AUCTORES
Globalize your Research

Journal of Neuroscience and Neurological Surgery
Salim Hirani*

Open Access

Research Article

# Refine Grading of Carpal Tunnel Syndrome (CTS) via Nerve Conduction Study with Case Presentation

**Salim Hirani**

Neurophysiology Department, Ysbyty Gwynedd Hospital, Bangor, North Wales, UK. LL57 2PW

***Corresponding Author:** Salim Hirani, Neurophysiology Department, Ysbyty Gwynedd Hospital, Bangor, North Wales, UK. LL57 2PW.

**Received date:** January 20, 2026; **Accepted date:** January 29, 2026; **Published date:** Febuary 05, 2026

**Citation:** Salim Hirani, (2026), Refine Grading of Carpal Tunnel Syndrome (CTS) via Nerve Conduction Study with Case Presentation, *J. Neuroscience and Neurological Surgery,* 19(2); **DOI:10.31579/2578-8868/398**



## Abstract

**Background:**

The severity of carpal tunnel syndrome (CTS) may be categorised in a number of ways, utilising one of a range of presently available grading tools. This paper details a new grading system explained in this paper, with a case presentation to demonstrate its use in practice.

The aim of this research is to establish, to show the grading system mentioned in Hirani's grading in 201914 on evidence base with case presentation including, patient history, Neurophysiological findings, and Consultant conclusion. This is to show the proposed grading scale is clinically appropriate of the current CTS nerve conduction grading tool. It also suggests the improvements in currently used grading system which is 25 years old. The revised grading system confirms with my previously publish research paper in 201914.

The suggested revised grading system is based on descriptive categories, ranging from Normal to Early Sensory, Mild Sensory, Mild Sensory Motor, Moderate Sensory, Moderate Sensory Motor, Severe Sensory Motor, Extremely Severe Sensory Motor, and Complete absence.

**Method:**

One case presentation with history, Neurophysiological findings and Consultant conclusion of each grading category is included to understand each grade significance. All previously raised questions were answered in this paper which were raised in different National and International Neurophysiology conferences.

**Result:**

Each refine Neurophysiological grading shows a clear information with each case presentations and confirms the grading which was previously publish by the Hirani grading in 201914.

**Conclusion:**

The revised grading tool clearly offers more diverse grading scale with case presentation to the Clinical Physiologist. This could help the surgeon to ascertain a more precise level of severity which could be used when making decisions regarding conservative or surgical approach to treatment.

**Keywords:** grading tools for carpal tunnel syndrome, CTS gradings, neurophysiological CTS grading

## Introduction

The pathology of Carpal Tunnel Syndrome (CTS) is described as "A Neuropathy caused by entrapment of the median nerve at the level of the carpal tunnel" [2], [3]. Nerve Conduction Studies (NCS) are one of the basic tools used to support clinical diagnosis. NCS are objective tests that assess the physiological status of the median nerve across the carpal tunnel7.

### Reason for Grading Carpal Tunnel Syndrome:

The Grading tool is used for the diagnostic assessment of CTS in conjunction with the patient's clinical history and symptoms in order to diagnose the degree of severity of CTS3.

There are several primary grading tests mentioned in the literature, associated with Phalen's, Tinel's and Durkan's signs which are subjective and are based on patient clinical response. Other tests like Ultrasound,

NCS and EMG needle examination are objective tests that have been used for CTS grading which are reliable, evidence-based and objective, not dependent on patient clinical response 2.

However, to ascertain the degree of severity of CTS, a specific neurophysiological grading scale is required12. There are several grading scales for investigations specifically related to CTS; [Campbell5, Padua12, Bland4, Giannini7, Carvalho6, Ajeena2, Jeong9 and Jerosh-Herold10]. Most of the studies show grading in subjectivity which are based on patient experience. Few researchers have used sensitive techniques to diagnose early or very mild CTS or in severe cases used Lumbrical responses to differentiate its severity from complete absence, which therefore cannot be diagnosed as CTS with complete certainty.

In the UK, the Canterbury grading is largely followed due to its depth of detail. In 2014 the Association of Neurophysiological Science (ANS), in collaboration with the British Society for Clinical Neurophysiology (BSCN) published guidelines outlining the accepted grading of CTS in the United Kingdom, which follows the Canterbury4 grading system. The reason given was that it focuses on the clinical physiologist specialism, as well as its element of flexibility. But actually this was not fulfil the whole criteria of the grading system.

The aim of this research is to establish, to show the grading system mentioned in Hirani's grading in 201914 on evidence base with case presentation including, patient history, Neurophysiological findings and Consultant conclusion to show the propose grading scale is clinically appropriate of the current CTS nerve conduction grading tool. It also suggests the improvements in currently used grading system which is 25 years old. The revised grading system confirms with my previously publish research paper in 201914.

No clinical assessment was conducted during the Neurophysiological test so as to avoid bias from the patient's condition.

## Method:

No ethical approval has been taken as this is a retrospective presentation with all patient data anonymised.

The Association of Neurophysiological Scientists (ANS) (2014) guidelines are the minimum standards for the practice of Clinical Neurophysiology in the United Kingdom and AAEM are followed. A few new gradings were introduced after looking at the data to cover the full range of gradings as these new changes are not covered by the Canterbury grading system.

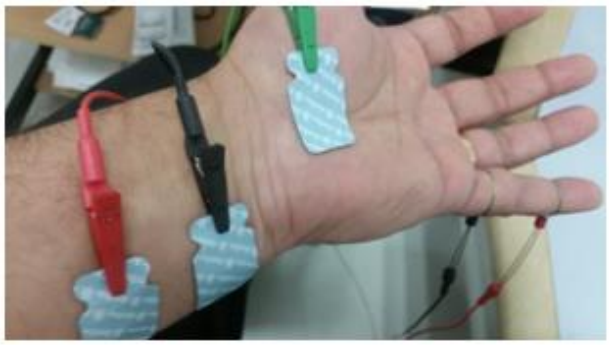
The test was performed by a qualified Clinical Physiologist (Neurophysiology) using Keypoint 9033A07 (Skovlunde, Denmark) machine, on the basis of departmental protocol (Peripheral protocol1, 2015) by checking patient's hand temperature i.e., more than 30 degrees centigrade. No individual patient was recruited in this research as all cases was selected from the retrospect data collection of 2017. No clinical assessment was conducted prior to the study in the department but patient clinical history was taken directly from the patient and compared with the information mentioned in the referral for counter check. Referral of CTS was considered based on paraesthesia, pain, swelling in median distribution area or digits I-V, worsened by sleep.

The procedure started by carrying out the sensory testing, by placing the stimulating ring electrodes on digit III (which is more sensitive than digit II4) and the recording electrode on the surface of the median nerve at the wrist. The orthodromic technique was used for the sensory and motor NCS test, through the median and ulnar nerves. A supramaximal stimulus was applied to record the full response of the nerve, at the digits II-IV for median sensory and digit V for ulnar sensory recording. A supramaximal current was applied to stimulate median nerve pathways at the wrist and at the elbow for motor recording from abductor pollicis brevis (APB)1 and ulnar nerve pathways from First dorsal interosseous (FDI). Digit II was stimulated only when either the response from digit III was less than 3μV or absent; digit IV was stimulated only when the response from digit III showed conduction velocity between 45-50m/sec. Amplitude was recorded from peak to peak for sensory responses, and base to peak for motor responses. If responses were not recordable from median sensory digit II, III and motor from APB muscles, then motor responses were elicited by placing recording electrodes on 2nd lumbricals by stimulating median and ulnar nerves at the wrist1,6,11,13. If the motor response from FDI shows more than 30% reduction in amplitude below and across elbow as compared to the wrist, the response elicited from median the nerve while recording from FDI was performed to identify the Martin Gruber anomaly. The distance from APB to wrist was kept between 6.5-7.5 cm while recording the motor median nerve.

Median and Ulnar senss

Median sensory recording by stimulating digit III

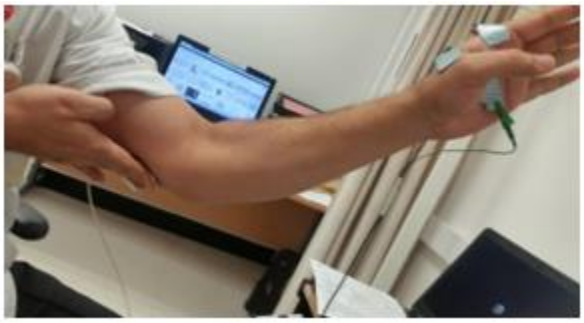
Median motor recording at elbow



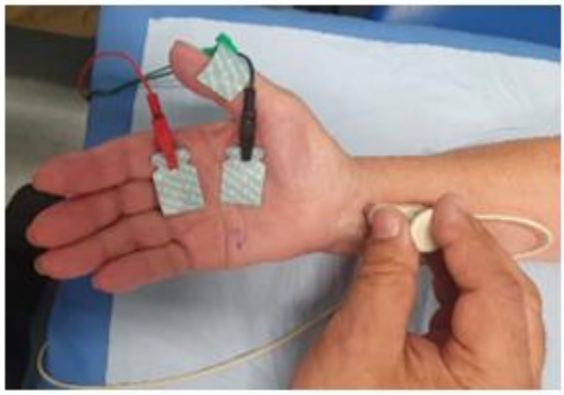
Median sensory early changes from digit IV

Ulnar FDI motor recording below elbow

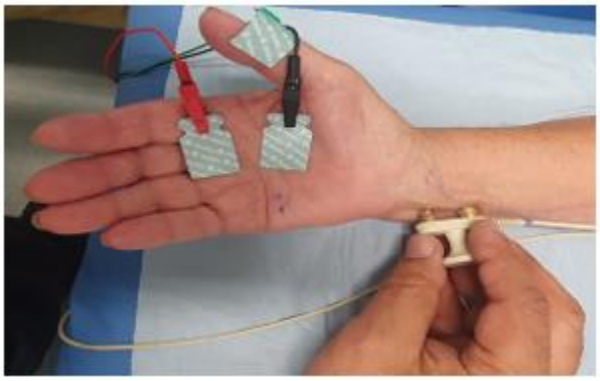
Median motor recording at wrist



Ulnar FDI motor recording across elbow



Recording from median 2nd Lumbricals for very severe changes. APB wasting



Recording from ulnar 2nd lumbricals for very severe changes. APB wasting

All selected patient data was collected by fulfilling the criteria mentioned above and the grades created which are as follows:

The grades are:

Normal (Grade 0): where sensory conduction velocity (SCV) is above 50 m/s and amplitude ≥5 μV with DML ≤4.2 ms, amplitude ≥5mV and motor conduction velocity (MCV) ≥50 m/s.

Early (Grade 1): where SCV is between 45-50 m/s from digit III and double peak latency in digit IV is >0.5ms with DML ≤4.2ms and normal sensory and motor amplitude >5 (sensory in μV and motor in mV).

Mild Sensory (Grade 2): where SCV is between 40-44.9 m/s from digits III with normal sensory amplitude and motor values mentioned in Grade 0.

Mild Sensory-Motor (Grade 3): where SCV is between 40-44.9 m/s from digits III with normal sensory amplitude mentioned in Grade 0, DML ≥4.2ms with normal motor amplitude and CV.

Moderate Sensory (Grade 4): where SCV is less than 40 m/s from digits III with normal sensory amplitude and normal motor values mentioned in Grade 0.

Moderate Sensory-Motor (Grade 5): where SCV is less than 40 m/s from digits III with normal sensory amplitude, DML ≥4.2ms with normal motor amplitude and CV.

Severe Sensory-Motor (Grade 6): where sensory potentials from digits III and digit II are absent or <3μV in both digits III and II with SCV <30m/s, DML ≥4.2ms, MCV is either slow or normal.

Extremely Severe Sensory-Motor (Grade 7): where sensory and motor potentials are absent and response recordable only from 2nd lumbricals,

where median lumbricals are prolonged compared and low amplitude to ulnar lumbricals.

Complete (Grade 8): where both sensory and motor potentials are absent and responses are not recordable from median 2nd lumbricals but recordable from ulnar 2nd lumbricals. (Please refer to a Comparison of the Canterbury grading with the proposed revised grading is given at the end of this study for more understanding).

## Results:

One case presentation for each gradings with their history, findings in a form of data and the conclusion was mentioned below. So that the audience can see the differences in the different grading system.

## Case 1

29-year-old right-handed working as a Nursery Assistant, presented with intermittent pins and needles in digits I-III in both hands up to the forearms which appears any time for a year. Patient had steroid injections at the base of left thumb 3 weeks ago. Patient has poor hand grip. No Hx of arthritis or diabetes or any symptoms between the elbows to neck.

### Sensory and motor data

| Sensory studies | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Median Sensory Left | | | | | |
| Digit III - Wrist | 2.35 | 34.7 | 1.06 | 125 | 65.8 |
| Digit IV - Wrist | **2.56** | 16.1 | 1.21 | | -- |
| Median Sensory Right | | | | | |
| Digit III - Wrist | 2.56 | 19.2 | 1.02 | 140 | 66.7 |
| Digit IV - Wrist | **2.52** | 13.8 | 1.04 | | -- |
| Ulnar Sensory Left | | | | | |
| Digit IV - Wrist | **2.48** | 11.2 | 1.33 | | -- |
| Digit V - Wrist | 2.00 | 13.3 | 1.17 | 105 | 68.2 |
| Ulnar Sensory Right | | | | | |
| Digit IV - Wrist | 2.42 | 7.6 | 1.17 | | -- |
| Digit V - Wrist | 2.04 | 13.5 | 1.27 | 110 | 69.6 |

| Motor Studies | | | | | |
|---|---|---|---|---|---|
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |
| 1 Median Motor Left | | | | | |
| Wrist - APB | 2.83 | 10.3 | 6.0 | 7 | |
| Elbow-Wrist | 6.60 | 9.8 | 6.2 | 230 | 61.0 |
| 1 Median Motor Right | | | | | |
| Wrist - APB | 2.60 | 11.5 | 5.9 | 7.1 | |
| Elbow-Wrist | 6.15 | 10.0 | 5.8 | 220 | 62.0 |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist - FDI | 2.56 | 11.0 | 5.2 | | |
| Bl. Elbow-Wrist | 5.61 | 10.7 | 5.4 | 200 | 65.6 |
| Ab. Elbow-Bl. Elbow | 7.21 | 10.4 | 5.5 | 105 | 65.6 |
| 2 Ulnar FDI Motor Right | | | | | |
| Wrist - FDI | 2.54 | 14.6 | 5.1 | | |
| Bl. Elbow-Wrist | 5.61 | 13.8 | 5.3 | 215 | 70.0 |
| Ab. Elbow-Bl. Elbow | 7.19 | 13.3 | 5.3 | 105 | 66.5 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist - ADM | 2.33 | 9.4 | 6.4 | | |
| Bl. Elbow-Wrist | 5.42 | 8.6 | 5.9 | 200 | 64.7 |
| Ab. Elbow-Bl. Elbow | 7.17 | 9.1 | 6.0 | 105 | 60.0 |
| 3 Ulnar ADM Motor Right | | | | | |
| Wrist - ADM | 2.38 | 8.7 | 5.1 | | |

| | | | | | |
|---|---|---|---|---|---|
| Bl. Elbow-Wrist | 5.50 | 7.5 | 5.3 | 215 | 68.9 |
| Ab. Elbow-Bl. Elbow | 6.83 | 8.3 | 5.4 | 105 | 78.9 |

## Conclusion:

This study is normal. There is no evidence of Carpal Tunnel Syndrome or ulnar nerve entrapment on either side.

## Case 2:

38-year-old right-handed Gardener, presented with numbness in all fingers bilaterally at night or when she is gardening for the past 1year 6 months. The patient gets shocking pain in both palms. There is a history of neck stiffness. Patient has right tennis elbow and weak grip in hands bilaterally.

### Sensory motor data:

| Sensory | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Median Sensory Left | | | | | |
| Digit III – Wrist | 2.50 | 14.7 | 0.97 | 120 | 55.6 |
| Digit IV – Wrist | **2.58** | 9.0 | 1.02 | | -- |
| Median Sensory Right | | | | | |
| Digit III – Wrist | 2.81 | 14.9 | 1.19 | 120 | 52.4 |
| Digit IV – Wrist | 3.00 | 5.0 | 1.04 | | -- |
| Ulnar Sensory Left | | | | | |
| Digit IV – Wrist | **2.35** | 6.5 | 1.67 | | -- |
| Digit V – Wrist | 2.02 | 7.2 | 1.40 | 100 | 64.9 |
| Ulnar Sensory Right | Interpeak latency: 0.6ms | | | | |
| Digit IV – Wrist | 2.48 | 7.7 | 1.35 | | -- |
| Digit V – Wrist | 2.44 | 7.0 | 1.33 | 105 | 60.7 |
| Motor | | | | | |
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |
| 1 Median Motor Left | | | | | |
| Wrist – APB | **3.04** | 13.5 | 6.0 | 7 | |
| Elbow-Wrist | 6.65 | 13.5 | 6.0 | 210 | 58.2 |
| 1 Median Motor Right | | | | | |
| Wrist – APB | **3.48** | 11.4 | 5.3 | 7.2 | |
| Elbow-Wrist | 7.48 | 11.0 | 5.4 | 220 | 55.0 |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist – FDI | 2.46 | 15.9 | 4.7 | | |
| Bl. Elbow-Wrist | 5.62 | 15.3 | 4.5 | 195 | 61.7 |
| Ab. Elbow-Bl. Elbow | 7.82 | 14.0 | 4.3 | 115 | 52.3 |
| 2 Ulnar FDI Motor Right | | | | | |
| Wrist – FDI | 2.89 | 15.5 | 4.5 | | |
| Bl. Elbow-Wrist | 5.78 | 14.6 | 4.7 | 190 | 65.7 |
| Ab. Elbow-Bl. Elbow | 7.35 | 15.6 | 4.6 | 110 | 70.1 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist – ADM | 2.81 | 13.5 | 5.9 | | |
| Bl. Elbow-Wrist | 5.48 | 12.2 | 6.3 | 195 | 73.0 |
| Ab. Elbow-Bl. Elbow | 7.33 | 11.8 | 6.5 | 115 | 62.2 |
| 3 Ulnar ADM Motor Right | | | | | |
| Wrist – ADM | 2.15 | 12.4 | 6.2 | | |
| Bl. Elbow-Wrist | 5.00 | 10.8 | 5.9 | 190 | 66.7 |
| Ab. Elbow-Bl. Elbow | 6.67 | 12.1 | 5.6 | 110 | 65.9 |

## Conclusion:

Above changes in the right hand are a very early sign of carpal tunnel syndrome and could be improved with conservative treatment. If symptoms persist a repeat study in 6 months' time may be helpful.

There is no evidence of ulnar nerve lesion on either side.

## Case 3:

54-year-old left-handed support worker attended again. Her previous study in 2018 shows bilateral early CTS. She still gets intermittent pins

and needles and numbness in all fingers bilaterally since 2016. Symptoms become worse at night and she has poor grip bilaterally. She uses crutches in her right hand due to previous right foot surgery. The patient had left ulnar decompression 30 years ago with good symptomatic outcome. No symptoms between elbows to neck.

**Sensory motor data:**

| Sensory | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Median Sensory Left | | | | | |
| Digit III - Wrist | 3.48 | 15.4 | 1.21 | 130 | **44.8** |
| Median Sensory Right | | | | | |
| Digit III - Wrist | 3.38 | 10.1 | 1.63 | 135 | 51.3 |
| Digit IV - Wrist | **3.21** | 3.0 | 1.10 | | -- |
| Ulnar Sensory Left | | | | | |
| Digit V - Wrist | 2.60 | 9.6 | 1.90 | 100 | 60.6 |
| Ulnar Sensory Right | Interpeak latency: **0.5ms** | | | | |
| Digit IV - Wrist | **2.69** | 7.0 | 1.73 | | -- |
| Digit V - Wrist | 2.38 | 8.8 | 1.60 | 105 | 60.7 |

| Motor | | | | | |
|---|---|---|---|---|---|
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |
| 1 Median Motor Left | | | | | |
| Wrist - APB | **3.35** | 13.4 | 5.9 | 7.5 | |
| Elbow-Wrist | 7.04 | 14.4 | 6.1 | 235 | 63.7 |
| 1 Median Motor Right | | | | | |
| Wrist - APB | **3.19** | 6.6 | 6.0 | 7.4 | |
| Elbow-Wrist | 7.10 | 6.1 | 6.2 | 230 | 58.8 |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist - FDI | 2.51 | 11.4 | 4.9 | | |
| Bl. Elbow-Wrist | 5.61 | 10.0 | 6.7 | 215 | 69.4 |
| Ab. Elbow-Bl. Elbow | 7.23 | 9.4 | 6.4 | 105 | 64.8 |
| 2 Ulnar FDI Motor Right | | | | | |
| Wrist - FDI | 2.45 | 14.3 | 4.7 | | |
| Bl. Elbow-Wrist | 5.46 | 13.6 | 5.1 | 205 | 68.1 |
| Ab. Elbow-Bl. Elbow | 7.07 | 13.3 | 5.0 | 105 | 65.2 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist - ADM | 2.23 | 7.8 | 6.8 | | |
| Bl. Elbow-Wrist | 5.40 | 7.9 | 6.7 | 215 | 67.8 |
| Ab. Elbow-Bl. Elbow | 6.88 | 7.3 | 6.8 | 105 | 70.9 |
| 3 Ulnar ADM Motor Right | | | | | |
| Wrist - ADM | 2.31 | 7.5 | 6.9 | | |
| Bl. Elbow-Wrist | 5.15 | 8.0 | 7.1 | 205 | 72.2 |
| Ab. Elbow-Bl. Elbow | 6.67 | 8.1 | 6.9 | 105 | 69.1 |

## Conclusion:

There is evidence of left mild sensory carpal tunnel syndrome.

There is no evidence of ulnar nerve lesion on either side.

## Case 4

A 36-year-old left-handed health care assistant, presented with intermittent pins and needles and numbness in all fingers bilaterally which becomes worse when holding the phone or driving since February 2022 Test was conducted in 2024.There was no history of diabetes or arthritis. She had pain between elbows to neck and had weak handgrip.

## Sensory motor data:

| Sensory | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Median Sensory Left | | | | | |
| Digit III - Wrist | 4.06 | 8.7 | 1.81 | 135 | 42.3 |
| Median Sensory Right | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Digit III - Wrist | 3.48 | 7.0 | 1.44 | 130 | 43.9 |
| Ulnar Sensory Left | | | | | |
| Digit V - Wrist | 2.19 | 5.4 | 1.35 | 110 | 66.7 |
| Ulnar Sensory Right | | | | | |
| Digit V - Wrist | 2.23 | 9.2 | 1.35 | 110 | 66.7 |
| Motor | | | | | |
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |
| 1 Median Motor Left | | | | | |
| Wrist - APB | 5.02 | 8.1 | 5.0 | 7.3 | |
| Elbow-Wrist | 8.75 | 7.9 | 5.5 | 220 | 59.0 |
| 1 Median Motor Right | | | | | |
| Wrist - APB | 4.33 | 9.0 | 4.5 | 7.2 | |
| Elbow-Wrist | 8.29 | 8.7 | 4.7 | 220 | 55.6 |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist - FDI | 2.51 | 14.2 | 4.2 | | |
| Bl. Elbow-Wrist | 5.49 | 13.5 | 4.4 | 200 | 67.1 |
| Ab. Elbow-Bl. Elbow | 6.95 | 12.8 | 4.3 | 110 | 75.3 |
| 2 Ulnar FDI Motor Right | | | | | |
| Wrist - FDI | 2.36 | 15.4 | 4.2 | | |
| Bl. Elbow-Wrist | 5.62 | 14.7 | 4.4 | 210 | 64.4 |
| Ab. Elbow-Bl. Elbow | 7.13 | 13.6 | 4.3 | 105 | 69.5 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist - ADM | 2.13 | 12.8 | 4.4 | | |
| Bl. Elbow-Wrist | 5.00 | 13.2 | 4.7 | 200 | 69.7 |
| Ab. Elbow-Bl. Elbow | 6.50 | 11.8 | 4.5 | 110 | 73.3 |
| 3 Ulnar ADM Motor Right | | | | | |
| Wrist - ADM | 2.19 | 12.6 | 4.4 | | |
| Bl. Elbow-Wrist | 5.20 | 12.3 | 4.9 | 210 | 69.8 |
| Ab. Elbow-Bl. Elbow | 6.73 | 12.5 | 4.6 | 105 | 68.6 |

## Conclusion:

There is evidence of bilateral mild sensori-motor carpal tunnel syndrome.

There is no evidence of ulnar nerve lesion on either side.

## Case 5:

A 52 year old right-handed nurse assistant who was diagnosed as having autoimmune hepatitis, presented with intermittent numbness and pins and needles in all fingers bilaterally, right more than the left for the past 4 years. Occasionally changing to pain in the hands. Symptoms become worse during sleep. She has a history of neck pain. Hand strength is 5/5 on the MRC Scale and there is no stiffness in the hands. The left shoulder has limited movements with pain.

### Sensory and motor data:

| Sensory | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Median Sensory Left | | | | | |
| Digit III - Wrist | 2.79 | 26.0 | 1.31 | 110 | 52.2 |
| Digit IV - Wrist | 3.15 | 4.8 | 1.56 | | -- |
| Median Sensory Right | | | | | |
| Digit III - Wrist | 3.96 | 6.7 | 2.6 | 115 | 37.3 |
| Ulnar Sensory Left | Interpeak latency:0.3ms | | | | |
| Digit IV - Wrist | 2.84 | 5.8 | 1.47 | | -- |
| Digit V - Wrist | 2.52 | 6.8 | 1.31 | 90.0 | 50.8 |
| Ulnar Sensory Right | | | | | |
| Digit V - Wrist | 2.59 | 5.6 | 1.47 | 100 | 50.5 |
| Motor | | | | | |
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |

| | | | | | |
|---|---|---|---|---|---|
| 1 Median Motor Left | | | | | |
| Wrist - APB | 2.92 | 9.8 | 5.9 | 7.3 | |
| Elbow-Wrist | 7.21 | 10.4 | 5.9 | 235 | 54.8 |
| 1 Median Motor Right | | | | | |
| Wrist - APB | 3.98 | 8.2 | 6.3 | 7.2 | |
| Elbow-Wrist | 8.04 | 8.2 | 7.1 | 235 | 57.9 |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist - FDI | 2.47 | 16.2 | 5.0 | | |
| Bl. Elbow-Wrist | 6.01 | 15.9 | 5.0 | 215 | 60.7 |
| Ab. Elbow-Bl. Elbow | 7.75 | 15.1 | 5.1 | 110 | 63.2 |
| 2 Ulnar FDI Motor Right | | | | | |
| Wrist - FDI | 2.79 | 15.6 | 5.3 | | |
| Bl. Elbow-Wrist | 6.25 | 14.4 | 5.5 | 220 | 63.6 |
| Ab. Elbow-Bl. Elbow | 7.91 | 14.2 | 5.6 | 110 | 66.3 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist - ADM | 2.21 | 11.1 | 5.2 | | |
| Bl. Elbow-Wrist | 5.73 | 10.9 | 5.1 | 215 | 61.1 |
| Ab. Elbow-Bl. Elbow | 7.52 | 10.3 | 5.3 | 110 | 61.5 |
| 3 Ulnar ADM Motor Right | | | | | |
| Wrist - ADM | 2.33 | 11.4 | 5.0 | | |
| Bl. Elbow-Wrist | 5.58 | 10.1 | 5.2 | 220 | 67.7 |
| Ab. Elbow-Bl. Elbow | 7.06 | 10.9 | 5.1 | 110 | 74.3 |

## Conclusion:

There is evidence of left moderate sensory carpal tunnel syndrome.

There is no evidence of ulnar nerve entrapment on either side.

## Case 6:

A 46-year-old right-handed handyman presented with numbness and tingling in all fingers bilaterally most of the time for the last 6 years. In the past 3-4 years, hand symptoms had become worse. The patient also gets pins and needles in his feet. He has weak hand grip. There were no symptoms between the elbows to neck or any history of diabetes or arthritis.

### Sensory and motor data:

| Sensory | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Median Sensory Left | | | | | |
| Digit III - Wrist | 3.60 | 8.8 | 1.35 | 150 | 51.4 |
| Digit IV - Wrist | 3.35 | 8.7 | 1.50 | | -- |
| Median Sensory Right | | | | | |
| Digit III - Wrist | 5.44 | 3.5 | 1.94 | 145 | 33.8 |
| Ulnar Sensory Left | Interpeak latency: 0.9ms | | | | |
| Digit IV - Wrist | 2.63 | 5.3 | 1.40 | | -- |
| Digit V - Wrist | 2.63 | 5.6 | 1.17 | 130 | 63.7 |
| Ulnar Sensory Right | | | | | |
| Digit V - Wrist | 2.48 | 5.5 | 1.31 | 125 | 64.4 |

| Motor | | | | | |
|---|---|---|---|---|---|
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |
| 1 Median Motor Left | | | | | |
| Wrist - APB | 3.75 | 12.1 | 6.5 | 7 | |
| Elbow-Wrist | 8.60 | 11.1 | 6.7 | 250 | 51.5 |
| 1 Median Motor Right | | | | | |
| Wrist - APB | **5.60** | 9.8 | 6.9 | 7 | |
| Elbow-Wrist | 10.3 | 10.7 | 7.2 | 255 | 54.3 |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist - FDI | 2.79 | 7.7 | 7.1 | | |

| | | | | | |
|---|---|---|---|---|---|
| Bl. Elbow-Wrist | 7.34 | 7.8 | 7.4 | 245 | 53.8 |
| Ab. Elbow-Bl. Elbow | 9.38 | 7.1 | 7.5 | 120 | 58.8 |
| 2 Ulnar FDI Motor Right | | | | | |
| Med-Ulnar - FDI | 9.10 | 3.0 | 7.5 | | |
| Wrist - FDI | 2.69 | 10.3 | 7.3 | | |
| Bl. Elbow-Wrist | 7.01 | 5.5 | 7.2 | 240 | 55.6 |
| Ab. Elbow-Bl. Elbow | 9.13 | 6.5 | 7.6 | 110 | 51.9 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist - ADM | 2.58 | 6.7 | 5.6 | | |
| Bl. Elbow-Wrist | 7.04 | 5.8 | 5.5 | 245 | 54.9 |
| Ab. Elbow-Bl. Elbow | 8.94 | 5.9 | 5.9 | 120 | 63.2 |
| 3 Ulnar ADM Motor Right | | | | | |
| Wrist - ADM | 2.54 | 6.0 | 5.0 | | |
| Bl. Elbow-Wrist | 6.58 | 5.8 | 5.5 | 240 | 59.4 |
| Ab. Elbow-Bl. Elbow | 8.40 | 5.8 | 5.7 | 110 | 60.4 |

## Conclusion:

- There is evidence of moderate right sensory motor Carpal Tunnel Syndrome and an early sign of Carpal Tunnel Syndrome over the left.
- In addition, there is evidence of right Martin Gruber Anastomosis which is an anatomical variant where the median and ulnar nerves travel all or in part along each other's pathway.

## Case 7:

A 48-year-old right-handed man who works in a Bar, presented with weakness in the wrist and pain from the forearm to the elbows bilaterally for 5 years. The patient was also having symptoms of intermittent numbness and pins and needles in all fingers bilaterally, which became worse at night. The patient has poor hands grip and wasting of APB muscles in the right hand. No Hx of arthritis or diabetes.

### Sensory and motor data:

| Sensory | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Median Sensory Left | | | | | |
| Digit III - Wrist | 4.00 | 6.3 | 1.44 | 150 | 45.0 |
| Digit IV - Wrist | 4.06 | 2.5 | 1.17 | | -- |
| Median Sensory Right | | | | | |
| Digit III - Wrist | Absent | -- | -- | | |
| Digit II - Wrist | Absent | -- | -- | | |
| Ulnar Sensory Left | Interpeak latency: 1.25ms | | | | |
| Digit IV - Wrist | 2.81 | 6.9 | 1.23 | | -- |
| Digit V - Wrist | 2.63 | 7.9 | 1.46 | 110 | 53.9 |
| Ulnar Sensory Right | | | | | |
| Digit V - Wrist | 2.71 | 6.7 | 1.71 | 115 | 56.4 |
| Motor | | | | | |
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |
| 1 Median Motor Left | | | | | |
| Wrist - APB | 3.69 | 11.3 | 6.8 | 7 | |
| Elbow-Wrist | 7.52 | 12.5 | 7.0 | 220 | 57.4 |
| 1 Median Motor Right | | | | | |
| Wrist - APB | **5.29** | 8.1 | 7.4 | 7 | |
| Elbow-Wrist | 9.00 | 8.2 | 8.8 | 230 | 62.0 |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist - FDI | 2.81 | 13.5 | 4.8 | | |
| Bl. Elbow-Wrist | 5.93 | 12.7 | 5.3 | 210 | 67.3 |
| Ab. Elbow-Bl. Elbow | 7.92 | 12.4 | 5.3 | 110 | 55.3 |
| 2 Ulnar FDI Motor Right | | | | | |
| Med-Ulnar - FDI | 8.00 | 2.9 | 4.0 | | |

| | | | | | |
|---|---|---|---|---|---|
| Wrist - FDI | 2.51 | 14.9 | 5.4 | | |
| Bl. Elbow-Wrist | 5.98 | 10.5 | 5.6 | 225 | 64.8 |
| Ab. Elbow-Bl. Elbow | 7.72 | 10.7 | 5.6 | 105 | 60.3 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist - ADM | 2.56 | 10.3 | 5.7 | | |
| Bl. Elbow-Wrist | 6.15 | 9.2 | 5.6 | 210 | 58.5 |
| Ab. Elbow-Bl. Elbow | 7.85 | 9.7 | 5.7 | 110 | 64.7 |
| 3 Ulnar ADM Motor Right | | | | | |
| Wrist - ADM | 2.50 | 9.3 | 7.5 | | |
| Bl. Elbow-Wrist | 5.71 | 7.3 | 7.1 | 225 | 70.1 |
| Ab. Elbow-Bl. Elbow | 7.17 | 9.0 | 7.4 | 105 | 71.9 |

## Conclusion:

- There is evidence of right severe sensory motor Carpal Tunnel Syndrome and an early sign of Carpal Tunnel Syndrome over the left.
- There is evidence of evidence of right Martin Gruber anastomosis which is a normal variant when ulnar nerve travel in median pathways.

**Case 8:** 81 year old retired nurse presented with almost constant pins and needles in digits I-IV of the left hand for 2 years with poor gripping. Left APB muscles were wasted. Each shoulder gets pain. The right thumb was infected and covered by tape and the hand was in a glove to stop spreading infection. Left median artery had previously been removed for coronary artery bypass grafting.

### Sensory and motor data:

| Sensory | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Dorsal Ulnar Cutaneous Sensory Left | | | | | |
| Wrist - IV dorsal space | 1.66 | 7.3 | 1.24 | 75.0 | 71.4 |
| Median Sensory Left | | | | | |
| Digit III - Wrist | Absent | -- | -- | | |
| Digit II - Wrist | Absent | -- | -- | | |
| Ulnar Sensory Left | | | | | |
| Palm - Wrist | Absent | -- | -- | | |
| Digit V - Wrist | Absent | -- | -- | | |

| Motor | | | | | |
|---|---|---|---|---|---|
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |
| 1 Median Motor Left | | | | | |
| Wrist - APB | Absent | -- | -- | | |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist - FDI | 3.26 | 10.5 | 6.3 | | |
| Bl. Elbow-Wrist | 7.60 | 8.6 | 6.4 | 245 | 56.5 |
| Ab. Elbow-Bl. Elbow | 10.2 | 7.7 | 6.5 | 110 | 42.3 |
| Axilla-Ab. Elbow | 12.2 | 7.5 | 6.7 | 110 | 55.0 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist - ADM | 2.53 | 6.9 | 6.2 | | |
| Bl. Elbow-Wrist | 6.65 | 6.3 | 6.7 | 245 | 59.5 |
| Ab. Elbow-Bl. Elbow | 9.20 | 5.8 | 7.0 | 110 | 43.1 |
| Axilla-Ab. Elbow | 10.9 | 5.6 | 6.9 | 110 | 64.7 |
| 4 2nd Lumbrical Motor Left | | | | | |
| Palm - Uln-wrist | 3.40 | 5.1 | 5.1 | 8 | |
| Palm - Med-wrist | 9.93 | 0.39 | 6.3 | 8 | |

## Conclusion:

Nerve conduction studies on the left median nerve show no response on the left from digits II and III sensory and motor from APB muscles across the carpal tunnel. The only recordable response is from the 2nd lumbricals muscles by stimulating median and ulnar nerves at mid-palm, where the median distal latency is prolonged as compared to the ulnar distal latency at an 8 cm distance from the palm to wrist.

There is evidence of left double crush syndrome of the ulnar nerve i.e. Sensory Guyon's Canal entrapment and mild Ulnar nerve entrapment across the elbow.

## Case 9:

68 years right-handed retired male presented with constant numbness in digits I-III in the right hand for a year. The Complete Right APB wasting was seen, with partial wasting on the left. No paraesthesia was described in the left hand. Occasionally he drops things from both hands. There were no symptoms between the elbows to the neck. No history of diabetes or of arthritis.

### Sensory and motor study data:

| Sensory | | | | | |
|---|---|---|---|---|---|
| Nerve | Peak Lat | Amp | Dur | Dist | CV |
| | ms | uV | ms | mm | m/s |
| Dorsal Ulnar Cutaneous Sensory Left | | | | | |
| Wrist - IV dorsal space | 1.77 | 8.7 | 1.35 | 65.0 | 62.5 |
| Dorsal Ulnar Cutaneous Sensory Right | | | | | |
| Wrist - IV dorsal space | 1.65 | 10.3 | 1.35 | 65.0 | 72.2 |
| Median Sensory Left | | | | | |
| Digit III - Wrist | Absent | -- | -- | | |
| Digit II - Wrist | Absent | -- | -- | | |
| Median Sensory Right | | | | | |
| Digit III - Wrist | Absent | -- | -- | | |
| Digit II - Wrist | Absent | -- | -- | | |
| Ulnar Sensory Left | | | | | |
| Palm - Wrist | 2.10 | 2.9 | 1.17 | 80.0 | 49.7 |
| Digit V - Wrist | 3.54 | 0.95 | 1.40 | 105 | 37.2 |
| Ulnar Sensory Right | | | | | |
| Palm - Wrist | 2.84 | 4.7 | 1.52 | 80.0 | 39.4 |
| Digit V - Wrist | 3.65 | 4.1 | 1.77 | 105 | 37.4 |

| Motor | | | | | |
|---|---|---|---|---|---|
| Nerve | Lat | Amp | Dur | Dist | CV |
| | ms | mV | ms | mm | m/s |
| 1 Median Motor Left | | | | | |
| Wrist - APB | 5.90 | 5.8 | 6.1 | | |
| Elbow-Wrist | 11.5 | 5.4 | 6.4 | 255 | 45.5 |
| 1 Median Motor Right | | | | | |
| Wrist - APB | Absent | -- | -- | | |
| 2 Ulnar FDI Motor Left | | | | | |
| Wrist - FDI | 3.06 | 8.1 | 5.8 | | |
| Bl. Elbow-Wrist | 7.32 | 7.1 | 6.2 | 235 | 55.2 |
| Ab. Elbow-Bl. Elbow | 9.83 | 6.3 | 6.2 | 110 | 43.8 |
| Axilla-Ab. Elbow | 12.1 | 6.0 | 6.1 | 120 | 52.9 |
| 2 Ulnar FDI Motor Right | | | | | |
| Wrist - FDI | 3.85 | 8.2 | 5.6 | | |
| Bl. Elbow-Wrist | 8.32 | 7.3 | 5.8 | 240 | 53.7 |
| Ab. Elbow-Bl. Elbow | 10.7 | 7.4 | 6.1 | 105 | 44.1 |
| Axilla-Ab. Elbow | 12.4 | 6.3 | 5.7 | 100 | 58.8 |
| 3 Ulnar ADM Motor Left | | | | | |
| Wrist - ADM | 2.31 | 6.9 | 6.5 | | |
| Bl. Elbow-Wrist | 6.57 | 6.8 | 6.5 | 235 | 55.2 |
| Ab. Elbow-Bl. Elbow | 8.94 | 5.8 | 7.1 | 110 | 46.4 |
| Axilla-Ab. Elbow | 10.9 | 5.8 | 7.3 | 120 | 61.2 |
| 3 Ulnar ADM Motor Right | | | | | |
| Wrist - ADM | 2.63 | 5.6 | 6.7 | | |

| | | | | | |
|---|---|---|---|---|---|
| Bl. Elbow-Wrist | 6.68 | 6.8 | 7.1 | 240 | 59.3 |
| Ab. Elbow-Bl. Elbow | 8.95 | 6.5 | 7.1 | 105 | 46.3 |
| Axilla-Ab. Elbow | 10.8 | 6.3 | 7.0 | 100 | 54.1 |
| 4 2nd Lumbrical Motor Right | | | | | |
| Palm - Uln-wrist | 2.88 | 6.9 | 4.4 | | |
| Palm - Med-wrist | Absent | -- | -- | | |

## Conclusion:

Electrophysiologically it is difficult to pin point the entrapment of left median nerve due to response not being recordable from the median-innervated 2nd lumbricals but recordable from ulnar 2nd lumbricals as well. There is no previous study available to compare with current condition.

There is evidence of severe left sensory motor Carpal Tunnel Syndrome.

In addition, there is evidence of mild ulnar nerve entrapment across both elbows.

## Discussion:

The grading system devised by Bland4 and used to grade the levels of severity of CTS over the last 23 years within the UK has certain limitations, and the author believes that it needs modification in order to accommodate current practice. The revised grading system mentioned above is evident that, the Canterbury scale is not fulfil the criteria to visualise the grading of CTS properly.

The revised grading tool offer a more precise grading, which is both objective and repeatable. This could not only help the Clinical Physiologist to grade their result according to the proposed grading scale but probably it also supports the surgeon to ascertain the level of severity and thus help to decide on either a conservative or surgical approach to treatment. It is advisable according to each case conclusion that surgeons could consider proposed Grade 1-2 for physiotherapy treatment, Grade 3-4 for conservative or intervention of steroid treatment and Grade 5-7 for surgical intervention where the chances of full recovery. Surgeon could decide for surgical intervention of Grade 8 cases, whether it would be beneficial or not would be in keeping with the patient's age and other medical history. Grade 9 does not clearly indicate the level of entrapment and further EMG study may be helpful to localise the lesion precisely at the higher level from wrist.

## Abbreviations:

Carpal tunnel syndrome -CTS, Nerve Conduction Studies -NCS, Betsi Cadwaladr University Health Board -BCUHB, General Practices -GPs, Association of Neurophysiological Scientists - ANS, abductor polices braves - APB, sensory conduction velocity - SCV, conduction velocity - CV, British Society for Clinical Neurophysiology - BSCN, Distal Motor Latency - DML, normal sensory amplitude - NSA, Sensory nerve action potentials -SNAP, normal motor amplitude - NMA, Motor nerve action potentials -MNAP, motor conduction velocity – MCV

### Written Consent from participants:

A written consent was obtained from all participants and filed in patient notes and a copy kept in the department.

### Consent for Publication:

Not Applicable

### Availability of data and materials:

The datasets analysed during the current study are not publicly available as they are held within patient records but are available from the corresponding author on request.

### Competing Interests:

The Author declares that they have no competing interests.

### Funding:

The Author contributed by the collection, analysis and interpretation of data and in writing the manuscript. No funding was arranged in collecting cases, preparing and writing manuscript.

### Acknowledgements:

The author would like to acknowledge and thank Dr.Gareth Payne for his encouragement, guidance and help with this study.

## References

1. AAEM, AAN, AAPMR. (1993), Prectice parameter for electrodiagnostic studies in carpal tunnel syndrome: summary statement. Muscles Nerve b;16:1390-1391
2. Ajeena I.M., Al-Saad R.H., Al-Mudhafar A., Hadi N.R., Al-Mridhy S.H. (2013),Ultrasonic sssessment of females with carpal tunnel syndrome proved by nerve conduction study. Neural Plasticity, 754564:1-6.
3. Alfonso C., Jann S., Massa R., Torreggiani A. (2010), Diagnosis, treatment and follow-up of the carpal tunnel syndrome: a review. Neurological Sciences 31; 3:243-252.
4. Bland, J. (2000), A neurophysiological grading scale for carpal tunnel syndrome. Muscle Nerve 23;1:1280–1283.
5. Campbell, E.D.R. (1962), The carpal tunnel syndrome: investigation and assessment of treatment.Proceedings of the Royal Society of Medicine 55;5:401–405.
6. Carvalho F.N., Carneiro A.P., Paulinelli R.R. (2007), Carvelho T.N. Neurophysiological classification of the carpal tunnel syndrome. Acta Fisiatrica, 14;4:190–195.
7. Giannini F., Cioni R., Mondelli M., Padua R., Gregori B., D'Amico P., et al. (2002), A new clinical scale of carpal tunnel syndrome: validation of the measurement and clinical-neurophysiological assesment. Clinical Neurophysiology 113;1:71-77
8. Ibrahim I., Khan W.S., Goddard N., Smitham P, (2012), Carpal tunnel syndrome: a review of the recent literature. Open Orthopaedics Journal 6;suppl 1: M8:69-76
9. Jeong D.H., Kim C.H. (2014), The quantitative relationship between physical examination and the nerve conduction of the carpal tunnel syndrome in patients with and without a diabetic polyneuropathy. Annals of Rehabilation Medicine 38;1:57-63.
10. Jerosh-Herold C., Shepstone L., Wilson E.C.F., Dyer T., Blake J. (2014), Clinical course, costs and predictive factors for response to treatment in Carpal Tunnel Syndrome: The PALMS study protocol. BMC Musculoskeletal Disorders 15;35:1-7.
11. Ozben, Acar, Gunaydin. (2012)The Second Lumbrical-Interosseous Latency Comparision in Carpal Tunnel Syndrome. Clinical Neurophysiology 29;3:263-267
12. Padua L., Monaco M.L., Valente E.H., Tonali P.A. (1996), A useful electrophysiologic parameter for diagnosis of carpal tunnel syndrome. Muscle &Nerve 19;1:48–53.

13. Preston D,Logigian EL. (1992), Lumbrical and interossei recording in carpal tunnel syndrome. Muscle Nerve 15:1253-1257.

14. Hirani S, (2019), A study to further develop and refine carpal tunnel syndrome (CTS) nerve conduction grading tool. BMC Musculoskeletal Disorders. 20:518.



**DOI:10.31579/2578-8868/398**