# Transcarpal Median Sensory Conduction: Detection of Latent Abnormalities in Mild Carpal Tunnel Syndrome

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**ABSTRACT:** The major slowing of nerve conduction in the carpal tunnel syndrome is located in the palm to wrist segment. The aim of this study is to develop a reliable, sensitive and accessible approach to measure transcarpal median sensory nerve conduction. For this purpose, a fast recovery amplifier with a stimulus artifact suppressor was designed by the author. On stimulation of digits II or III, evoked orthodromic sensory nerve action potentials were simultaneously recorded at the palm and at the wrist. Distances were determined with a ruler. Median sensory nerve conduction velocity was estimated from digit to palm and from palm to wrist in 80 healthy hands and 253 hands with a presumptive diagnosis of carpal tunnel syndrome. According to conventional criteria, 131 of the 253 hands from those suspected of carpal tunnel syndrome were thought to have median nerve compression. When transcarpal median sensory conduction velocity was taken into account, the diagnostic yield increased by 18.1%. The described technique provides a simple, sensitive and reliable method of diagnosing mild or early carpal tunnel syndrome.

**RÉSUMÉ: Conduction sensitive médiane transcarpienne: présence d'anomalies occultes dans le syndrome du canal carpien à l'état fruste** La conduction des fibres sensitives du nerf médian dans le syndrome du canal carpien se ralentit principalement entre la paume et le poignet. Ce travail vise à mettre au point une méthode fiable, sensible et pratique pour mesurer la vitesse de conduction transcarpienne médiane sensitive. A cette fin, l'auteur a construit un amplificateur à temps de récupération court muni d'un système de suppression de l'artéfact de stimulation. L'index ou le majeur est stimulé et les potentiels d'action sensitifs résultants sont enrégistrés simultanément à la paume et au poignet. Une règle mesure les distances. Les vitesses de conduction sensitive médiane du doigt à la paume et de la paume au poignet ont été ainsi déterminées à partir de 80 mains normales et de 253 mains affectées possiblement d'un syndrome du canal carpien. Les critères conventionels démontrent une compression du nerf médian au poignet parmi 131 des 253 mains présumément atteintes. En tenant compte de la vitesse de conduction sensitive transcarpienne, le nombre des cas pathologiques s'accroit de 18,1 %. La technique proposée se révèle un outil simple, sensible et fiable pour diagnostiquer le syndrome du canal carpien à l'état fruste ou au stade précoce.

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The value of nerve conduction studies in the diagnosis of carpal tunnel syndrome has been well established since an initial report by Simpson[1] in 1956. Buchtal and Rosenfalck[2,3] and Kimura[4,5] demonstrated that the major slowing of nerve conduction in the carpal tunnel syndrome occurs in the palm to wrist segment while median nerve conduction velocities distal to the carpal ligament are either normal or slightly reduced. Brown et al[6] measured the median sensory conduction at the time of surgical exploration in patients with carpal tunnel syndrome and have confirmed that the major conduction abnormalities in the median nerve most frequently are located in the first 1-2 cm distal to the proximal border of the flexor retinaculum. The same study also revealed definite abnormalities of conduction in median nerves that had a motor terminal latency or distal sensory latencies in the normal range.[6]

Needle electromyography has definitely been found to be less sensitive than nerve conduction studies in patients with suspected carpal tunnel syndrome.[7] Median nerve sensory latencies represent a more sensitive electrodiagnostic criterion for carpal tunnel syndrome than the distal motor latency.[3,7-9] However in 25% of patients with clinical evidence of median nerve entrapment at the wrist, sensory conduction from digits to wrist is normal or borderline.[3] Because of persistent symptoms of carpal tunnel syndrome, patients often have surgical decompression of their median nerve in spite of their normal electrophysiological studies; disappearance of symptoms following surgical decompression indicates that these patients indeed had carpal tunnel syndrome.[10]

Buchtal and Rosenfalck investigated the carpal tunnel segment using near nerve recording.[2,3] While this method may give more exact values by reducing the distance between nerve fibers and electrodes, the technique is too uncomfortable for patients to allow its use as a routine procedure. Kimura[4-5] and Long and Wolfgang[11] have proposed a technique that consists

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of stimulating the wrist to the midpalm at 1 cm intervals. Although their procedure may be helpful in demonstrating minor local conduction delay or drop of amplitude, repeated stimulation of the palm area prolongs the technique and results in increased discomfort for patients. The diagnostic value of other complicated methods such as refractory period measurements,[12] nerve conduction studies during ischemia[13] or wrist flexion,[14] repetitive stimulation[15] or mechanical stimulation of digital nerves[16] is yet to be determined. In 1975, Eklund[17] reported a procedure that consists of stimulating the palm and recording orthodromically at the wrist. While this method may represent a sensitive and practical approach, volume conducted current spreading[18] in the palm may create the problem of not knowing where sensory nerves are actually stimulated and there is also the disadvantage of occasional concomittant stimulation of the nearby motor branch of the median nerve. Terminal latency index[19] and residual latency determination[20] are extrapolated from motor distal latencies and are less sensitive than sensory studies.[21-23] Early surgical decompression is advisable[24] and hence we should continue to search for sensitive and acceptable methods.

The aim of this study is to develop a practical, reliable and acceptable method for detecting minimal slowing of median sensory nerve conduction velocity which escapes conventional electrophysiologic diagnostic techniques. By stimulating the middle or index finger and simultaneously recording the evoked median sensory nerve action potentials at the wrist and the palm, nerve conduction velocity can be measured over the finger to palm segment as well as over the palm to wrist segment. This paper reports on both technical and clinical aspects of this approach in normal subjects and patients with suspected carpal syndrome.

## Material

### Control group

In all, eighty hands were examined. The group consisted of 43 healthy volunteers, 21 males, 21 to 67 years of age (mean = 31.8) and 22 females, 20 to 73 years of age (mean = 34.8). None had any history, symptoms, or signs of peripheral nerve disease.

### Patients with suspected carpal tunnel syndrome

To be accepted in the study, the criterion was acroparesthesia in the median nerve distribution with or without Tinel or Phalen's sign. Detailed clinical histories and complete neurological examinations were obtained. Patients with clinical or electrophysiological evidence of polyneuropathy, medico-legal and workmen's compensation board cases were excluded. Associated disorders were mild diabetes mellitus (3 patients), previous Colles' fracture (2 cases) and mild rheumatoid arthritis (1 patient). Duration of symptoms extended from 6 weeks to 12 years with a mean of 2.6 years. Two hundred and fifty-three hands from one hundred and fifty patients (109 women and 41 men) were then studied. The average age of the female patients was 47.7 years with a range from 20 to 84 years; for the male patients, the average age was 47.4 years with a range of 18 to 73 years. Follow-up information was obtained in all patients who were found to have a carpal tunnel syndrome solely on the basis of significant slowing of transcarpal sensory nerve conduction velocity.

## Methods

Throughout the study, finger-to-wrist distance is defined as total or conventional distance; finger-to-palm segmental distance is identified as digital distance and palm-to-wrist distance as transcarpal distance. Orthodromic sensory nerve action potentials evoked at the palm are named median palmar and those evoked at the wrist, carpal sensory nerve action potentials.

### Motor conduction

Motor conduction studies were performed using standard methods.[25]

### Sensory conduction

#### *1. Stimulation*

The stimulating electrodes (Figure 1) were finger-clip electrodes with the cathode placed around the proximal phalanx of digit II or III (median nerve) or digit V (ulnar nerve); the anode was positioned 3.0 cm distally over the distal phalanx. Cotton wool was used to separate the fingers and to insulate the electrodes.

The stimulus was a rectangular constant current pulse, 50 μsec in duration. The stimulus intensity was gradually increased until the response was maximum.

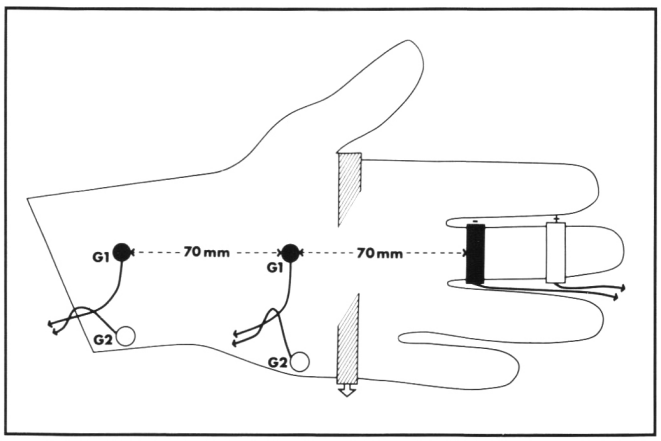


*Figure 1 — Arrangement of stimulating, recording and grounding electrodes (Digit III).*

#### *2. Recording electrodes*

The recording electrodes (Figure 1) were platinum subdermal electrodes (Grass Instrument Company Type E2). The active electrode was located over the median nerve and reference electrode 3.5-4.0 cm from the active at a right angle to the course of the nerve. At the wrist, the active electrode was placed on the volar surface over the median or ulnar nerve which had been located at the time of the motor conduction study; at the palm, the active electrode was positioned at mid-distance between the digit III stimulating cathode and the wrist active electrode. The ground (Figure 1) was a Dantec 13K93 grounding electrode wrapped around the palm and dorsum of the hand between the stimulating cathode and the palmar recording electrodes.



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### *3. Amplifier*

To record palmar sensory nerve action potentials, a custom-built amplifier was designed with an integrated stimulus artifact suppressor (Figures 2 and 3, upper trace). This amplifier has a fast recovery time (< 500 μsec), a low input voltage noise (0.3 μV RMS at bandwith of 10 Hz-10 kHz), a high common mode rejection ratio (> 122 dB at 100 Hz) and a high input impedance (> 100 MΩ at 1 kHz). The leads carrying the electrode signal were directly connected to a remote preamplifier located near the recording electrodes. The carpal sensory nerve potentials were recorded using a standard sensory amplifier (Dantec 15C02). Lower and upper frequency limits (–3dB) of both amplifiers were set at 20 Hz and 2 kHz. Averaging of 4 to 16 responses was obtained.

### *4. Measurements*

#### a. Distances

The mean total distance was 140 mm (Figure 1). On occasion, 10 mm or 20 mm were added or subtracted to accommodate large and small hands. The mean digital and transcarpal distances were thus half the mean total distance (70 mm) with a range of 60 mm to 80 mm.

The short distances over which conduction velocities were calculated required that they be measured as accurately as possible.[26] The curved contour of the carpal region is a potential source of error in the measurement of the transcarpal distance. Comparative measurements of distances with a ruler and a curvimeter (Uchida digital curvimeter Model D) actually revealed some discrepancies in the evaluation of this particular distance (Table 1). Curvimeter, like flexible tape measure, tends to follow the skin surface and yields a larger value than a ruler which bypasses the surface contour variations. As a result, all distances were measured with a ruler applied on a fully extended hand.

**Table 1: Comparative Measurements of Distance with a Ruler and a Curvimeter**

| Segment | Subject | Distance[1] (millimeter) Ruler | Curvimeter | Difference |
|---|---|---|---|---|
| Digital | 1 | 60.3 ± 0.9 | 60.6 ± 0.5 | 0.5% |
| | 2 | 65.0 ± 0.0 | 66.0 ± 0.0 | 1.5% |
| | 3 | 70.0 ± 0.0 | 71.3 ± 1.8 | 1.9% |
| Transcarpal | 1 | 60.3 ± 0.5 | 68.6 ± 0.5 | 13.8% |
| | 2 | 65.0 ± 0.0 | 70.0 ± 0.0 | 7.7% |
| | 3 | 71.0 ± 0.0 | 74.0 ± 0.0 | 4.2% |

[1]Mean and standard deviation of 3 consecutive measurements. Resolution is ± 1.0 mm for the ruler and ± 0.5 mm for the digital curvimeter.

#### b. Latencies and amplitudes

There is evidence suggesting that the greatest source of error may be attributed to time measurement.[27] To obtain a better resolution in time, the sweep speed was increased to 0.5 msec/division. The latency of the sensory response (Figures 2 and 3) was determined from the onset of the stimulus artifact to the time of the initial positive-to-negative deflection corresponding either to the initial positive peak or to the onset of the negative peak when the initial positive peak was not easily identifiable. The transcarpal latency was obtained by subtracting the digital latency from the total latency. Amplitudes were measured from peak to peak.

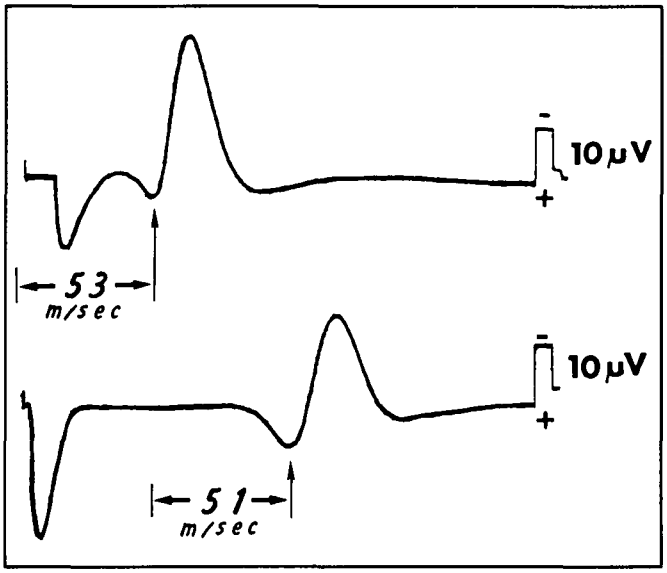


*Figure 2 — Evoked median sensory nerve action potentials at the palm (upper trace) and the wrist (lower trace) in a healthy hand. The digital and the transcarpal latencies are 1.33 and 1.36 msec. Both distances are 70 mm. In the upper trace, the first 250μsec are blocked by the custom-built stimulus artifact suppressor.*

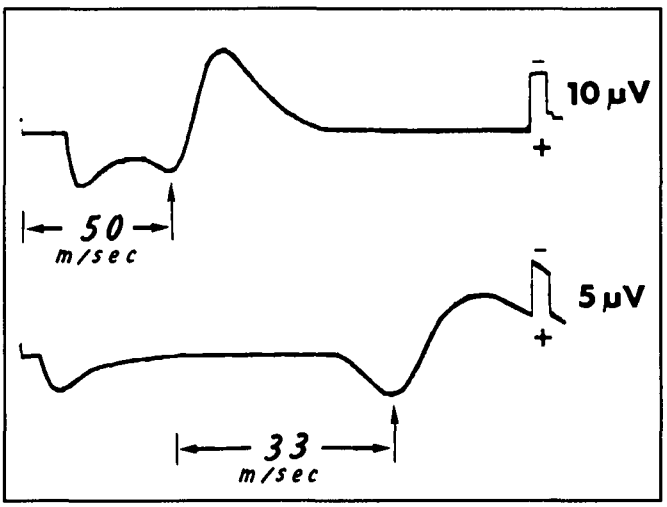


*Figure 3 — Evoked median sensory nerve action potentials in a hand with suspected carpal tunnel syndrome. The digital and the transcarpal latencies are 1.39 and 2.10 msec. Both distances are 70 mm. This case belongs to subgroup 5 (Table 3); the total conduction velocity in this hand is 40.1 msec (estimated normal value > 39.2) and the only detectable electrophysiological abnormality is latent slowing of the transcarpal conduction velocity (estimated normal value > 37.3 msec).*

### *5. Temperature*

When temperature fell below 32°C, the limb was warmed using an infrared lamp (Dantec 15H03).

### Statistical analysis

Pertinent clinical and electrophysiological data were collected and correlated with an electronic spreadsheet (Lotus 123



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Release 2.01). Statistical analysis was performed using standard methods.[28-30] To avoid false positive diagnoses, upper and lower limits of the confidence intervals were corrected for age and defined as 2.57 S.D. above and below the mean.

## Results

### Control group

The values of median and ulnar sensory conduction studies for the control hands are given in Table 2.

Motor terminal latencies are 3.2 msec ± 0.4 msec for the median nerve and 2.9 msec ± 0.4 msec for the ulnar nerve. Motor nerve conduction velocities from elbow to wrist were 56.9 m/sec ± 3.5 m/sec for the median nerve and 58.7 m/sec ± 4.6 m/sec for the ulnar nerve.

Conventional median sensory conduction velocity is 50.5 m/sec ± 4.4 m/sec for digit III and 50.7 m/sec ± 4.4 m/sec for digit II. When the age of the subjects is taken into consideration, regression analysis showed that this velocity actually is equal to 53.7 m/sec – (0.10 × age) ± 4.5 m/sec ($r = 0.32$ and $P < 0.001$) which means a reduction of 1.0 m/sec per decade of age.

This study reveals a difference of 2.4 m/sec (Digit III) and 2.1 m/sec (Digit II) between transcarpal median sensory conduction velocities and digital median conduction velocities. This difference is significant ($t = 3.4$ and $P < 0.001$). Regression analysis showed that transcarpal conduction velocity is equal to 0.95 × digital conduction velocity ± 4.5 m/sec ($r = 0.30$ and $P < 0.01$).

**Table 2: Conduction Velocity and Amplitude of Sensory Potentials in the Hands of Healthy Subjects**

| Nerve | Distance | Conduction Velocity (m/sec) | Side-to-Side Difference (m/sec) | Peak-to-Peak Amplitude (μV) |
|---|---|---|---|---|
| Median Digit III | Digital Transcarpal Total | 51.8 ± 5.1(38.7)[1] 49.4 ± 4.7(37.3)[1] 50.5 ± 4.4(39.2)[1] | 3.8 ± 3.0(11.5)[2] 3.0 ± 2.7(9.9)[2] 2.6 ± 2.3(8.5)[2] | 30.5 ± 14.7 18.7 ± 8.4 |
| Median Digit II | Digital Transcarpal Total | 52.4 ± 5.4(38.7)[1] 49.3 ± 4.8(37.1)[1] 50.7 ± 4.4(39.5)[1] | 4.2 ± 3.2(12.4)[2] 3.2 ± 2.9(10.7)[2] 2.6 ± 2.0(7.7)[2] | 23.7 ± 14.6 13.4 ± 6.9 |
| Ulnar | Total | 48.6 ± 4.8(36.3)[1] | 2.8 ± 2.0(7.9)[2] | 10.5 ± 4.8 |

Mean, Standard Deviation and 99% Confidence Limits of 80 Nerves from 43 Healthy Subjects: 21 Males, 21 to 67 Years of Age (Average 32) and 22 Females. 20 to 73 Years of Age (Average 35). Skin Temperature = 32°-35° C.
1 Lower limit of normal calculated as mean – 2.57 S.D.
2 Upper limit of normal calculated as mean + 2.57 S.D.

### Patients with suspected carpal tunnel syndrome

The results of the 5 subgroups are summarized in Table 3.

Electrophysiological evidence of carpal tunnel syndrome was found in 63.2% (160 hands) of the 253 symptomatic hands examined. Motor conduction studies were abnormal in 60.7% of the hands (subgroup 1, 2 and 3). Conventional nerve conduction sensory studies provided an additional 21.2% of positive cases (subgroup 4). In 18.1% of the hands, the only detectable neurophysiological abnormality was slowing of transcarpal sensory nerve conduction velocity demonstrated with the proposed method (subgroup 5). It is interesting to note that in this latter subgroup, no false positive was found in the 40% which had subsequent surgical section of the carpal ligament.

**Table 3: Frequency of Electrophysiologic Abnormalities Associated with Carpal Tunnel Syndrome**

| Sub group | Electrophysiologic Abnormalities: Distal Motor Latency > 4.2 msec | Conventional Sensory ≤ 39.2 m/sec | Transcarpal Sensory ≤ 37.3 m/sec | n = 160 symptomatic hands |
|---|---|---|---|---|
| 1 | [+] | [+] | [+] | 52.5% (84/160) |
| 2 | [+] | [–] | [–] | 1.3% ( 2/160) |
| 3 | [+] | [–] | [+] | 6.9% (11/160) |
| 4 | [–] | [+] | [+] | 21.2% (34/160) |
| 5 | [–] | [–] | [+] | 18.1% (29/160) |

## Discussion

This study shows that the described method is a reliable approach for diagnosing mild or early carpal tunnel syndrome. The technique is accessible to a clinically oriented laboratory and requires only the use of additional recording electrodes at the palm; both carpal and palmar potentials can be simultaneously recorded. Moreover, the procedure is well tolerated by the patients and can be easily adopted as a routine technique.

The sensitivity of the proposed technique is enhanced because nerve conduction studies can more easily demonstrate entrapment neuropathies when the segmental distance containing the suspected entrapment is shorter; the focal slowing of conduction caused by the entrapped portion of the nerve is not diluted by the faster conduction of the adjacent normal nerve. The major problem with this approach is the likelihood of greater inaccuracy in the conduction velocities calculated for the shorter segments; the shorter the distance, the greater the percentage of the variance in measurement. In this study, the accuracy in measuring segmental distances was increased through the use of a rigid ruler (Table 1). Needle electrodes also are more reliable for precisely determining the latency of the evoked sensory potentials[31]. The standard deviation (Table 2) of the segmental velocities measured with the described method extends from ± 4.9 m/sec to ± 5.4 m/sec; these values are quite acceptable and in the range of the standard deviations reported with numerous conventional sensory conduction studies[25]. The proposed approach thus increases the diagnostic yield without significantly sacrificing the accuracy of the conduction velocities.

Another technical difficulty is the larger stimulus artifact resulting from the shorter distances between recording electrodes and stimulating cathode. The compound sensory nerve action potential may be evoked at the palm as early as 1.0 m/sec after the stimulus. As a result, the initial positive peak of the palmar potentials tends to be masked by the prolonged "tail" of the stimulus artifact. Positioning the recording electrodes at a right angle with the course of the median nerve is helpful in reducing the stimulus artifact; with such an arrangement, the distance from the recording electrodes to the stimulating cathode becomes more analogous and the stimulus artifact then



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appears principally as a common mode signal. The duration of the stimulus artifact can be shortened by recording with needle electrodes rather than with disc electrodes; with their low capacity, needle electrodes do not act like capacitors and are not charged by the volume conducted current of the stimulus. A suitable amplifier is also an effective means of reducing the stimulus artifact; desirable characteristics of the amplifier are fast recovery time, high common mode rejection ratio and some sort of stimulus artifact suppression system.

With the described method, faster values were obtained for the digital segments than for the transcarpal segments. The difference is 2.4 m/sec for digit III and 1.4 m/sec for digit II (Table 2). It is not clear whether this 5% difference is real or if it reflects a possible error in determining effective distances between the active electrode and the stimulating cathode. Even if overstimulation is carefully avoided, proximal displacement of the point of stimulation relative to the position of the cathode is always possible. This unmeasurable displacement may reduce the effective distance and account for the faster conduction velocities and the larger standard deviations (Table 2). However this error may occur only in determining digital distances which are less relevant for diagnosing carpal tunnel syndrome; transcarpal conduction velocities are unaffected by this potential error as distances for this segment are estimated between two recording electrodes. This is not the case, however, with palmar stimulation;[32-35] in this latter method, transcarpal distances are measured from a stimulating cathode to a recording electrode. The described method offers an interesting alternative to palmar stimulation for accurately measuring transcarpal conduction velocities.

In patients with carpal tunnel syndrome studied using the described technique (Table 3), sensory and motor conduction velocities are respectively abnormal in 98.7% and 60.7% of hands which were examined. This confirms that sensory nerve conduction studies are more sensitive than motor nerve conduction studies.[3, 7-9] Nevertheless in 2 hands (Table 3, subgroup 2), the terminal motor latency was significantly prolonged while both conventional and transcarpal sensory nerve conduction velocities were within normal limits. This indicates that motor fibers may be exclusively or preferentially impaired in some patients with carpal tunnel syndrome.

Digital nerves are an infrequent site of entrapment[36] and in carpal tunnel syndrome, conduction velocities in the digital segment are normal or only slightly reduced.[2-6] However, digital velocities are slow or slower than transcarpal velocities in generalized neuropathy.[16] Comparison of transcarpal and digital conduction velocities may thus be useful for separating diffuse neuropathy or more proximal focal neuropathy from entrapment at the wrist.[31] Further studies are necessary to evaluate the diagnostic value of this approach.

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