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SURGERY ARTICLES

Correlation between preoperative Kimura inching studies and intraoperative findings during endoscopic-assisted decompression of the ulnar nerve at the elbow

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Abstract
Background During the evolution of the senior author's technique of ulnar nerve transposition to in situ decompression for ulnar neuropathy at the elbow, nerve conduction studies (NCS) including the Kimura inching method were performed preoperatively in an effort to ensure that all potential sites of compression were investigated intraoperatively. The purpose of this study is to compare the results of the Kimura inching technique with the intraoperative findings noted during decompression of the ulnar nerve at the elbow.
Methods The medical records of consecutive patients who underwent in situ decompression of their ulnar nerves combined with endoscopic examination between March and December of 2009 were retrospectively reviewed. The site of ulnar nerve compression noted using the Kimura inching technique was compared with the intraoperative findings.
Results Twelve consecutive patients (four with bilateral symptoms) underwent endoscopic ulnar nerve compression in the study period for a total of 16 cases analyzed. In 12 cases, the Kimura method localized the site of compression to Osborne's bands and/or the aponeurosis of the flexor carpi ulnaris (FCU). Intraoperatively, compression was noted at Osborne's bands, the FCU aponeurosis, and/or the FCU) muscle proper in all 16 patients. There was partial or full correlation between the nerve conduction data and intraoperative findings in 13/16 cases.
Conclusions There was good but not perfect agreement between the NCS and intraoperative findings, perhaps because transcutaneous NCS are less accurate when a nerve is surrounded by muscle. The information obtained in this study is valuable when planning surgery to address ulnar nerve compression.

Keywords Kimura inching technique · Cubital tunnel syndrome · Ulnar neuropathy · Endoscopic in situ decompression

Background

The Kimura inching technique was first described in 1978 by Dr. Jun Kimura [6], as a method for determining nerve conduction velocity (NCV) across relatively short distances. It was initially used to pinpoint median nerve compression at the carpal tunnel, but is now a widely used method to precisely localize focal slowing in ulnar neuropathy, peroneal neuropathy at the fibular head, and carpal tunnel syndrome [3, 8, 9]. The term "inching" is in fact a misnomer, as many neurologists performing these studies use 1–2-cm increments, rather than inches. During the evolution of the senior surgeon's (DJN) technique of ulnar nerve transposition to in situ decompression for ulnar neuropathy at the elbow, nerve conduction studies (NCS) including the Kimura method were performed preoperatively on consecutive patients in an effort to ensure that all potential sites of compression were investigated intraoperatively. To date, no studies exist which correlate preoperative Kimura NCS-defined sites of nerve compression

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to the surgeon's findings at the time of nerve decompression surgery. The purpose of this study is to compare the preoperative Kimura inching study results in patients with ulnar neuropathy at the elbow with the sites of compression noted at the time of ulnar nerve decompression.

Methods

A retrospective chart review was conducted on consecutive patients who underwent in situ decompression of the ulnar nerve combined with endoscopic evaluation performed by the senior surgeon (DJN) between March and December of 2009. There were no exclusion criteria. Nerve conduction studies were performed on all patients preoperatively by a single neurologist (MMM) in all patients. The Kimura inching technique was performed as part of this study and involves segmental stimulation of the ulnar nerve at 2-cm intervals from a point 4 cm proximal to the medial epicondyle to a point 4 cm distal to the medial epicondyle (see Fig. 1). The arm is kept in a slightly flexed position in order to maximally correlate skin surface measurement and true nerve length [8]. The compound muscle action potential is recorded from the abductor digiti minimi muscle, and the latency and NCV of the ulnar nerve are determined at 2-cm increments. The point(s) of greatest difference in latency between inching segments were noted. A significant difference in latency was defined as being greater than or equal to 0.8 ms between inching segments. The senior surgeon's ulnar nerve decompression technique has been described elsewhere [7] and involves a 4-cm incision posterior to the medial epicondyle and release of any compressive fibers within the proximal cubital tunnel. A 2.7-mm 30° endoscope is then inserted atraumatically and the nerve is visualized 8–10 cm proximal and distal to the medical epicondyle. Any compressive fibers crossing the ulnar nerve are noted and released. The sites of compression visualized as well as the locations of release at the time of surgery were recorded from the medical record. The aforementioned zones 1 through 4 shown in Fig. 1 can be correlated to the following deeper structures: zone 1, the proximal medial intramuscular septum/distal edge of the arcade of Struthers/deep brachial fascia; zone 2, the distal medial intramuscular septum and the anconeus epitrochlearis; zone 3, Osborne's bands and the aponeurosis of the two heads of the flexor carpi ulnaris (FCU); and zone 4, the FCU muscle. These correlations are approximate and are likely to vary from patient to patient.

Results

A total of 12 patients (four women and eight men) underwent endoscopic ulnar nerve decompression at the elbow during the study period. Four patients underwent decompression on both left and right ulnar nerves on separate occasions, for a total of 16 cases analyzed in this study.

Nerve Conduction Data

The nerve conduction study results and intraoperative findings are listed in Table 1. No patients had focal nerve conduction delay noted within zone 1 (the proximal medial intramuscular septum/distal edge of the arcade of Struthers/deep brachial fascia) or zone 4 (the FCU muscle). In three patients, the inching technique suggested significant compression only at zone 2 (the distal medial intramuscular septum and the anconeus epitrochlearis). Eleven patients had compression noted only at zone 3 (Osborne's bands and the aponeurosis of the two heads of the FCU). In one patient, the zone of neuropathy was suggested as spanning zones 2 and 3 (2 cm above to 2 cm below the medial epicondyle). One patient with clinical

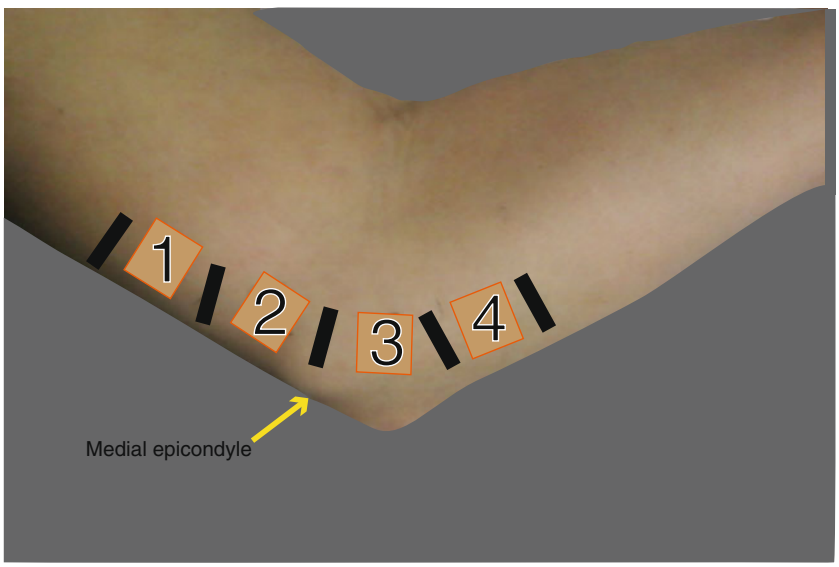

Fig. 1 Medial aspect of the elbow. *Zone 1* The proximal medial intramuscular septum/distal edge of the arcade of Struthers/deep brachial fascia. *Zone 2* The distal medial intramuscular septum and the anconeus epitrochlearis. *Zone 3* Osborne's bands and the aponeurosis of the two heads of the FCU. *Zone 4* The FCU muscle

Table 1 Zones of compression listed for individual patients based on nerve conduction studies and intraoperative findings

			Zone of compression	
Patient #/arm		Difference in latency at point of compression (ms)	Defined by Kimura inching technique	Defined by operative findings
1		3.4	2	2 and 3
2		2.45	3	3 and 4
3	L	1.25	3	3 and 4
	R	2.1	3	3
4		0.8	3	3 and 4
5		1.2	3	3
6		1.35	3	3
7	L	0.95	2 and 3	3 and 4
	R	0.95	3	3 and 4
8	L	1.05	3	3 and 4
	R	1.2	3	3
9		1.2	3	3 and 4
10	L	0.8	3	3
	R	1	2	3
11		1.65	2	3 and 4
12		n/a	n/a	3 and 4

Patient no. 12 had clinical symptoms strongly suggestive of ulnar neuropathy but failed to reveal any evidence of ulnar nerve compression on the nerve conduction study

ms milliseconds, *n/a* not applicable

symptoms strongly suggestive of ulnar neuropathy failed to reveal any evidence of ulnar nerve compression on the nerve conduction study. The average difference in motor latency within the segment of compression (excluding the latter patient) was 1.42 ms.

Intraoperative Findings

No patients were noted to have compressive bands within zone 1 (the deep brachial fascia/distal arcade of Struthers or proximal medial intramuscular septum). One patient had compression noted at both zones 2 and 3 (the distal medial intramuscular septum/anconeus epitrochlearis/Osborne's bands and/or the aponeurosis proximal to the FCU). In six patients, zone 3 was found to be the site of compression (Osborne's bands and/or the aponeurosis proximal to the FCU muscle). Nine patients had compressive pathology in both zones 3 and 4 (the latter corresponding to the FCU muscle).

Correlation between the Kimura Inching Method and Intraoperative Findings

The majority of cases (13/16) had partial or total agreement between the Kimura inching NCV results and the intraoperative findings (eight and five patients, respectively). Partial agreement was defined as finding compression in least one of the same zones on both the NCV study and intraoperatively. Total agreement was defined finding the exact same zones of compression on both accounts. In 3 of the 16 cases, there was no correlation found between the NCV data and intraoperative results.

Discussion

In the evolution of his practice, the senior surgeon transitioned from anterior transposition of the ulnar nerve to in situ decompression. With the former procedure, the entire nerve is liberated in order to transpose it to its new position, effectively releasing any potential sites of compression. However, simple decompression does not entail extensive release. The Kimura NCS were used as a screening tool to avoid missing any specific regions of compression intraoperatively. To our knowledge, this is the first study comparing preoperative nerve conduction studies to the surgeon's findings noted at the time of ulnar nerve decompression surgery.

Interestingly, at the time of surgery, we found no areas of compression at the arcade of Struthers, consistent with the senior author's previous experience with both open and endoscopic release of the ulnar nerve at the elbow. The effect of this structure on ulnar nerve compression at the elbow is controversial and likely only to be relevant after anterior transposition [1, 4, 10–12].

The zones of compression defined in this study are approximate and have not been independently validated. Intraoperative nerve conduction studies would be required to confirm the precise correlation between the electromyographic findings and the zones of compression identified at the time of surgery. Unfortunately, given its retrospective nature, we could not obtain this information and acknowledge this as a limitation of the study. An additional limitation of this study is the potential confirmation bias introduced by the surgeon's preoperative knowledge of the NCS findings. This was unavoidable given the purpose of obtaining the preoperative NCS described above.

The Kimura method correlated with the sites of compression noted intraoperatively in the majority of the patients, suggesting good, but not perfect agreement. The most common intraoperative finding in our patients was compression of the nerve within zones 3 and 4 (at Osborne's bands, the FCU aponeurosis, and within the FCU muscle itself), while the Kimura technique suggested compression most often only within zone 3. One of the reasons for the discrepancy may be that transcutaneous nerve conduction velocity is not accurately measured when a nerve is surrounded by muscle. Many of the patients in this study had compression by the FCU fascia or muscle, and this may have been difficult to pick up by the NCV study. Interestingly, comparison of ultrasound and nerve conduction studies evaluating the

median nerve within the carpal tunnel suggests that focal slowing may be located *proximal* to the area of physical compression [5]. How this relates to compression of the ulnar nerve at the elbow has not been studied. MRI has also been shown to be both sensitive and specific in diagnosing ulnar nerve entrapment at the elbow [2] and would be a useful adjunct to the preoperative workup in these patients.

Despite the imperfect correlation, it is important to note that the inching technique localized the site of compression to the region of the cubital tunnel in the majority (13/16) patients, rather than at more distal or proximal sites. Although this study has limitations outlined above, the information is nonetheless valuable when planning surgery to address ulnar nerve compression.

Conflict of interest The authors have no financial disclosures or grant support to declare.

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