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The Impact of Carpal Tunnel Syndrome on Ulnar Nerve: An Electro-Clinical Study

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Abstract

Introduction: The paresthesias' spread to whole hand in carpal tunnel syndrome (CTS) raises the hypothesis of ulnar nerve involvement. We performed this study to verify this hypothesis.

Methods: We analyzed electro-clinical data of 304 patients with suspected idiopathic CTS to investigate correlations between nerve conduction study (NCS) parameters (amplitude of sensory potential (ASP), sensory conduction velocity (SCV) and motor distal latency (MDL)) of ulnar (u) and median (m) nerves, and between ulnar parameters and paresthesias' topography.

Results: A positive correlation between ASPu and ASPm (r= 0.13, p<0.05), and significant difference of ulnar parameters averages between affected and healthy hands were highlighted. Ulnar parameters averages were different according to paresthesias' topography (median territory versus whole hand), but not statistically significant.

Discussion: Our results support the hypothesis of CTS impact on ulnar nerve at the wrist, which has major implications not only to understand physiopathology and symptoms, but also for therapeutic management.

Keywords: Carpal tunnel syndrome (CTS); Ulnar nerve entrapment electrodiagnosis electroneuromyography (ENMG); Nerve conduction study (NCS); Paresthesias' topography

Abbreviations

ASP: Amplitude of Sensory Potential; ASPm: Amplitude of Sensory Potential of Median Nerve; ASPu: Amplitude of Sensory Potential of Ulnar Nerve; BMI: Body Mass Index; CTS: Carpal Tunnel Syndrome; ENMG: Electroneuromyography or Electroneuromyographic; Kg: Kilogram; m: Meter; MDL: Motor Distal Latency; MDLm: Motor Distal Latency of Median Nerve; MDLu: Motor Distal Latency of Ulnar Nerve; MRI: Magnetic Resonance Imaging; n: Number; NCS: Nerve Conduction Study; s: Second; SCV: Sensory Conduction Velocity; SCVm: Sensory Conduction Velocity of Median Nerve; SCVu: Sensory Conduction Velocity of Ulnar Nerve; SDLu: Sensory Distal Latency of Ulnar Nerve; TCL: Transverse Carpal Ligament; UTS: Ulnar Tunnel Syndrome

Introduction

Carpal tunnel syndrome (CTS) is the most common compressive neuropathy in humans. It is related to a focal compression of the median nerve in the carpal tunnel due to a local hypertension. Its clinical, paraclinical and therapeutic aspects were the subjects of many studies worldwide [1-4].

Patients with idiopathic CTS may complain of paresthesias (prickling, itching, numbness and other abnormal sensations) of whole palmar surface of the hand, involving the sensory territory of the ulnar nerve [2,5-8] (**Figure 1**). This raises the hypothesis of a possible transfer of excessive pressure from the carpal tunnel to the Guyon canal, which could bring out an entrapment of the ulnar nerve [3,5,9].

The association between CTS and ulnar tunnel syndrome (UTS), which is a compression of the ulnar nerve in the Guyon's lodge, has been frequently debated. In 1973, a study conducted by Sedal et al. [10] evoked for the first time a correlation between NCS parameters of the ulnar nerve and those of the median one in hands affected by CTS. However, a number of studies published since the 1970s, based on electroneuromyography (ENMG) and/or other tools such as pressure measurement in the Guyon tunnel using endoscopic techniques [11,12] or ultrasonographic morphology [13], showed conflicting results [14,15].

The aim of the present study was:

- To highlight possible repercussions of CTS on the nerve conduction study (NCS) parameters of the ulnar nerve at the wrist.

- To establish a presumed correlation between the severity of CTS and the degree of ulnar nerve entrapment.
- To investigate the hypothesis of a correlation between changes in NCS parameters of the ulnar nerve and the spread of paresthesias to the sensory territory of the ulnar nerve in some patients with idiopathic CTS.

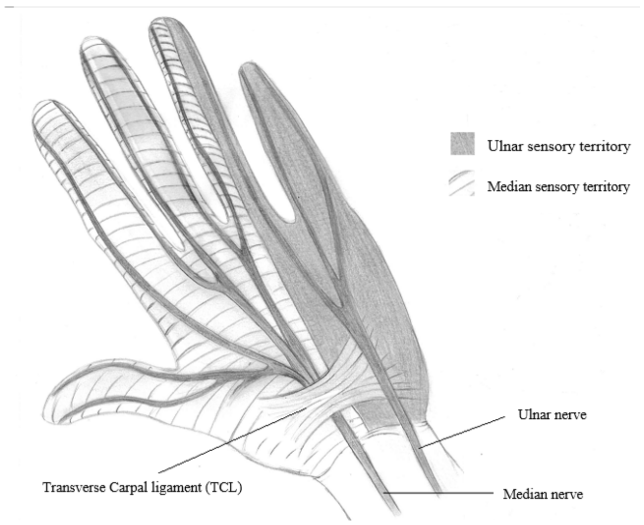

Figure 1 Median and ulnar nerves sensory territories in the palmar surface of the hand. (Please note that TCL is both the roof of the carpal tunnel and the floor of Guyon's canal).

Population and Methods

Study design

This work was retrospective. Clinical and electrophysiological data of patients with unilateral or bilateral CTS confirmed by ENMG were collected. A period of three years (early 2010 until the end of 2012) was fixed.

Inclusion and non-inclusion criteria

Only data of subjects with idiopathic CTS were retained, regardless of their age, gender, ethnic origins and professions. Thus, all those who had an history of systemic disorders predisposing to this disease (such as diabetes mellitus, hypothyroidism or chronic renal failure), an history or clinical signs of peripheral neuropathy, cervical radiculopathy or a trauma of upper limb including fractured wrist, were excluded from this study.

Population

304 patients were retained. All of them were examined and recorded in the nervous system functional explorations department of Sahloul teaching hospital (Tunisia), by the same physician in order to guarantee the reliability and the reproducibility of the results.

The study was both:

- Intra-individual: 43 unilateral and 261 bilateral CTS.
- Inter-individual: Two groups of hands had been constituted from the whole of the 608 hands: “affected hands” with electrophysiological signs of CTS (n=565), and “healthy hands” with normal nerve conduction study (n=43).

NCS parameters

The following parameters of median and nerves were used for this study:

- Sensory nerve conduction velocity (SCV): respectively SCVm and SCVu.
- Amplitude of sensory potential (ASP): respectively ASPm and ASPu.
- Motor distal latency (MDL): respectively MDLm and MDLu.

To highlight a possible correlation between the severity of CTS and the degree of repercussion on the parameters of the ulnar nerve, we used a local ectrophysiological CTS classification in 5 increasing severity stages, based on ENMG data. This classification, presented in **Table 1**, was inspired from Bland et al. graduation of CTS [16].

Recording system

The same ENMG device, a Neuropack MEB-2200 K, manufactured by Nihon Kohden company (Japan), was used to record all patients.

Table 1 Local electroneuromyographic classification of CTS.

Increasing severity stages	Title	Description
1	Minimal CTS	Decreased SCVm and/or ASPm, with normal MDLm.
2	Intermediate CTS	Decreased SCVm and/or ASPm, with elongated MDLm < 6 ms.
3	Moderate CTS	Decreased SCVm and/or ASPm, with elongated MDLm ≥ 6 ms.
4	Severe	Absent sensory response and elongated MDLm ≥ 6 ms.
5	Very severe	Absent sensory and motor responses.

Abbreviations: SCVm: Sensory nerve conduction velocity of the median nerve. ASPm: Amplitude of sensory potential of the median nerve. MDLm: Motor distal latency of the median nerve. Local Standards: normal SCVm ≥ 40 m/s (meters per second); normal APSm ≥ 10 µV (microvolt); normal LDM ≤ 4 ms (millisecond)

Recording protocol

Both hands of each patient were examined systematically. To explore the median nerve, we proceeded as follows:

- For the sensory response, we stimulated the middle finger and collected the response on the anterior face of the wrist (**Figure 2A**).
- The motor response was obtained by stimulating the median nerve in two points: a distal point on the anterior surface of the wrist, and a proximal point on the middle of the elbow crease. The motor potential was collected on the abductor pollicis brevis muscle (thenar eminence) (**Figure 2B**).

To explore the ulnar nerve, we used the following techniques:

- The sensory response was obtained by stimulating the fifth finger and collecting on the internal edge of the wrist frontal surface (**Figure 2C**).
- The motor response was recorded by making a distal stimulation on the same point used for the collection of the sensory response, and a proximal one just below the internal epicondyle of the humerus. The collection was done on the abductor digiti minimi muscle (hypothenar eminence) (**Figure 2D**).

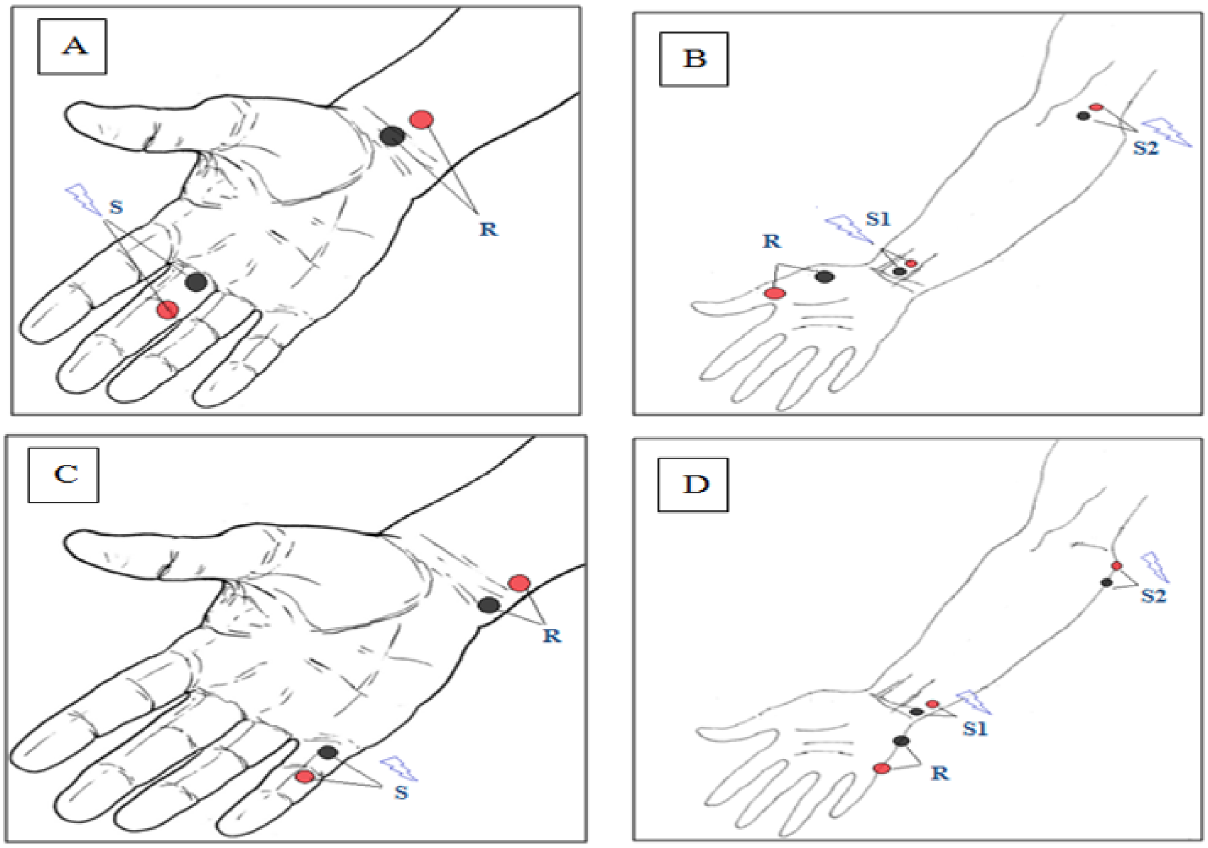

Figure 2 Nerve conduction study (NCS) Recording protocol: **A**: Sensory conduction study of the median nerve. **B**: Motor conduction study of the median nerve. **C**: Sensory conduction study of the ulnar nerve. **D**: Motor conduction study of the ulnar nerve. (S: sensory stimulation. S1: first=distal motor stimulation. S2: second=proximal motor stimulation. R: record. Black point: active electrode. Red point: reference electrode.)

Statistical study

SPSS software (version 20) was used to perform data entry and analysis. Pearson correlation was used to search significant correlation between the parameters of the median nerve and those of the ulnar one.

Comparing averages of the NCS parameters was done using Student test. Significance was fixed at the 0.05 level [17].

Results

On the basis of established ENMG criteria, CTS was diagnosed in 304 patients (mean age: 45 years, range: 18-81 years). 93% of them were women. According to the calculated body mass index (BMI), 49% were obese (BMI > 30 $Kg.m^{-2}$) and 35% had overweight (BMI > 25 $Kg.m^{-2}$). Clinical complaints were bilateral in 79% of patients and asymmetric in 64% of cases. Nerve conduction study showed bilateral CTS in 86% of patients and was asymmetric (different electrophysiological stage) for 69% of them.

Intra-individual study

For the 43 patients with unilateral CTS, we compared ulnar NCS parameters of the affected side with those of the healthy one. Results were as follows:

ASP and SCV of ulnar nerve (ASPu, SCVu) of affected side were lower, in 65.1% of patients, than those of the opposite one. The MDL of ulnar nerve (MDLu) of the affected side was also more elongated, compared to the opposite one, in 65.1% of cases. However, the difference between the APSu of the two sides was significant (≥30% [18]) in only 32.1% of the cases and all ulnar NCS parameters were in normal standards.

For the 209 patients suffering from bilateral CTS with predominant side (different electrphysiological stages), we compared ulnar NCS parameters of the two sides. We noted that ASPu and SCVu were lower in the more affected side for respectively 57.4% and 54.5% of patients. Moreover, the MDLu of the more affected side was more elongated than that of the opposite side in 52.1% of cases.

52 patients had bilateral CTS with the same electrophysiological stage in both hands. They were not included in the intra-individual study.

Inter-individual study

This study concerned 608 hands (corresponding to 304 subjects) divided in two groups: "affected hands" (n=565) and "healthy hands" (n=43).

In the affected hands group, the topography of paresthesias was localized in the sensory territory of the median nerve in 48.4% of cases, and in whole hand in 51% of cases. The remaining 1.6% concerned atypical presentations such as exclusive paresthesias in ulnar nerve sensory territory. In the same group, there was statistically significant positive linear correlation between ASPm and ASPu (r = 0.13, p<0.05) (**Figure 3**). However, no significant correlation was found between respectively SCVm and SCVu, MDLm and MDLu, MDLm and ASPu, and MDLm and SCVu.

The comparison of ulnar NCS parameters averages of the two groups is summarized in **Table 2**, which shows that there saw significant difference for all parameters (ASPu, SCVu and MDLu).

To study changes of ulnar nerve NCS parameters according to CTS severity, the affected hands group was divided in two ways:

1. Based on our previously cited classification of CTS severity, in five increasing stages. The following distribution was found: stage 1 (29%, n=163 hands), stage 2 (56%, n=315), stage 3 (7%, n=40), stage 4 (7%, n=42), stage 5 (1%, n=5). The averages of ulnar NCS parameters of each stage were compared with those of "healthy hands" group. Statistically significant values were found for stages 1, 2 and 3 but not for stages 4 and 5 (**Table 3**). Changes of ulnar NCS parameters were more important in stage 2 than in stage 1. They were statistically significant for SCVu and MDLu (**Table 4**).
2. Based on another neurophysiological classification of CTS severity, proposed by Ginanneschi et al. [1]. "Affected hands" group was divided in two stages: stage I defined as "abnormal SCVm and/or ASPm and normal MDLm", n=163 (29%), and stage II defined as "abnormal SCVm and/or ASPm and elongated MDLm", n=402 (71%). Changes of ulnar NCS parameters according to CTS severity degree was studied by comparing averages of ulnar NCS parameters in each stage with those of "healthy hands" group. The results are shown in **Table 5**. Changes of SCVu and MDLu were significantly more prominent in stage II than in stage I (**Table 6**).

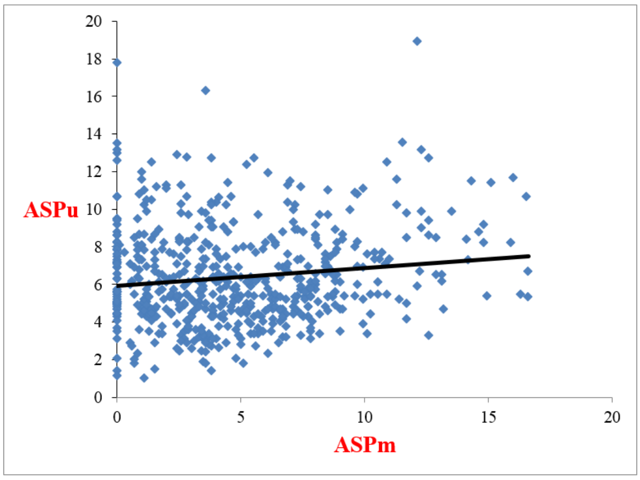

Figure 3 Correlation curve of ASPu and ASPm. (ASPu: Amplitude of sensory potential of the ulnar nerve. ASPm: Amplitude of sensory potential of the median nerve.)

Table 2 Averages' comparison of ulnar nerve NCS parameters between "affected hands" and "healthy hands" groups.

	Affected hands n=565	Healthy hands n=43	p-value
ASPu (µV)	6.38	7.61	0.003 **
SCVu (m/s)	52.17	54.21	0.005 **
MDLu (ms)	2.75	2.59	0.004 **

Abbreviations: SCVm: Sensory nerve conduction velocity of the median nerve. ASPm: Amplitude of sensory potential of the median nerve. MDLm: Motor distal latency of the median nerve.

Local Standards: normal SCVm ≥ 40 m/s (meters per second); normal APSm ≥ 10 µV (microvolt); normal LDM ≤ 4 ms (millisecond)

Table 3 Averages of ulnar NCS parameters in each CTS severity stage (local classification), in comparison with those of "healthy hands" group.

	CTS stage 1 (n=163)	CTS stage 2 (n=315)	CTS stage 3 (n=40)	CTS stage 4 (n=42)	CTS stage 5 (n=5)
ASPu (µV)	6.5 (H=7.61) p=0.010**	6.18 (H=7.61) p=0.001***	6.68 (H=7.61) p=0.102	6.73 (H=7.61) p=0.160	9.04 (H=7.61) p=0.350
SCVu (m/s)	52.77 (H=54.21) p=0.731	51.56 (H=54.21) p=0.001***	52.25 (H=54.21) p=0.020*	54.1 (H=54.21) p=0.901	53.58 (H=54.21) p=0.760
MDLu (ms)	2.68 (H=2.59) p=0.912	2.8 (H=2.59) p<0.001***	2.73 (H=2.59) p=0.040*	2.69 (H=2.59) p=0.160	2.67 (H=2.59) p=0.610
Abbreviations: H: Average of the corresponding parameter in « healthy hands » group; n= number of hands; ms: millisecond; m/s: meter /second; µV: microvolt. *Significant: 0.05 ≥ p > 0.01; **Highly significant : 0.01 ≥ p > 0.001; *** Very highly significant : p≤0.001					

Table 4 Comparison of ulnar NCS parameters averages between stages 1 and 2 (local classification).

	CTS stage 1 (n=163)	CTS stage 2 (n=315)	p (stage 1/stage 2)
ASPu (µV)	6.5	6.18	0.202
SCVu (m/s)	52.77	51.56	0.008**
MDLu (ms)	2.68	2.8	<0.001***
Abbreviations: n=Number of hands; ms: millisecond; m/s: meter/second; µV: microvolt. * Significant: 0.05 ≥ p > 0.01; **Highly significant: 0.01 ≥ p > 0.001; *** Very highly significant: p ≤ 0.001			

Table 5 Averages of ulnar NCS parameters in each CTS severity stage (Ginanneschi's classification), in comparison with those of "healthy hands" group.

	CTS stage I (n=163)	CTS stage II (n=402)
ASPu (µV)	6.52 (H=7.61) p=0.020*	6.33 (H=7.61) p=0.003**
SCVu (m/s)	52.81 (H=54.21) p=0.084	51.91 (H=54.21) p= 0.002**
MDLu (ms)	2.68 (H=2.59) p=0.091	2.78 (H=2.59) p=0.001**
Abbreviations: H: average of the corresponding parameter in « healthy hands » group; n= number of hands; ms: millisecond; m/s: meter /second; µV: microvolt. * Significant: 0.05 ≥ p > 0.01; **Highly significant : 0.01 ≥ p > 0.001; *** very highly significant : p ≤ 0.001		

Finally, we sought to find any correlation between modification of ulnar NCS parameters and topography of paresthesias. **Table 7** shows that in case of CTS with paresthesias restricted to median nerve territory (n=252), the averages of the sensory parameters of the ulnar nerve (ASPu and SCVu) were significantly decreased compared with those of"healthy hands"group.

Table 6 Comparison of ulnar NCS parameters averages between stages 1 and 2 (Ginanneschi's classification).

	CTS stage I (n=163)	CTS stage II (n=402)	p (StadeI/ StadeII)
ASPu (µV)	6.52	6.33	0.437
SCVu (m/s)	52.81	51.91	0.036*
MDLu (ms)	2.68	2.78	0.003**
Abbreviations: n=number of hands; ms: millisecond; m/s: meter /second; µV: microvolt. *Significant: 0.05 ≥ p > 0.01; **Highly significant: 0.01 ≥ p > 0.001; ***Very highly significant: p ≤ 0.001			

These values were also decreased and statistically more significant when paresthesias extended to the ulnar nerve territory and thus covering the whole palmar surface of the hand (n=267). Moreover, the average of MDLu was significantly more elongated in hands with paresthesias in the only median territory compared to MDLu average of "healthy hands" group. This elongation becomes more significant when paresthesias affect the whole hand. When comparing ulnar nerve NCS parameters averages of the two groups of paresthesias' topography, there were no significant differences.

Table 7 Variation of the averages of ulnar NCS parameters according to paresthesias' topography.

	Restricted Paresthesias to the median nerve territory (n=252)	Paresthesias in the whole hand (n=267)
ASPu (µV)	6.6 (H=7.61) p = 0.023*	6.24 (H=7.61) p = 0.002**
SCVu (m/s)	52,35 (H=54.21) p = 0.017*	52,04 (H=54.21) p= 0.004**
MDLu (ms)	2,74 (H=2.59) p =0.010*	2,75 (H=2.59) p =0.004**
Abbreviations: H: average of the corresponding parameter in « healthy hands » group; n= number of hands; ms: millisecond; m/s: meter /second; µV: microvolt. *Significant: 0.05 ≥ p > 0.01; **Highly significant: 0.01 ≥ p > 0.001; ***Very highly significant: p ≤ 0.001		

Discussion

The idea for this study took its origins from two observations:

- The first one is that many patients with CTS, confirmed by an ENMG exam, complained clinically of paresthesias which were not limited to the sensory territory of the median nerve, but also reached the territory of the ulnar nerve.
- The second one is that in some patients with idiopathic CTS, we have noted that ulnar nerve electrophysiological parameters (especially MDLu, ASPu and SCVu) tended to a change.

The question was then: is there an impact of CTS on the ulnar nerve at the wrist?

Discussion of the Results

Population characteristics and clinical data

Population characteristics of the present study were similar to what is usually mentioned in CTS literature. This concerned especially mean age which was equal to 45 years [5,10], women predominance (93% of patients) [19-21], frequent obesity (49% had a BMI value beyond 30 kg.m^{-2}) [21-24] and predominance of bilateral CTS (86% of patients) [25,26].

In addition, 51% of our patients had paresthesias at the whole palmar surface hand. Several other studies have also reported the same phenomenon during CTS with similar percentages [6,7,27].

Intra-individual study

Approximately two-thirds of patients with unilateral CTS had lower ASPu and SCVu and more elongated MDLu in the affected side compared to the opposite one. The difference between the APSu of the two sides were electrically significant, with reference to criteria set by Fournier [18], in 32.1% of the cases. Similarly, more than half of patients with bilateral CTS had lower ASPu and SCVu and more elongated MDLu in the predominant side.

To our knowledge, no study had conducted similar comparison.

Inter-individual study

The present study found a statistically significant positive correlation between ASPu and ASPm in CTS. Similar results were found by some authors [10,28,29]. However, there was no significant positive correlation between MDLu and MDLm, which was also noted by Ginanneschi et al. [28]. Moreover, contrary to what has been reported in other studies [3,10,27,28], we did not detect correlations, neither positive nor negative, between other parameters, especially SCVu and SVCm [28], ASPu and SCVm [10], ASPu and MDLm [3,10,28], SCVu and MDLm [27,28] and sensory distal latency of ulnar nerve (SDLu) and MDLm [27].

On the other hand, the present study showed statistically significant decrease in mean values of sensory parameters of the ulnar nerve (ASPu and SCVu) and increase of MDLu average in the group of affected hands in comparison with the corresponding values in the healthy hands' group. Similar results were found by other authors both for sensory parameters of the ulnar nerve [3,10,27] and MDLu [10,28]. However, Azmy et al. [30] found a non-significant difference between APSu averages of healthy and affected hands. In addition, Ginanneschi et al. [28] have not noticed a significant difference for MDLu. They explain this result by a greater fragility of the sensory fibers than the motor ones, which resist more to nerve compression in case of CTS, thus preserving the motor NCS parameters of the ulnar nerve.

In the present study, we also investigated changes of ulnar nerve NCS parameters according to the severity of CTS, by considering two CTS neurophysiological classifications. The averages of ulnar nerve NCS parameters of each stage were compared with those of “healthy hands” group:

1. According to local classification of CTS. Significant correlation was found for stages 1, 2 and 3, but not for stages 4 and 5. However Ginanneschi et al. reported increasing ulnar sensory parameters’ changes when going from stage 2 to stage 5 [3,28], using a comparable classification [31]. This difference of results could be explained by the difference of hands’ number and the age-mismatch of each stage in both studies. In order to avoid the bias of age, Ginanneschi et al. [28] formed for each stage, a control group of healthy hands belonging to subjects of similar age range.
2. Using another CTS classification model with only two stages (I: moderate and II: severe), according to the elongation or not of MDLm, like proposed by Ginanneschi et al. [3]. A significant correlation was found. Thus, the impact of CTS on ulnar parameters was significantly higher in stage II than in stage I, as well as these authors showed in their study.

In another hand, even, the averages of ulnar nerve parameters were different between patients with whole hand paresthesias CTS and those with only median nerve territory paresthesias, these differences were not statistically significant. Similar results were noted in some other studies, but were statistically significant [27,32]. Furthermore, when comparing the averages of these parameters in each group (“whole hand” and “limited to median nerve territory” paresthesias) with the averages of the correspondent parameters in “healthy hands” group, statistically significant differences were found. These differences were more significant for the group “whole hand paresthesias”. Thus, the extension of paresthesias at the whole hand could express a greater impact of CTS on ulnar nerve, even if Tamburin et al. [33] have reported opposite results.

Review of other arguments reported in the literature about CTS impact on the ulnar nerve

The hypothesis of a possible impact of CTS on the ulnar nerve [34,35] was based on a clinical observation. It consists in disappearance of paresthesias in the ulnar nerve territory after CTS surgical release [5,7]. In addition, Murata et al. [36] noted that in case of associated idiopathic CTS and Guyon's canal syndrome, the only median nerve neurolysis can improve the symptoms in ulnar nerve territory. Thus, the first studies to investigate this hypothesis used clinical tests. In 1985, Silver et al. [7] used two subjective validated tests: the "Two-point discrimination" [37] and the "Semmes-Weinstein monofilament" [38] tests. They found that 34% of patients with CTS had abnormalities in at least one of the two tests, in both median and ulnar sensory territories. In addition, they reported clinical improvement in the two territories, respectively in 86% for the "Two-point discrimination" test and in 94% in "Semmes-Weinstein monofilament" test, after surgical neurolysis of the median nerve [7].

In 1990, Imai et al. [39] studied the vibratory sensitivity of the index and the fifth digit, which are respectively innervated by sensory fibers of median and ulnar nerves. The authors found that 36% of hands with CTS had a high vibratory threshold in both fingers in comparison with control hands.

The same hypothesis was investigated by some other authors [5,9,40] using ENMG exam. Indeed, Ginanneschi et al. demonstrated significant improvement of SCVu and ASPu six months after surgical release of CTS [5] and even after only one month for SCVu [9]. Similar results concerning MDLu were noted by Green et al. [40].

In another study, Ginanneschi et al. [2] used the “stimulus-response curves”, which is an unusual electrophysiological test reflecting the recruitment level of motor axons [41]. They found that the ulnar curve closely followed the median one in both moderate and severe CTS. Indeed, they noted a drop of curves’ slopes for both median and ulnar nerves, which was especially important when CTS is severe. In another study using the same electrophysiological test, Ginanneschi et al. [5], noted postoperative improvement of the recruitment rate for both motor and sensory axons of the ulnar nerve, in comparison to preoperative rates.

Another original method consisted in investigating NCS parameters of the dorsal cutaneous branch of the ulnar nerve, which do not cross the Guyon’s tunnel [3]. The authors found that these parameters don’t change in CTS group in comparison to controls.

In order to provide morphological arguments and to compare them with functional parameters, other authors have used different tools:

1. Measurement of the intraductal pressure in the carpal and the Guyon's tunnels. Ablove et al. [11] and Okutsu et al. [12] were able to demonstrate a significant decrease of pressure at the two tunnels after surgical treatment of CTS by sectioning the TCL, using an angiocatheter inserted at the wrist and directly joined to a pressure monitor. This can be explained by the fact that carpal and Guyon's tunnels are contiguous at the wrist. Indeed, the transverse carpal ligament (TCL) is both the roof of the carpal tunnel and the floor of Guyon's canal [42], in such a way that in case of CTS, the high pressure in the first canal spreads progressively to the second one, causing significant morphological and functional impairment of the ulnar nerve [11,12].
2. Morphological examinations of the wrist (ultrasound and MRI). Ultrasound was used by Ginanneschi et al. [5]. They noted that the cross-sectional area of the ulnar nerve at the Guyon's channel increased significantly 6 months after TCL section in comparison to its preoperative measurements. They also reported that cross-sectional area’s shape changed from a flat form during CTS, to an oval configuration after surgical release.

3. Other researchers have used MRI and demonstrated that the Guyon's channel, which had a triangular shape with a radial direction before surgery, turned to take rounded [43] or oval shape with a longer dimension in the palmo-dorsal direction [44] after CTS release. These morphological changes could be an argument to explain functional postoperative improvement of the ulnar nerve [44].

Finally, according to the results of the present study, and after a large review of international literature, it may seem evident that CTS can cause an impact on the ulnar nerve at wrist. However, some authors, like Moghtaderi and Ghafarpoor [45], reported opposite results using electrophysiological arguments, and rejecting any association between CTS and ulnar nerve compression at the wrist. They tried to explain their results implicating different racial groups and dissimilar NCS techniques and cutoff values in comparison with other studies. More recently, in 2015, Kang et al. [15] reported conflicting results between morphological and functional arguments. Indeed, they found significant ultrasonographic changes of cross-sectional areas of ulnar and median nerves in the wrist in case of CTS, but no significant correlation between their respective NCS parameters. In the same year, Eom et al. [14] reported exactly the opposite findings.

Discussion of the Methodology

Most authors who conducted similar studies compared the parameters of the ulnar nerve in affected hands with reference standards used in daily practice [7,9,10,34,35]. This could be a methodological error since there is a great variability of these parameters in normal subjects, especially according to the height and the recording conditions such as skin temperature. Thus, the comparison of ulnar NCS parameters between the two hands of the same subject provides greater objectivity and reliability of the results. The present work has the merit of having carried out an intra-individual study for the first time. It consisted in comparing affected and healthy hands in case of unilateral CTS, and most and less affected hand in case of bilateral CTS with predominant side.

However, to confirm the impact of CTS on the ulnar nerve, both structurally and functionally, it was better to confront patient's ENMG data to those of other types of explorations. This was unfortunately not possible since our study was retrospective and complementary investigations were not realized for the majority of the patients. Thus, a prospective study would have a larger contribution, not only to better characterize this impact, but also to monitor unlar NCS parameters after treatment, especially after surgical neurolysis.

Physiopathological explanations of the hypothesis of ulnar nerve impairment associated to CTS

In patients with CTS, postoperative improvement of symptoms, stimulation tests [7] and electrophysiological abnormalities [9] of the ulnar nerve, appears to be the result of pressure's drop in Guyon's lodge [11] that follows the same phenomenon in the carpal tunnel. Hence, even if paraesthesias affect the whole hand and/or electrophysiological changes of the ulnar nerve are obvious, a simultaneous decompression of the Guyon's channel during surgical carpal tunnel release seems to be useless [7,9].

According to some authors [2,3], by analogy to functional abnormalities of the median nerve in cases of moderate CTS, the ulnar nerve may present an Na^+/K^+ pump dysfunction causing functional disorders and nerve conduction changes, rather than lesional disorders (alteration of the myelin sheath in particular). This is even more likely since these changes are rapidly reversible after surgical release of CTS.

Regarding to sensory extension of paresthesias to ulnar nerve territory, some authors have pointed out that maintaining the membrane potential of sensory afferent fibers is much more dependent on Na^+/K^+ pump activity than for motor axons [46-48]. Thus, the spread of high pressure from carpal to Guyon's tunnel could disrupt the functioning of Na^+/K^+ pump in sensory fibers of the ulnar nerve which could clinically be expressed by paresthesias in its territory.

On another hand, Ginanneschi et al. [2,3] indicate that paresthesias extension to the ulnar territory may be due, at least in part, to plastic changes of cortical representation of the hand at the sensory cortex. Indeed, Tecchio et al. [49] reported a wider representation of the hand at the sensory cortex in patients suffering from CTS complaining of paresthesias of the whole hand. This increased representation could be related to a peripheral deafferentation of the median nerve territory which contributes to the spread of paresthesias to the whole hand [2,33].

Conclusion

In conclusion, the present study was based on clinical and electrophysiological findings we made during our daily practice, suggesting an impact of CTS on ulnar nerve. Our results, showed significant changes in ulnar NCS parameters in comparison with a control group of healthy hands. These changes were more important when CTS was severe and when paresthesias reached the ulnar nerve sensory territory. Despite these changes are within the standard norms, this could argue in favor of possible impact of CTS on the ulnar nerve. To explain this, transfer of high pressure from carpal tunnel to Guyon's one was widely evoked [11]. We defend the hypothesis of functional disorders, especially local Na^+/K^+ pump dysfunction [2] at the expense of the hypotheses of axon/myelin lesions or changes of the hand representation at the sensory cortex, since there is a rapid clinical, electrophysiological and morphological back to normal of ulnar nerve after surgical release of CTS [5,9,11,12,40].

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