



Localization of Ulnar Neuropathy at the Wrist Using Motor and Sensory Ulnar Nerve Segmental Studies

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Background and Purpose Diagnosing ulnar neuropathy at the wrist (UNW) is often challenging, and performing several short segmental studies have been suggested for achieving this. We aimed to determine the utility of ulnar nerve segmental studies at the wrist (UNSWs) in patients with suspected UNW.

Methods Fourteen patients with typical symptoms of unilateral UNW were evaluated using conventional electrophysiological tests, UNSWs, and ultrasonography (US). In UNSWs, the ulnar nerve was stimulated at three sites (3 cm distal, just lateral, and 2 cm proximal to the pisiform), and recordings were made at the first dorsal interosseous (FDI) muscle and the fifth digit. Four types of UNW were identified by conventional ulnar nerve conduction studies based on motor and sensory fiber involvement. UNW was also categorized as either a proximal or distal lesion relative to the pisiform based on the UNSWs. The relationships between the conventional electrophysiological type, UNSW categorization results, and lesion location as verified by US were analyzed.

Results Proximal UNW lesions were associated with involvement of the entire deep motor and the superficial sensory fibers (type I). Distal lesions were more closely related to deep motor fibers that innervated the FDI (type III). All five proximal and six distal lesions seen in US matched the lesion locations found on UNSWs.

Conclusions Motor and sensory UNSW are considered useful assistive techniques for diagnosing UNW and localizing its lesion sites.

Keywords ulnar nerve; wrist; electrodiagnosis; ultrasonography; short segmental study.

INTRODUCTION

Ulnar neuropathy at the wrist (UNW) is a relatively rare disease that is primarily caused by direct trauma, ganglion cysts, chronic repetitive compressions on the ulnar hand, and injuries related to hand surgery.¹⁻⁶ The proper diagnosis and treatment of UNW requires the lesion sites to be localized and to be differentiated from proximal lesions using the following electrophysiological findings: a prolonged distal latency to the first dorsal interosseous (FDI) muscle, sparing of the dorsal ulnar cutaneous nerve (DUCN), and sparing of the ulnar-nerve-innervated muscles proximal to the wrist on needle electromyography (EMG).⁷⁻¹⁰ However, because of the variability of the involvement of fibers and difficulties in evaluating proximal lesions, conventional nerve conduction studies and needle EMG examinations have limitations in clearly localizing lesions around the wrist.

Short-segment incremental studies have been developed to overcome the above-described issue. At least three sets of short segmental studies with variable interval distances (including Guyon's canal from 1 cm to 8 cm) were developed for diagnosing UNW.^{7,11,12} Among them, ulnar nerve segmental studies at the wrist (UNSWs), introduced by Kim et al.,¹² enabled eval-

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uation of lesions that are proximal and distal to the pisiform (in 2- and 3-cm segments, respectively). The method also enabled assessment of the ulnar motor fibers to the FDI and ulnar sensory fibers (motor and sensory UNSWs, respectively).¹² Although reference values for normal individuals were determined using this method, researches on its usefulness in diagnosing UNW are lacking.

The aim of this study was to determine the usefulness of motor and sensory UNSWs in diagnosing UNW, and to present the clinical, electrophysiological, and ultrasonography (US) features of proximal and distal UNW lesions.

METHODS

Participants

Fourteen patients (10 males and 4 females) with unilateral UNW and typical symptoms of ulnar neuropathy (tingling sensations in the fourth or fifth finger, and weakness of the abductor digiti minimi [ADM] or FDI), and who underwent motor and sensory UNSWs were retrospectively enrolled between April 2004 and June 2017. Patients with bilateral UNW, polyneuropathy, cervical radiculopathy, other peripheral neuropathies including superficial radial sensory neuropathy, or who had undergone surgery to Guyon's canal were excluded. This study was approved by the Institutional Review Board of Korea University Ansan Hospital with a waiver of informed consent (approval no. 2017AS0096).

Electrophysiological assessment

The nerve conduction studies were performed using a Viking Select Electrodagnostic instrument (Nicolet Viasys Healthcare, Madison, WI, USA). The skin temperature of the patients' hands was maintained at over 34°C. Conventional ulnar motor nerve conduction studies with ADM and FDI muscle recordings were performed. The active recording electrode (E1) was attached to the belly of each muscle, while the reference recording electrode (E2) was attached to the base of the proximal phalanx bone of the fifth digit for the ADM, and to the proximal phalanx of the thumb for the FDI. The ulnar nerve was stimulated at the wrist (8 cm proximal to the E1 for the ADM), 3 cm distal to the medial epicondyle, and 7 cm proximal to the medial epicondyle with supramaximal stimulation.^{13,14} The baseline-to-peak amplitude, onset latency, and conduction velocity of the ulnar motor responses with ADM and FDI muscle recordings were measured. The difference in ipsilateral distal latency between FDIs and ADMs and the difference in side-to-side latency of ADMs and FDIs were calculated. The upper limits of the normal values of distal motor latency (DML) to the ADM, DML to the FDI, the difference in ipsilateral distal latency between the FDI and

ADM, and the difference in side-to-side latency of the ADM and FDI were set to 3.5, 4.2, 1.1, 0.5, and 0.6 ms, respectively. In addition, the normal reference values of the ADM and FDI amplitudes were set to 7.6 mV and 7.4 mV, respectively.

Ulnar sensory and dorsal ulnar cutaneous sensory nerve conduction studies were also performed. The involvement of motor and sensory fibers was evaluated based on the results of conventional ulnar nerve conduction studies. Ulnar nerve lesions were classified into the following four types according to the modified classification of UNW¹⁵: 1) type I, involvement of both deep motor fibers to the ADM and FDI, and superficial sensory fibers; 2) type II, involvement of both deep motor fibers to the ADM and FDI; 3) type III, involvement of deep motor fibers to the FDI; and 4) type IV, involvement of superficial sensory fibers (Fig. 1).

The lesions around the wrist were localized by performing motor UNSWs with FDI recordings and sensory UNSWs with fifth-finger recordings. In motor and sensory UNSWs, the ulnar nerve was stimulated at the following three points: 3 cm distal, just lateral, and 2 cm proximal to the pisiform.¹² If a

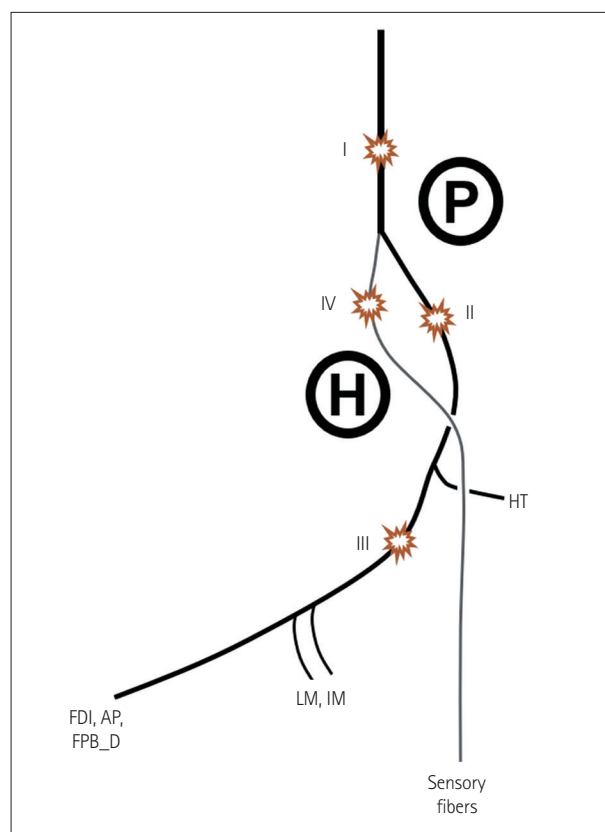


Fig. 1. Classification of ulnar neuropathy at the wrist and hand according to the method of Oh.¹⁵ AP, adductor pollicis; FDI, first dorsal interosseous; FPB_D, deep head of flexor pollicis brevis; H, hook of hamate; HT, hypothenar muscles; IM, interosseous muscles; LM, lumbrical muscles; P, pisiform bone.

more-distal lesion was suspected, additional stimulation was applied 5 cm distal to the pisiform. The upper normal limit of the latency difference of the proximal segment between the pisiform and 2 cm proximal to the pisiform, and the latency difference of the distal segment between the pisiform and 3 cm distal to the pisiform were set to 0.5 ms and 0.7 ms, respectively. The lower normal limits of the amplitude ratio of the proximal motor segment (between the pisiform and 2 cm proximal to the pisiform) and the amplitude ratio of the distal motor segment (between the pisiform and 3 cm distal to the pisiform) were both set to 0.92.¹² The lower normal limits of the amplitude ratios of the proximal and distal sensory segments were set to 0.89 and 0.87, respectively.

Needle EMG of the ADM, FDI, ulnar flexor digitorum profundus, and flexor carpi ulnaris was then performed, with the results designated as 0 for normal findings, 1 for abnormal motor-unit action potentials, and 2 for abnormal spontaneous activities with abnormal motor-unit action potentials. The types of UNW according to the involvement of the ADM, FDI, and distal ulnar sensory nerves in conventional electrophysiological studies were compared with the results for lesion localization (proximal or distal) on UNSWs. In addition, the sensitivities of the electrophysiological parameters in diagnosing UNW were obtained.

US assessments

After performing conventional ulnar nerve conduction studies and UNSWs, the ulnar nerve around the wrist was investigated by an expert physiatrist using US (Accuvix V20 system, Samsung Medison, Seoul, Korea) with a 5–13 MHz linear-array transducer in transverse and longitudinal views, and the patient in the supine position with their forearms supinated. Abnormal US findings for the ulnar nerve or adjacent structures were recorded, and compared with the proximal or distal lesion sites indicated by UNSWs.

RESULTS

The median age of the patients was 41 years (range: 28–62 years) and the median duration of symptoms was 3 months (range: 1–24 months). The clinical characteristics and findings are presented in Table 1. The conventional ulnar nerve conduction studies revealed that eight patients were type I, one patient was type II, and five patients were type III.

Motor UNSWs revealed proximal lesions to the pisiform in seven patients with type I UNW, with distal lesions observed in four type III patients and one type II patient. The patients with distal lesions included one (case 13) with an abnormal latency difference between 3 and 5 cm distal to the pisiform. A proximal lesion was shown in one patient (case 14) with

Table 1. Clinical characteristics and electrophysiological and US findings for the 14 subjects

Case	Sex	Age (yr)	Side	Type*	Lesion_M [†]	Lesion_S [‡]	EMG_ADM [†]	EMG_FDI [†]	Etiology	US finding	US lesion level
1 [§]	M	52	R	I	Proximal	NT	2	2	Compression	Ganglion	P+2 to P-0.5
2	F	58	R	I	Proximal	Proximal	1	1	Idiopathic	Ganglion	P+1 to P
3	M	28	R	I	Proximal	Proximal	2	1	Compression	Ganglion	P+2 to P
4 [§]	M	62	R	I	Proximal	NT	1	1	Laceration	Swelling	P+1
5	M	33	L	I	Proximal	Proximal	1	1	Idiopathic	Swelling	P+1
6	F	34	L	I	Proximal	Proximal	2	2	Fracture	NT	
7	M	32	R	I	Proximal	Proximal	2	1	Compression	NT	
8	F	53	R	I	Distal	Normal	2	1	Postoperative	Swelling	P-2
9	M	40	L	II	Distal	Normal	0	2	Compression	Ganglion	P-0.5 to P-2
10 [¶]	M	34	L	III	Distal	Normal	0	2	Idiopathic	Ganglion	4th metacarpal bone
11	M	42	R	III	Distal	Normal	0	1	Idiopathic	Intraneural cyst	P to P-2
12	M	47	L	III	Distal	Normal	0	2	Idiopathic	Swelling	P-2.5
13	M	50	L	III	Distal	Normal	0	2	Piercing	Swelling	P-1
14**	M	34	R	III	Proximal	Normal	0	2	Fracture	NT	

*Type I indicates an involvement of both deep motor fibers (to the ADM and FDI) and superficial sensory fibers, type II is a lesion involving both deep motor fibers to the ADM and FDI, and type III corresponds to an involvement of deep motor fibers to the FDI; [†]Lesion_M and Lesion_S indicate lesion site relative to the pisiform according to latency difference in motor and sensory UNSWs, respectively; [‡]Needle EMG of the ADM and FDI designated as 0 for normal findings, 1 for abnormal motor-unit action potentials only, and 2 for abnormal spontaneous activities with abnormal motor-unit action potentials; [§]In cases 1 and 4, UNSW was not tested (NT) because an ulnar sensory response was not obtainable or of very low amplitude; ^{||}In case 8, UNW developed following carpal tunnel release, and US demonstrated swelling of superficial and deep branches at 2 cm distal to the pisiform; [¶]In case 10, modified motor UNSW was performed to demonstrate the lesion site between 3 and 5 cm distal to the pisiform; ^{**}In case 14, multiple hand fractures including of the piriformis bone were produced using a cutting machine.

ADM, abductor digiti minimi; EMG, electromyography; F, female; FDI, first dorsal interosseous; L, left; M, male; NT, not tested; R, right; UNSWs, ulnar nerve segmental studies at the wrist; UNW, ulnar neuropathy at the wrist; US, ultrasonography.

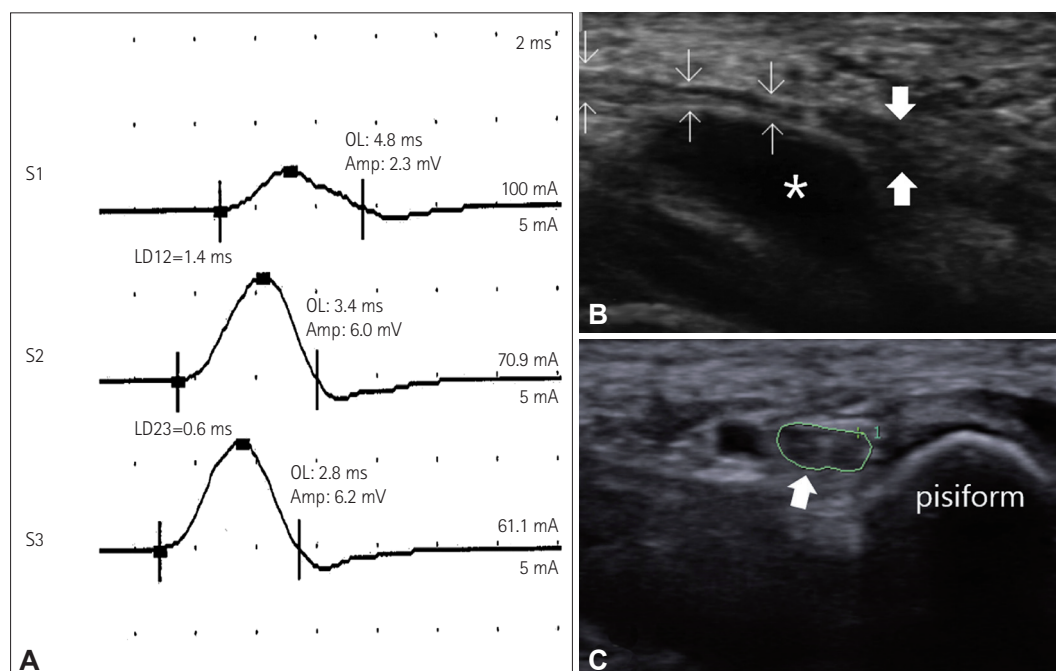


Fig. 2. Direct trace (A) of a motor ulnar nerve segmental study at the wrist (UNSW) and ultrasound images (B: longitudinal, C: axial) in a 52-year-old patient (case 1) with numbness and tingling sensation on his right little finger after playing table tennis using a heavier-than-usual bat. Conduction block and slowing were seen in the segment between the pisiform and 2 cm proximal to the pisiform in UNSW. Ultrasonography revealed that the ulnar nerve was compressed (thin arrows) by a ganglion cyst (asterisk) proximal to the pisiform and showed nerve swelling (thick arrows) at the pisiform level (cross-sectional area: 8.91 mm²). Amp, baseline-to-peak amplitude; LD12, latency difference between S1 and S2; LD23, latency difference between S2 and S3; OL, onset latency; S1, 2 cm proximal to the pisiform; S2, just lateral to the pisiform; S3, 3 cm distal to the pisiform.

type III UNW. Also, there was a distal lesion in one patient (case 8) with type I UNW.

US was performed in 11 of the 14 patients with UNW. Abnormal findings included ulnar nerve swelling (five cases), ganglion cysts (five cases) (Fig. 2), and an intraneural cyst (one case). US revealed five proximal and six distal lesions that matched the localization results (proximal or distal) indicated by motor UNSWs (Table 1).

The sensitivities of electrophysiological parameters for UNW are listed in Table 2. Although the statistical significance was low because of the small number of cases, the sensitivities of DMLs, amplitudes, or side-to-side latency differences of the FDI tended to be higher than those of the ADM.

DISCUSSION

This study evaluated the utility of motor and sensory UNSWs in diagnosing UNW. Also, the findings of the UNSWs were compared with those from conventional electrophysiological tests and US. Proximal UNW lesions were associated with type I, while distal lesions were related to type III. The US findings were consistent with the lesion localization results obtained in the UNSWs. Given the matching of the results between UNSWs and conventional lesion localizing methods

(electrophysiological tests and US), motor and sensory UNSWs are considered a useful assistive evaluation tool for diagnosing UNW.

UNW can be diagnosed to some extent using conventional ulnar nerve conduction studies and needle EMG. However, since stimulation is applied in the conventional tests only at the site proximal to the wrist, abnormalities such as conduction block or slowing at the wrist might not be directly observed. Also, selective nerve fascicle involvement in the forearm or elbow with DUCN sparing may be mistaken for a nerve lesion at the wrist.^{16,17} In contrast, four patients in the present study had abnormal DUCN conduction results, which may be due to an isolated injury caused by a fracture, compression, or laceration around the wrist. Such cases can be mistaken for ulnar nerve lesions at the forearm or elbow. In addition, although case 14 in the present study had a nerve lesion at the wrist proximal to the pisiform, the patient could have been misdiagnosed as having a lesion distal to the pisiform because the conventional examination showed an abnormality only in the FDI. In these situations, short segmental studies of the wrist can directly indicate abnormalities in the suspected area, thereby allowing the location of the ulnar nerve injury to be determined more accurately.

Several methods involving the use of short segmental

Table 2. Sensitivity of electrophysiological parameters for diagnosing ulnar neuropathy at the wrist

Parameter	Normal cutoff	Abnormal cases (sensitivity, %)		
		Total (14 cases)	Proximal (8 cases)	Distal (6 cases)
DML to ADM (ms)	3.8	6 (43)	5 (63)	1 (17)
DML to FDI (ms)	4.4	10 (71)	7 (88)	3 (50)
Ipsilateral LD between FDI and ADM (ms)	1.4	6 (43)	4 (50)	2 (33)
Side-to-side LD of ADM (ms)	0.5	9 (64)	7 (88)	2 (33)
Side-to-side LD of FDI (ms)	0.6	11 (79)	8 (100)	3 (50)
Amplitude of ADM (mV)	7.0	8 (57)	6 (75)	2 (33)
Amplitude of FDI (mV)	8.4	12 (86)	7 (88)	5 (83)
Motor UNSW, LD of proximal segment (ms)	0.5	8 (57)	8 (100)	0 (0)
Motor UNSW, LD of distal segment (ms)	0.7	6 (43)	0 (0)	6 (100)
Motor UNSW, AR of proximal segment	0.92	9 (64)	7 (88)	2 (33)
Motor UNSW, AR of distal segment	0.92	5 (36)	1 (13)	4 (67)
Sensory UNSW, LD of proximal segment (ms)	0.5	2 (14)	2 (25)	0 (0)
Sensory UNSW, LD of distal segment (ms)	0.7	0 (0)	0 (0)	0 (0)
Sensory UNSW, AR of proximal segment	0.89	5 (36)	4 (50)	1 (17)
Sensory UNSW, AR of distal segment	0.87	2 (14)	1 (13)	1 (17)

ADM, abductor digiti minimi; AR, amplitude ratio; DML, distal motor latency; FDI, first dorsal interosseous; LD, latency difference; UNSW, ulnar nerve segmental study at the wrist.

studies to diagnose UNW have been suggested previously. McIntosh et al.¹¹ reported on a short segmental study with FDI recordings in two patients with UNW. They found conduction blocks and delayed latencies of the ulnar nerve at the wrist with 1-cm incremental stimulation. However, the ulnar nerve in the wrist and palm runs in a curved line, making it difficult to accurately stimulate the ulnar nerve around Guyon's canal when using an interval of 1 cm. In addition, the larger number of stimuli may lengthen the procedure. To overcome these shortcomings, Cowdery et al.⁷ proposed a method in which two points were stimulated: the wrist and the palm around Guyon's canal. However, that method involves a relatively long distance between the two stimulations (6–8 cm), which could dilute focal nerve lesions and reduce the sensitivity of the test. On the other hand, the UNSW used in the present study utilized three stimulation points: one 2 cm proximal, one just lateral, and one 3 cm distal to the pisiform. This protocol can be performed relatively easily and rapidly, and has the advantage of distinguishing lesions that are distal and proximal relative to the pisiform.

This study used UNSWs to classify the sites of UNW lesion. Cases involving entire deep motor fibers and sensory fibers demonstrated abnormal findings in the proximal segments of both motor and sensory UNSWs. Cases involving entire deep motor branches or deep palmar branches of the distal ulnar nerve with sparing of sensation showed abnormal distal segments of motor UNSWs but normal sensory UNSWs. These findings indicate that UNSWs could provide valuable information regarding the location of UNW lesions

in conjunction with conventional ulnar nerve studies. Moreover, US performed following UNSWs confirmed nerve deformation (swelling) and adjacent structural abnormalities (ganglion cysts) that could have affected the corresponding lesion sites of the nerve. Since these US findings were consistent with the nerve lesion sites observed in the UNSWs, UNSWs are considered a useful assistive evaluation tool for diagnosing UNW.

The results of the electrophysiological tests indicated that the sensitivities of the latencies and amplitudes tended to be higher for FDI than for ADM recordings. This indicates that electrophysiological evaluations of FDI recordings should be considered even when the lesion site is suspected to be proximal to the pisiform.

This study had several limitations. First, the number of subjects was small, at 14, which limits the generalizability of our findings. Second, since the electrophysiological and US evaluations were performed only in patients with UNW, the specificity of the diagnostic tests could not be determined, and so future studies on the specificity of UNSW are needed. Third, cases involving only superficial sensory fibers were not observed in this study, while they have been reported previously.¹⁸ In order to demonstrate patterns involving motor or sensory fibers depending on location and etiology, further studies that include more patients with UNW are required. Fourth, the supramaximal stimulation intensities differed among individuals due to variations in the distance from the surface to the nerve.

In conclusion, motor and sensory UNSWs are considered

useful assistive techniques for diagnosing UNW and localizing the lesion sites. UNSW could be helpful in patients presenting typical symptoms of ulnar neuropathy without any electrophysiological abnormality in the elbow segment.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

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Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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REFERENCES

- Almeida V, de Carvalho M. Lesion of the deep palmar branch of the ulnar nerve: causes and clinical outcome. *Neurophysiol Clin* 2010;40:159-164.
- Seror P. Electrophysiological pattern of 53 cases of ulnar nerve lesion at the wrist. *Neurophysiol Clin* 2013;43:95-103.
- Kim NH, Kim DH. Ulnar neuropathy at the wrist in a patient with carpal tunnel syndrome after open carpal tunnel release. *Ann Rehabil Med* 2012;36:291-296.
- Soong M, Ring D. Ulnar nerve palsy associated with fracture of the distal radius. *J Orthop Trauma* 2007;21:113-116.
- Ginanneschi F, Filippou G, Milani P, Biasella A, Rossi A. Ulnar nerve compression neuropathy at Guyon's canal caused by crutch walking: case report with ultrasonographic nerve imaging. *Arch Phys Med Rehabil* 2009;90:522-524.
- Murata K, Shih JT, Tsai TM. Causes of ulnar tunnel syndrome: a retrospective study of 31 subjects. *J Hand Surg Am* 2003;28:647-651.
- Cowdery SR, Preston DC, Herrmann DN, Logigian EL. Electrodiagnosis of ulnar neuropathy at the wrist: conduction block versus traditional tests. *Neurology* 2002;59:420-427.
- Olney RK, Wilbourn AJ. Ulnar nerve conduction study of the first dorsal interosseous muscle. *Arch Phys Med Rehabil* 1985;66:16-18.
- Olney RK, Hanson M. AAEE case report #15: ulnar neuropathy at or distal to the wrist. *Muscle Nerve* 1988;11:828-832.
- Ebeling P, Gilliatt RW, Thomas PK. A clinical and electrical study of ulnar nerve lesions in the hand. *J Neurol Neurosurg Psychiatry* 1960;23:1-9.
- McIntosh KA, Preston DC, Logigian EL. Short-segment incremental studies to localize ulnar nerve entrapment at the wrist. *Neurology* 1998;50:303-306.
- Kim DH, Kang YK, Hwang M, Kwon HK, Lee HJ, Kim BG. Reference values of fractionated neurography of the ulnar nerve at the wrist in healthy subjects. *Clin Neurophysiol* 2005;116:2853-2857.
- Kim DH. Ulnar nerve conduction study of the first dorsal interosseous muscle in Korean subjects. *Ann Rehabil Med* 2011;35:658-663.
- Lee HJ, DeLisa JA. Manual of Nerve Conduction Study and Surface Anatomy for Needle Electromyography. Philadelphia: Lippincott Williams & Wilkins, 2005.
- Oh SJ. Clinical Electromyography: Nerve Conduction Studies. Philadelphia: Lippincott Williams & Wilkins, 1993.
- Venkatesh S, Kothari MJ, Preston DC. The limitations of the dorsal ulnar cutaneous sensory response in patients with ulnar neuropathy at the elbow. *Muscle Nerve* 1995;18:345-347.
- Mondelli M, Ginanneschi F, Aretini A. Diagnostic accuracy of sensory clinical findings of the hand dorsum and of neurography of the dorsal ulnar cutaneous nerve in ulnar neuropathy at the elbow. *Arch Phys Med Rehabil* 2019;100:908-913.
- Kim MJ, Kang JW, Kim GY, Lim SG, Kim KH, Park BK, et al. Diagnosis of pure ulnar sensory neuropathy around the hypothenar area using orthodromic inching sensory nerve conduction study: a case report. *Ann Rehabil Med* 2018;42:483-487.