supine position, with their arm abducted to 75°, their elbow fully extended, and their wrist supinated. First, a high-frequency linear array transducer was placed on a fictitious line between the humeral media epicondyle and the ulna olecranon process to scan the nerve in short axis. The probe was then rotated 90° to scan the nerve in the long axis and to observe the thickness, echogenicity, and

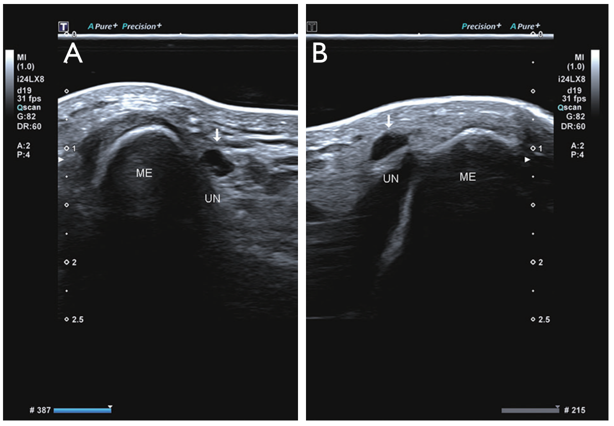

Figure 1 The different locations of the ulnar nerve in the extended position and extreme flexion position in the dislocation group. (A) The ulnar nerve in the cubital canal located posteriorly to the medial epicondyle of the humerus in the extended position. (B) The nerve crossed the medial epicondyle of the humerus completely and was displaced to fully anterior to the epicondyle in the extreme flexion position. The arrows indicate the short axis of the ulnar nerve, and the arrowheads indicate the apex of the medial epicondyle of the humerus. ME, medial epicondyle of humerus; UN, ulnar nerve; A, anterior to the medial epicondyle of the humerus; P, posterior to the medial epicondyle of the humerus.

adjacent anatomical structures of the ulnar nerve in the cubital tunnel. Following this, the maximum diameter was measured in long axis, and the maximum CSA was measured in the short axis. The maximum diameter and CSA were measured three times, from which an average was calculated. The SWE was measured in the long axis with the elbow fully extended using an elastic imaging model of the Canon Aplio i800 equipment. The ulnar nerve was placed in the central area of the Q-box (1 cm × 1 cm) and the selected region of interest (ROI; 2 mm in diameter). Ultrasonographic software (Canon Shear Wave Elastography USSW-AI900A software) was then used to automatically obtain shear modulus data, with the shear modulus values being expressed in kilopascals (kPa). SWE was measured three times at an interval of at least 5 seconds, and an average was taken. The imaging depth was 2–2.5 cm while the depth of focus was 1 cm for all measurements. During the examination, the transducer was held parallel to the skin and maintained perpendicular to the nerve, with the pressure on the pad being minimized. Finally, another two senior musculoskeletal ultrasound doctors with more than 5 years of experience determined whether dislocation was present during dynamic elbow flexion and extension performed actively by the participants according to the criteria proposed by Childress (1). The ulnar nerves at the elbow were then divided into a dislocation group and control group.

Statistical analysis was performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). The normal distribution of the study variables was verified with the Shapiro-Wilk test. Data are presented as the mean ± standard deviation (SD) and range. The independent samples *t*-test was used to assess the differences between mean maximum diameter, CSA, and the elasticity of the dislocation group and control group. A two-sided P value <0.05 was regarded as statistically significant. Intragroup correlation coefficient [ICC (2, k)] values (18) were used to evaluate intraobserver consistency.

Results

The grouping results about ulnar nerve dislocation or not were completely concordant between the two examiners. Ulnar nerve dislocation at the elbow was observed in 15.8% (12/76) of the participants (*Figure 1*). In the control group, the diameter of ulnar nerve was uniform, showing hypoechoic strips, within which high echo separation was apparent, and the internal fasciculus was clearly displayed. The sonogram of the ulnar nerve in the dislocation group showed decreased nerve echo and unclear internal fasciculus structure (*Figure 2*). SWE measurement of the ulnar nerve at the cubital tunnel for the dislocation group and control group is shown in *Figure 3*.

There was no significant difference between the maximum diameter of the ulnar nerve at the cubital tunnel in the dislocation group (0.194±0.022 cm) and that at corresponding site in the control group (0.181±0.023 cm) [t=1.888; 95% confidence interval (CI): 0.00075–0.02789; P=0.063]. The CSA and SWE of the ulnar nerve in elbow area in dislocation group were 0.064±0.009 cm^2 and 43.629±6.737 kPa, respectively, while those in the control group were 0.050±0.008 cm^2 and 31.293±7.858 kPa, respectively. The differences between the two groups were statistically significant (CSA: 95% CI: 0.00928–0.01916, P<0.001; SWE: 95% CI: 7.14221–16.79737, P<0.001) (*Table 1*).

The ICC values indicated good consistency between the observers in evaluating the maximum diameter (0.970; 95% CI: 0.951–0.981), CSA (0.900; 95% CI: 0.837–0.938), and SWE (0.915; 95% CI: 0.858–0.948) values of the ulnar nerve at the cubital tunnel.

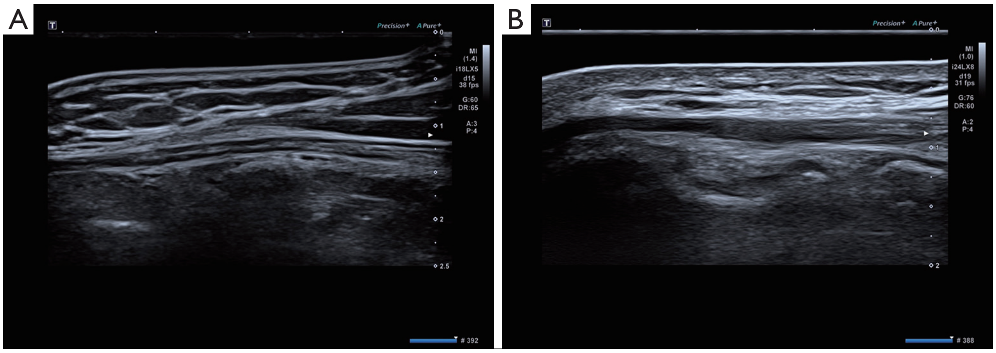

Figure 2 High-frequency sonographic characteristics of the ulnar nerve at the cubital tunnel of the dislocation group and control group. (A) High-frequency ultrasonography (24 MHz) showed that the diameter of ulnar nerve in the control group was uniform, showing hypoechoic strips, within which high echo separation was apparent, and the internal fasciculus was clearly displayed. (B) In the dislocation group, the ulnar nerve echo was decreased, and the internal fasciculus structure was not clearly displayed.

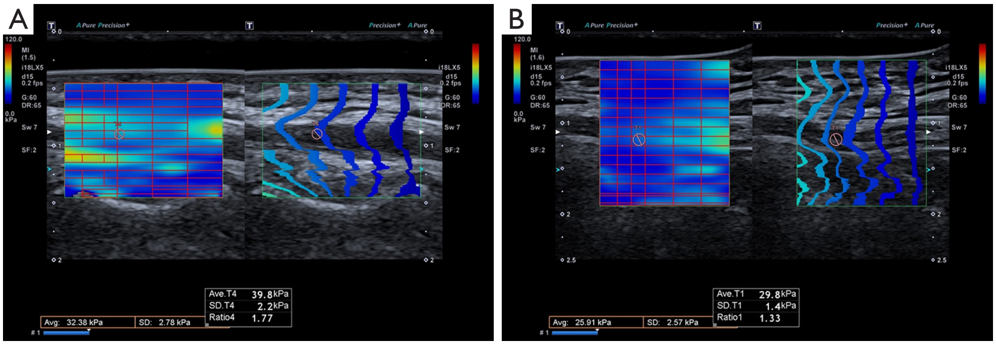

Figure 3 SWE measurement of the ulnar nerve at cubital tunnel of the dislocation group and control group. (A) The SWE value in the dislocation group was higher, and (B) the SWE value in the control group was lower. SWE, shear wave elastography.

Table 1 The maximum diameter, CSA, and SWE values of ulnar nerve at the cubital tunnel

Parameter	Dislocation group (n=12)	Control group (n=64)	P value
Diameter (cm)	0.194±0.022	0.181±0.023	0.063
CSA (cm²)	0.064±0.009	0.050±0.008	<0.001
SWE (kPa)	43.629±6.737	31.293±7.858	<0.001

Data are presented as the mean ± SD. CSA, cross-sectional area; SWE, shear wave elastography.

Discussion

Due to the related anatomical structure, the ulnar nerve is forced to stretch in the cubital tunnel during elbow motion. The underlying anatomic mechanism of ulnar nerve dislocation remains unclear, but possible causes include congenital anomalies such as a shallow groove or dysplasia, deficiency of the arcuate ligament (19,20), and hypertrophy of the triceps brachii muscle (21). The mechanism of ulnar nerve dislocation involves the volumetric reduction of the cubital tunnel when the arcuate ligament is strained during elbow flexion (22), which forces the ulnar nerve to displace inward (23).

Cubital tunnel syndrome is a highly common compressive neuropathy (24), second only second to carpal tunnel syndrome. There is controversy concerning whether ulnar nerve dislocation from the cubital tunnel can lead to ulnar neuropathy. Some believe there are no clinical implications correlated with ulnar nerve dislocation because studies have reported ulnar nerve dislocation in the healthy population (2-5). Meanwhile, other studies suggest that individuals with ulnar nerve dislocation have a higher predisposition for developing ulnar neuropathy; moreover, an underlying pathological process different from ulnar neuropathy that does not involve dislocation of the ulnar nerve has been revealed (25,26). Schertz *et al.* (25) found that ulnar nerve dislocation from the cubital tunnel was present in 49% of patients verified the presence of ulnar neuropathy by positive electromyographic results; however, this was present in only 23% of controls without neuropathy. Omejec *et al.* (26) reported that patients with abnormal ultrasonic morphology, but a normal electrodiagnostic examination were significantly more common in ulnar nerve dislocation group compared with controls. In our study, there were significant differences in the CSA of the ulnar nerve at the cubital tunnel between the dislocation group and control group although electrodiagnostic testing was not employed. We believe that the friction generated by repeated dislocation might have caused inflammation and swelling of the ulnar nerve.

SWE is a novel sonoelastographic technique, which can quantitatively and effectively assess nerve stiffness in the context of peripheral neuropathy. Miyamoto *et al.* (27) found that in patients with carpal tunnel syndrome, the median nerve stiffness increased significantly preceding morphological nerve alterations, and thus elastography was found to markedly improve the diagnostic accuracy of carpal tunnel syndrome. Paluch *et al.* (13) examined patients with ulnar neuropathy and found that their SWE values were three-fold higher than those of controls; therefore, SWE may aid in the diagnosis of peripheral neuropathies earlier than may conventional ultrasound. Wolny *et al.* (28) also confirmed that SWE of the ulnar nerve can be helpful in supporting and supplementing the diagnosis of patients with cubital tunnel syndrome. In our study, there were significant differences in the SWE of the ulnar nerve at the cubital canal between the dislocation group and control group. This may be attributable to the increased intranervous pressure produced by ulnar dislocation causing local nerve hypoxia, ischemia, and progressively greater stiffness (29).

This study had several limitations. First, operator dependency inevitably limited the reproducibility of the ultrasound findings. Second, as the cross-sectional study design targeted an asymptomatic population aged between 21 and 52 years, the generalizability of our findings may be limited. Third, we did not include electrodiagnostic testing or other imaging examinations (diffuse tensor magnetic resonance imaging etc.) in our asymptomatic participants, and we thus plan to examine their diagnostic value in future research. Fourth, we did not compare the rating scores for echogenicity of the ulnar nerve.

Conclusions

In asymptomatic individuals with ulnar nerve dislocation, the CSA and SWE values of the ulnar nerve at the cubital tunnel were significantly increased, and there was good agreement between the observers. The multimodal ultrasound technique of high resolution ultrasonography combined with elastography could comprehensively and quantitatively evaluate the morphological changes and mechanical properties of the dislocated ulnar nerve and monitor disease progress.

Acknowledgments

Funding: This study was supported by the Shandong Provincial Key R&D Program (No. 2019GSF108271), the Shandong Provincial Medical Science and Technology Development Program (No. 2019WS389), and the Shandong Provincial Natural Science Foundation (No. ZR2022MH043).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-301/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-301/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The ethical approval for this study was obtained from the Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University (No. MR-37-23-023994). This study conformed to the principles outlined in the Declaration of Helsinki (as revised in 2013). All participants provided signed informed consent.

References

1. Childress HM. Recurrent ulnar-nerve dislocation at the elbow. Clin Orthop Relat Res 1975;(108):168-73.
2. Cornelson SM, Sclocco R, Kettner NW. Ulnar nerve instability in the cubital tunnel of asymptomatic volunteers. J Ultrasound 2019;22:337-44.
3. Kawahara Y, Yamaguchi T, Honda Y, Tomita Y, Uetani M. The Ulnar Nerve at Elbow Extension and Flexion: Assessment of Position and Signal Intensity on MR Images. Radiology 2016;280:483-92.
4. Zaltz I, Waters PM, Kasser JR. Ulnar nerve instability in children. J Pediatr Orthop 1996;16:567-9.
5. Erez O, Khalil JG, Legakis JE, Tweedie J, Kaminski E, Reynolds RA. Ultrasound evaluation of ulnar nerve anatomy in the pediatric population. J Pediatr Orthop 2012;32:641-6.
6. Van Den Berg PJ, Pompe SM, Beekman R, Visser LH. Sonographic incidence of ulnar nerve (sub)luxation and its associated clinical and electrodiagnostic characteristics. Muscle Nerve 2013;47:849-55.
7. Kang JH, Joo BE, Kim KH, Park BK, Cha J, Kim DH. Ultrasonographic and Electrophysiological Evaluation of Ulnar Nerve Instability and Snapping of the Triceps Medial Head in Healthy Subjects. Am J Phys Med Rehabil 2017;96:e141-6.
8. Pisapia JM, Ali ZS, Hudgins ED, Khoury V, Heuer GG, Zager EL. Ultrasonography Detects Ulnar Nerve Dislocation Despite Normal Electrophysiology and Magnetic Resonance Imaging. World Neurosurg 2017;99:809.e1-5.
9. Łasecki M, Olchowy C, Pawluś A, Zaleska-Dorobisz U. The Snapping Elbow Syndrome as a Reason for Chronic Elbow Neuralgia in a Tennis Player - MR, US and Sonoelastography Evaluation. Pol J Radiol 2014;79:467-71.
10. Jacobson JA, Fessell DP, Lobo Lda G, Yang LJ. Entrapment neuropathies I: upper limb (carpal tunnel excluded). Semin Musculoskelet Radiol 2010;14:473-86.
11. Kerasnoudis A, Tsivgoulis G. Nerve Ultrasound in Peripheral Neuropathies: A Review. J Neuroimaging 2015;25:528-38.
12. Tang DT, Barbour JR, Davidge KM, Yee A, Mackinnon SE. Nerve entrapment: update. Plast Reconstr Surg 2015;135:199e-215e.
13. Paluch Ł, Noszczyk B, Nitek Ż, Walecki J, Osiak K, Pietruski P. Shear-wave elastography: a new potential method to diagnose ulnar neuropathy at the elbow. Eur Radiol 2018;28:4932-9.
14. Kowalska B. Assessment of the utility of ultrasonography with high-frequency transducers in the diagnosis of posttraumatic neuropathies. J Ultrason 2015;15:15-28.
15. Fink A, Teggeler M, Schmitz M, Janssen J, Pisters M. Reproducibility of Ultrasonographic Measurements of the Ulnar Nerve at the Cubital Tunnel. Ultrasound Med Biol 2017;43:439-44.
16. Dikici AS, Ustabasioglu FE, Delil S, Nalbantoglu M, Korkmaz B, Bakan S, Kula O, Uzun N, Mihmanli I, Kantarci F. Evaluation of the Tibial Nerve with Shear-Wave Elastography: A Potential Sonographic Method for the Diagnosis of Diabetic Peripheral Neuropathy. Radiology 2017;282:494-501.
17. Cingoz M, Kandemirli SG, Alis DC, Samanci C, Kandemirli GC, Adatepe NU. Evaluation of median nerve by shear wave elastography and diffusion tensor imaging in carpal tunnel syndrome. Eur J Radiol 2018;101:59-64.
18. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med 2016;15:155-63.
19. O'Driscoll SW, Horii E, Carmichael SW, Morrey BF. The cubital tunnel and ulnar neuropathy. J Bone Joint Surg Br 1991;73:613-7.
20. Granger A, Sardi JP, Iwanaga J, Wilson TJ, Yang L, Loukas M, Oskouian RJ, Tubbs RS. Osborne's Ligament: A Review of its History, Anatomy, and Surgical Importance. Cureus 2017;9:e1080.
21. Michael AE, Young P. Is triceps hypertrophy associated with ulnar nerve luxation? Muscle Nerve 2018;58:523-7.
22. Michelin P, Leleup G, Ould-Slimane M, Merlet MC, Dubourg B, Duparc F. Ultrasound biomechanical anatomy of the soft structures in relation to the ulnar nerve in the cubital tunnel of the elbow. Surg Radiol Anat 2017;39:1215-21.
23. Nakano K, Murata K, Omokawa S, Nakanishi Y, Shimizu

T, Kira T, Onishi T, Tanaka Y. Dynamic analysis of the ulnar nerve in the cubital tunnel using ultrasonography. J Shoulder Elbow Surg 2014;23:933-7.
24. Dong Q, Jacobson JA, Jamadar DA, Gandikota G, Brandon C, Morag Y, Fessell DP, Kim SM. Entrapment neuropathies in the upper and lower limbs: anatomy and MRI features. Radiol Res Pract 2012;2012:230679.
25. Schertz M, Mutschler C, Masmejean E, Silvera J. High-resolution ultrasound in etiological evaluation of ulnar neuropathy at the elbow. Eur J Radiol 2017;95:111-7.
26. Omejec G, Podnar S. Does ulnar nerve dislocation at the elbow cause neuropathy? Muscle Nerve 2016;53:255-9.
27. Miyamoto H, Halpern EJ, Kastlunger M, Gabl M, Arora R, Bellmann-Weiler R, Feuchtner GM, Jaschke WR, Klauser AS. Carpal tunnel syndrome: diagnosis by means of median nerve elasticity--improved diagnostic accuracy of US with sonoelastography. Radiology 2014;270:481-6.
28. Wolny T, Fernández-de-Las-Peñas C, Granek A, Linek P. Changes in Ultrasound Measurements of the Ulnar Nerve at Different Elbow Joint Positions in Patients with Cubital Tunnel Syndrome. Sensors (Basel) 2022.
29. Zhu Y, Jin Z, Luo Y, Wang Y, Peng N, Peng J, Wang Y, Yu B, Lu C, Zhang S. Evaluation of the Crushed Sciatic Nerve and Denervated Muscle with Multimodality Ultrasound Techniques: An Animal Study. Ultrasound Med Biol 2020;46:377-92.

Cite this article as: Liu L, Wang T, Qi H, Cui L, Bao S, Teng J. Multimodal ultrasound evaluation of asymptomatic ulnar nerve dislocation at the cubital tunnel. Quant Imaging Med Surg 2024;14(1):633-639. doi: 10.21037/qims-23-301