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Segmental analysis of motor conduction velocity in distal tracts of tibial nerve: A coaxial needle electrode study

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ABSTRACT

Objective: To describe a new method of segmental analysis of motor nerve conduction velocity (mCV) in the tibial nerve (Tn) tract distal to the upper margin of the tarsal tunnel (TT).
Methods: Compound muscle action potentials (CMAPs) were recorded with a coaxial needle electrode from the flexor hallucis brevis muscle (FHB), to test the medial plantar nerve (MPn), and from the flexor digiti quinti brevis (FDQB) and the first dorsal interosseous (FDI) muscles, to test the superficial and deep branches of the lateral plantar nerve (sLPn and dLPn, respectively). CMAPs were elicited by stimulating at three sites located above (S1) and below (S2) the TT and at the sole of the foot (S3 for MPn and S4 for LPn).
Results: In 20 normal subjects the mean mCV in the proximal (S1 to S2) tract was 44.5 ± 4.7, 43.5 ± 5.9 and 42.6 ± 4.2 m/s for the MPn, sLPn and dLPn, respectively. The corresponding values in the intermediate tract (S1 to S3/S4) were 40.7 ± 5.6, 39.4 ± 5.6 and 40.9 ± 5.8 m/s.
Conclusions: Segmental analysis of mCV in distal Tn can be performed when CMAPs are recorded using a coaxial needle electrode, which prevents simultaneous recording of activity from nearby muscles groups.
Significance: Conventional neurophysiological examination for suspected entrapments in distal Tn usually can not discriminate between a lesion inside the TT or distal to it. The proposed technique, as suggested by the reported results in clinical application, may help to better define the lesion site.

1. Introduction

The tarsal tunnel syndrome (TTS) is commonly considered a compression of the Tn as it curves behind the medial malleolus underneath the flexor retinaculum (Keck, 1962; Lam, 1962; Lau and Daniels, 1999; Oh and Meyer, 1999; Katirji, 2002). A selective or prevailing entrapment of the MPn and LPn, two of the terminal branches of Tn, is also possible at the TT; however, both of them can also be involved more distally (DeLisa and Saeed, 1983; Oh and Lee, 1987; Hah et al., 1992; Oh et al., 1999). It is very difficult to distinguish the two lesion sites on a merely clinical basis and electrodiagnostic (EDx) studies are often disappointing. Conventional EDx examination (Park and Del Toro, 1998; Oh and Meyer, 1999; Patel et al., 2005) includes both motor (mCV), sensory (sCV) as well as mixed nerve (nCV) conduction studies (Oh et al., 1979,1985; Fu et al., 1980; Saeed and Gatens, 1982; Belen, 1985; Ponsdorf, 1988; Antunes et al., 2000). However, since in any case a single nerve tract is examined, CV studies generally fail to provide localizing data. Felsenthal et al. (1992) tried to overcome these limitations by stimulating the nerve both above and below the TT and recording CMAPs from FHB and Abductor Digiti Minimi (ADM) muscles with surface electrodes; a similar approach was described for sCV (David and Doyle, 1996). The purpose of our paper is to demonstrate that a segmental analysis of mCV in the nerve tract distal to the upper TT can be performed by employing two more distal stimulating sites in addition to the standard one proximal to the TT, provided that muscle activity is selectively recorded with a coaxial needle electrode. As a matter of fact, surface recording proved to be misleading because pick up from near, unintended and differently innervated muscle cannot be avoided.

Abbreviations: ADM, abductor digiti minimi; AH, abductor hallucis; CMAP, compound muscle action potentials; CMT1A, Charcot–Marie–Tooth disease type 1A; dLPn, deep branch of the LPn; EMG, electromyography; FDGB, flexor digiti quinti brevis; FDI, first dorsal interosseous; FHB, flexor hallucis brevis; LPn, lateral plantar nerve; mA, milli-Ampere; mCV, motor conduction velocity; MPn, medial plantar nerve; mTLI, motor terminal latency index; MUAP, motor unit action potential; nCV, mixed nerve conduction velocity; Pn, peroneal nerve; sCV, sensory conduction velocity; sLPn, superficial branch of the LPn; Tn, tibial nerve; TT, tarsal tunnel; TTS, tarsal tunnel syndrome.

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2. Materials and methods

Twenty normal volunteers, 12 men and 8 women (age range 20–70 years) were examined, usually on the right side. In five of them both sides were studied. All of them gave full informed consent and the study was approved by the Local Ethics Committee. They were initially screened for any history, signs or symptoms of either peripheral neuropathy or compression syndrome of the lower extremities and a normal neurological exam was confirmed by normal mCV of the Tn and peroneal nerve (Pn) and sCV of sural nerve in the lateral malleolus-sura tract.

Moreover, the results obtained in four patients well representative of the diagnostic aid provided by the described method in clinical application are reported. They were two cases of focal plantar neuropathies, one case of sensory, axonal, probably diabetic polyneuropathy (pnp) and one defined case of inherited sensory-motor demyelinating pnp (Charcot–Marie–Tooth disease type 1A; CMT1A). Detailed clinical descriptions are reported in the Section 4.

2.1. Recording

In preliminary experiments performed on six controls, CMAPs were obtained by surface recording from FHB to test the MPn and from the FDQB and FDI muscles to test sLPn and dLPn, respectively (Perotto, 2005). Recording from more distal muscles as compared to the classic ones (AH and ADM) was chosen to make room for a further distal stimulation site at the sole of the foot. Since surface recording proved to be misleading because of the unavoidable occurrence of volume-conduction muscle activity from nearby, unintended muscles (see below), CMAPs were thereafter recorded by means of a coaxial needle electrode. Correct position of the needle in the intended muscle was revealed by the presence of well defined (1–3 mV) motor unit action potentials (MUAP) during attempts at voluntary activation. This was relatively easy for FHB and FDQB with simultaneous flexion of all toes but quite difficult for the FDI. However, recording of some MUAPs, few but enough to judge if the needle was correctly inserted in the muscle belly, was generally possible also from FDI during up and down movements of the toes.

2.2. Stimulation

The intermediate stimulation point (S2) was localized at first; it was searched about halfway along an imaginary line drawn from the apex of the heel to a point midway between the navicular tuberosity and the prominence of the medial malleolus (Fig. 1A). In all subjects, S2 was just distal to the distal border of the thickest portion of the flexor retinaculum. S2 coincides with the anatomical boundary between the upper TT (or tibio-talar), the fibro-osseus space located behind the medial malleolus, underneath the flexor retinaculum and the lower TT (or taleo-calcaneal) where the medial and lateral plantar nerves pass through fibrous openings in the origin of the AH muscle (the abductor tunnel). At this level, the tunnel for the tibial nerve is divided by the interfascicular septum in the upper and lower calcaneal chambers where the MPn and LPn travel, respectively. The proximal stimulation point (S1) was located 6 cm proximal to S2 with the ankle in a neutral position (90°). S1 was proximal to the upper border of flexor retinaculum in all subjects, independently of the individual length of the foot.

The distal stimulating points for MPn (S3) and LPn (S4) were located at the sole of the foot along a transversal line joining the 55–60% distal with the 40–45% proximal part of the total length of the foot (Fig. 1B). Surface stimulation was first attempted. When it proved to be ineffective due to excessive thickness of the skin, a fine (0.25 mm) monopolar needle was used as a stimulating cathode, the anode being a small (5 mm of diameter), round, surface electrode placed proximally, 2 cm away. We first located the correct point of needle insertion using surface stimulation and recording the corresponding nerve action potential at the medial malleolus.

During stimulation (1 Hz) the recording needle was gently moved, when necessary, until a response with a clear-cut, abrupt onset was obtained in order to facilitate detection of onset latency. Then great care was taken to maintain the needle position unchanged. Responses were accepted only if CMAPs with similar shape and amplitude were obtained after stimulation at each of the three sites.

The distances between S2 and S3/S4 were calculated using a calliper which was then transferred to a ruler to get an accurate measure. The distances between S3 or S4 and the insertion point of coaxial needle in FHB or FDQB were also measured to calculate (Shahani et al., 1979) the motor terminal latency index (mTLI) in the MPn and sLPn, respectively. This measurement was not taken for the dLPn because we reasoned to be unreliable to measure a conduction distance between a stimulus point at the sole of the foot and a recording site located on the dorsal aspect of the first metatarsal interspace. Skin temperature, measured at the middle of the sole of the foot, was maintained between 30 and 32 °C.

Examination was usually performed with the subject in prone position which made stimulation at S1 easier.

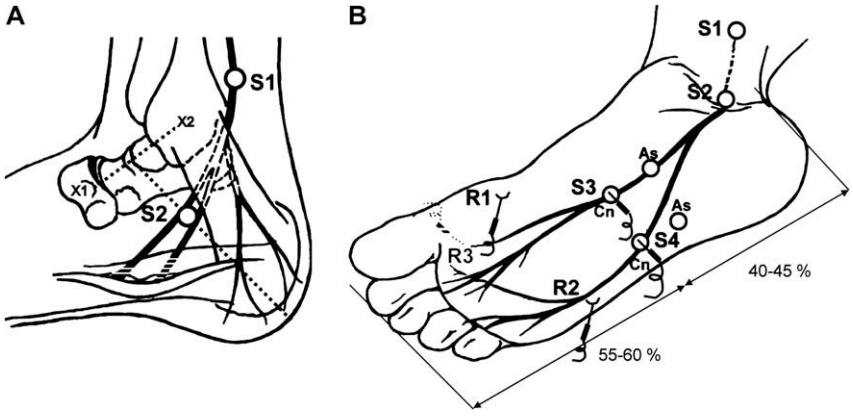

Fig. 1. Methodology for segmental analysis of motor-CV in the distal tract of Tn. Schematic representation of the stimulating and recording sites. S1, S2 and S3/S4 represent the stimulating sites located above and below the flexor retinaculum and at the sole of the foot, respectively. (A) S2 was localized about halfway along an imaginary line drawn from the apex of the heel to a point midway between the navicular tuberosity (X1) and the prominence of the medial malleolus (X2). S1 was placed 6 cm proximally to S2. (B) CMAPs were recorded with a coaxial needle electrode from FHB (R1), FDQB (R2) and from FDI (R3). Further explanation in the text.