

## Clinical Article

# Quantitative Evaluation of Median Nerve Motor Function in Carpal Tunnel Syndrome Using Load Cell : Correlation with Clinical, Electrodiagnostic, and Ultrasonographic Findings

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**Objective :** Major complaints of carpal tunnel syndrome (CTS) are sensory components. However, motor deficit also impedes functional status of hand. Contrary to evaluation of sensory function, the objective, quantitative evaluation of median nerve motor function is not easy. The motor function of median was evaluated quantitatively using load cell and its correlation with findings of electrodiagnostic study (EDS) was evaluated.

**Methods :** Objective motor function of median nerve was evaluated by load cell and personal computer-based measurement system. All of the measurement was done in patients diagnosed as having idiopathic CTS by clinical features and EDS findings. The strength of thumb abduction and index finger flexion was measured in each hand three times, and the average value was used to calculate thumb index ratio (TIR). The correlation of TIR with clinical, EDS, and ultrasonographic findings were evaluated.

**Results :** The TIR was evaluated in 67 patients (119 hands). There were 14 males and 53 females, mean age were 57.6 years (range 28 to 81). The higher preoperative nerve conductive studies grade of the patients, the lower TIR was observed [ $p < 0.001$ , analysis of variance (ANOVA)]. TIR of cases with thenar atrophy were significantly lower than those without ( $p < 0.001$ , t-test). TIR were significantly lower in patients with severe median nerve swelling in ultrasonography ( $p = 0.042$ , ANOVA).

**Conclusion :** Measurements of median nerve motor function using load cell is a valuable evaluation tool in CTS. It might be helpful in detecting subclinical motor dysfunction before muscle atrophy develops.

**Key Words :** Carpal tunnel syndrome · Thumb abduction strength · Load cell · Electrodiagnostic study · Ultrasonography.

## INTRODUCTION

Carpal tunnel syndrome (CTS), caused by median nerve compression at transverse carpal ligament, is one of the most common entrapment neuropathy. Its major complaints are sensory component, such as tingling, pain, numbness<sup>3</sup>. Sensory dysfunction of median nerve in CTS can be evaluated by semi-quantitative assessment by comparing ulnar nerve sensory function of the same hand. However, motor deficit, known to be present about 40% of the patients, also impedes patients' functional status of hand, especially in severe case<sup>10</sup>.

Power and key pinch dynamometry, although used most fre-

quently to assess the motor function of patients having CTS, are known to be not so valid or responsive<sup>5</sup>. In this study we assessed the motor functions using devices measuring the abductor pollicis brevis power and evaluated its correlation with clinical, radiological and electrodiagnostic study (EDS) findings.

## MATERIALS AND METHODS

### Device for motor function evaluation

Device capable of measuring muscle power of abductor pollicis brevis (APB) was made by department of medical engineer-

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ing, Seoul National University Hospital. It is based on design of Agabegi et al.<sup>1)</sup>. It was designed to measure strength using load cell in kilogram force from 0 to 50 with the maximum error of 0.15% (MNT50L, CAS, Seoul, Korea).

The device is composed of base plate with Velcro straps for securing the forearm and palm, adjustable metal arm for proper positioning of load cell (Fig. 1). An analog-to-digital converter transfers signals from the load cell to the computer via universal serial bus. The program for measurement was also developed in collaboration with department of medical engineering. It works under Windows operating system (Win XP, Microsoft, Seattle, WA, USA). It displays the change in measurement by graphs and it can display the maximum value of measurement with calibration before measurement (Fig. 2).

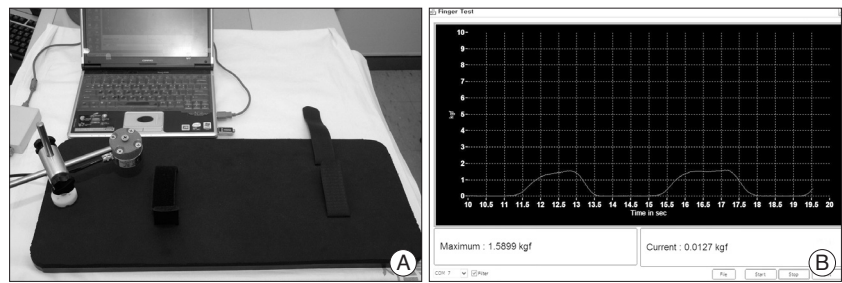
### Measurement of motor function

Measurement of median nerve motor function was done by strength of thumb abduction and index finger flexion in a standardized fashion. The base board was placed on desk, with the patient seated, the patient's forearm was supinated on the base board. The Velcro straps were tightened around the patient's hand and forearm to prevent any rotation of the forearm or wrist as well as other motions of wrist joint. Patients were asked to perform thumb abduction and index finger flexion to maximum strength. Measurement was done three times, with a 20-second interval of rest between each attempt. Before measurement, the movement for motor power evaluation was demonstrated to the patient and the importance of exerting maximum effort was emphasized. The tip of the load cell was placed at the radial border of the thumb interphalangeal joint flexion crease for measurement of thumb abduction strength; at the distal interphalangeal joint flexion crease the load cell was positioned for index finger flexion strength (Fig. 3). The maximum measured value from each attempt was used for analysis. Thumb index ratio (TIR), the measure of median nerve motor function, was calculated as follows :

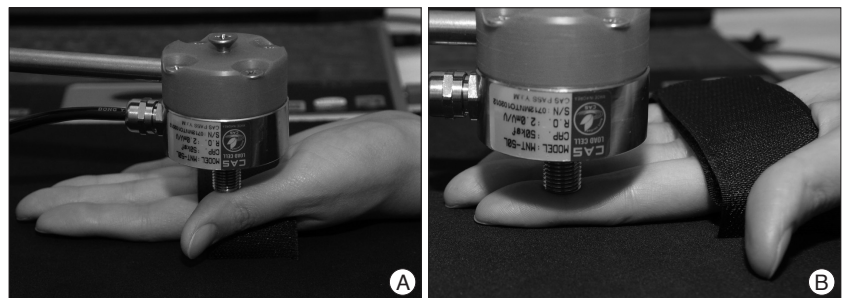
$$\text{TIR} = (\text{average of 3 thumb abduction power}) / (\text{average of 3 index finger flexion power})^{1)}$$

### Patients, EDS, USG

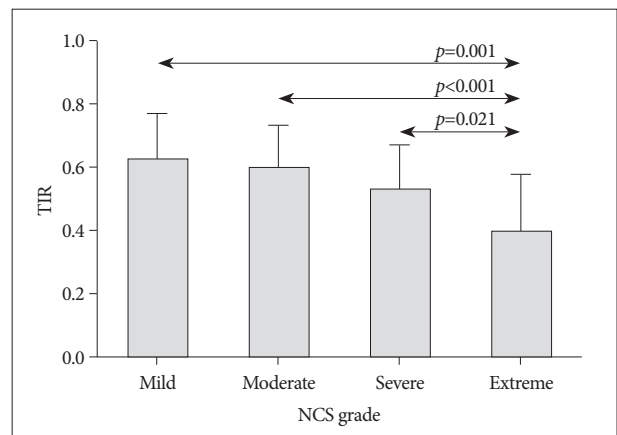
Subjects diagnosed as idiopathic CTS, by EDS and clinical features, were recruited for study. The measurement was done in outpatient clinic after confirmed diagnosis, before operation, from July 2009 to December 2012. Measurement was done in both hands for patients with bilateral disease, in one hand for



**Fig. 1.** Device and program for measuring thumb abduction strength. The device (A) is composed of base plate with velcro strap, load cell mounted on adjustable arm. The screen capture (B) shows graphic output of measured muscle strength in kilogram force.



**Fig. 2.** The measurement of thumb abduction and index flexion strength. Thumb abduction strength is measured by placing load cell at the radial border of the thumb interphalangeal joint flexion crease (A). Index flexion strength is measured by placing load cell at the distal interphalangeal joint flexion crease (B).



**Fig. 3.** The difference of TIR according to NCS grade. The TIR of NCS grade extremely severe was significantly lower than those of other NCS grades in post-hoc analysis. TIR : thumb index ratio, NCS : nerve conductive studies.

patients with unilateral disease or patients previously got operated for CTS. Bulk of thenar muscle was checked and presence or absence of thenar atrophy was recorded.

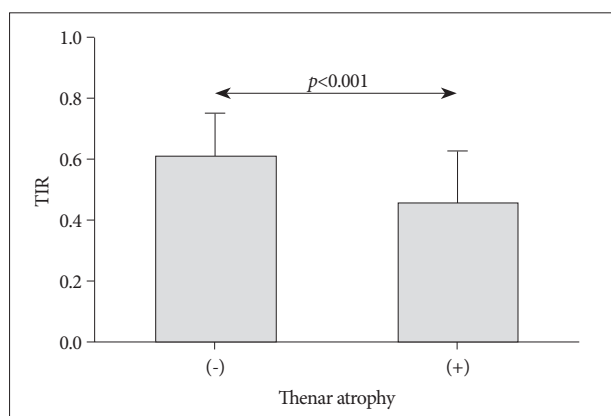
Nerve conductive studies (NCS) were performed for diagnosis using standard techniques of surface stimulation and recording (Nicolet Viking IV, Madison, WI, USA). Skin temperatures were maintained above 31.0°C. Median sensory nerve conduction velocity was orthodromically measured in the index finger-wrist segment, and the median distal motor latency from the wrist 5 cm proximal to the recording electrode at the

abductor pollicis brevis. Electromyographic study (EMG) was done at abductor pollicis brevis. The severity of CTS was assessed based on the results of NCS using a previously reported neurophysiologic classification from negative to extremely severe<sup>8)</sup>.

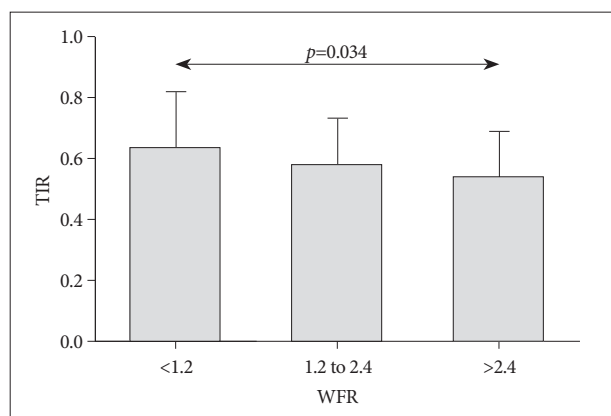
USG of the carpal tunnel was performed for preoperative evaluation of median nerve in cases with severe symptoms showing poor response to conservative treatment. The device used were HDI 3000 (Philips, Netherland), Sequoia 512 (Acuson, Mountain View, CA, USA). A 2-6 MHz linear array transducer was used. Cross sectional area (CSA) of median nerve was measured using elliptical method at two points : one at mid-forearm, the other at just proximal to carpal tunnel, where the nerve swelling is most prominent. The absolute value of nerve area at just proximal to carpal tunnel and ratio [wrist to forearm ratio (WFR)] of nerve swelling to mid-forearm was used for analysis.

### Statistical analysis

Statistical analysis was performed by SPSS (version 20, IBM SPSS Statistics, Armonk, NY, USA). One-way analysis of variance (ANOVA) and independent samples t-test and chi-square test were applied. The *p*-values less than 0.05 were considered



**Fig. 4.** The difference of TIR according to presence or absence of thenar atrophy on physical examination. TIR : thumb index ratio.



**Fig. 5.** The difference of TIR according to WFR. The patients with higher WFR have significantly lower TIR in post-hoc analysis ( $p=0.034$ ). TIR : thumb index ratio, WFR : wrist to forearm ratio.

statistically significant.

This study was approved by the Institutional Review Board of our hospital (20090506/06-2009-60/83).

## RESULTS

### Demographics

TIR measurement was done in 119 wrists out of 67 patients. There were 14 males and 53 females. The mean age of patients was 57.6 years (range from 28 to 81). EDS was done in all patients, USG done in 102 wrists (56 patients).

### TIR

The average of TIR was 0.57, with standard deviation of 0.16 (range from 0.046 to 1.037). The average value of left wrist was 0.58, and that of right was 0.55, without any statistically significant difference.

### Correlation of TIR with other variables

The TIR was significantly lower in patients with higher NCS grade (ANOVA,  $p<0.001$ ) (Fig. 3). The TIR of NCS extremely severe grade was significantly lower than those of other NCS grades in post-hoc analysis. In this analysis, one case with minimal NCS grade was excluded from analysis because the number of patient was too small for analysis.

The TIR was significantly lower in patients with thenar atrophy ( $0.45\pm0.17$ , mean $\pm$ standard deviation) than in patients without atrophy ( $0.61\pm0.14$ , t-test,  $p<0.001$ ) (Fig. 4). The abnormality of APB EMG was not significantly correlated with thenar atrophy. There was not significant difference in TIR in groups with or without EMG abnormality.

Although the CSA of median N at carpal tunnel showed not significant correlation with TIR, the patients with higher WFR showed lower TIR with statistical significance (ANOVA,  $p=0.042$ ) (Fig. 5).

## DISCUSSION

There have been several methods for evaluation of median nerve motor function in CTS, such as power grip, pinch grip, manual muscle testing, and assessing the thenar muscle atrophy<sup>5,6)</sup>. Power grip, which has been used most extensively, does not exclusively evaluate the muscles affected by CTS. Weakness of APB or opponens pollicis (OP) may be masked by compensatory action of synergistic muscles, such as the flexor digitorum superficialis and flexor digitorum profundus, particularly to the ring and little fingers, therefore not significantly reducing power grip. Key pinch or lateral pinch was the most common type of pinch grip assessed. APB or OP weakness may be compensated for during key pinch by synergistic muscle action or 'trick' movements<sup>11)</sup>. Muscle function evaluated by hand held dynamometer (Rotterdam Intrinsic Handheld Myometer, RIMH) has been suggested for better evaluation of motor functions of

CTS. It is equipped with easy-to-hold, ergonomic handgrip, and capable of detecting minute changes in hand muscles<sup>9</sup>.

Our device has several advantages. It measures the strength of APB, the most commonly affected muscle<sup>3</sup>. It uses load cell which generate digital output, easy to read with good reproducibility as demonstrated in RIMH<sup>9</sup>. Graphic display of measured strength is useful for detecting steady state of muscle power, preventing mislead by 'peak' of instant high power. It is operated on solid base, obviating the possible variance of power applied by the examiner. One of the distinguished merits compared to other studies measuring APB strength is its ability of internal control<sup>1,7</sup>. The measured APB strength is compensated by flexor strength of index finger; therefore it can be a measure of APB strength corrected for each cases intrinsic variation of muscle bulk or strength. It is known that muscle power of right hand is higher in about 10% that of left hand<sup>4</sup>. Our data shows no statistically significant difference in TIR of right and left hands, which supports the validity of internal control.

NCS grade used in our study gave higher grade in cases with abnormal responses in median nerve motor component<sup>8</sup>. Significantly lower TIR in extremely severe grade in our series reflects the dysfunction in motor components of median nerve. There has been a report that indicated no significant difference in TIR between NCS grades, which classified by prolongation of distal motor latency<sup>1</sup>. It might suggest delicate variation in distal motor latency is not well correlated with median nerve motor function, although presence or absence of motor NCS is correlated with TIR difference.

The difference of TIR in accordance of presence of thenar muscle atrophy shows objective measurement of strength is well correlated with qualitative assessment of median nerve motor dysfunction. The absence of correlation between APB EMG abnormality and TIR might be caused by the number of cases. In our hospital, APB EMG was not done for all of the patients with CTS, only 36 of 119 wrists underwent APB EMG. The lack of correlation between TIR and APB EMG support this speculation.

The lower TIR in patients with more severe median nerve swelling in USG has not been reported previously. Our data shows WFR, the relative swelling of median nerve, rather than absolute CSA of median nerve is a better reflection of median nerve dysfunction in CTS. It is known that severe median N swelling is correlated with higher NCS grade, supports the concepts that morphological change of median nerve is correlated with functional derangements of median nerve<sup>2</sup>.

It has been suggested that there might be a cut off value for diagnosis of CTS by median nerve motor dysfunction<sup>1</sup>. We think that it is impractical because median nerve motor dysfunction develops in severe cases of CTS, not in all of the patients. The larger variation in TIR in CTS patients, compared to normal control suggests that normal controls show relatively uniform values, whereas mixed values of normal and abnormal values appear in CTS patients<sup>1</sup>. There might be a cut off value for normal or abnormal value in TIR; however it requires large

population data with normal control. Although there might be a cut off value of TIR, it would better for use it for assessment of median N motor function, rather for diagnosis of CTS.

Our data show objective measurement of median nerve dysfunction is possible and its correlation with gross thenar muscle atrophy, NCS grade, and USG findings. It might be helpful for detecting patients with median nerve motor dysfunction without objective thenar muscle atrophy, thus to treat the patients before obvious muscle wasting and functional loss. It can be done without any discomfort, so it might be a good substitution for APB EMG, especially in repeated measurement for detecting recovery of motor function after surgery.

## CONCLUSION

Measurements of median nerve motor function using load cell is a valuable evaluation tool in CTS. It makes possible to objectively evaluate median nerve motor function without any discomfort to the patient. It shows correlation with clinical, radiological and functional status of median nerve. It might be helpful in detecting subclinical motor dysfunction before muscle atrophy develops.

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