CARPAL TUNNEL SYNDROME
reverse Phalen’s versus Phalen’s maneuver

Abstract
Carpal tunnel syndrome (CTS) is a compressive focal neuropathy of the median nerve (NM) at the wrist. We hypothesize that reverse Phalen’s test rather than the previously commonly proposed classic Phalen’s maneuver was a logical maneuver in the diagnosis of CTS from the anatomic, pathophysiological and electrophysiological viewpoint. Dorsal flexion of the hand results in an increase in the flexor retinaculum tension (RFT), extension of the finger long flexor muscle tendons and consequent NM entrapment between the tendons and flexor retinaculum (RF). Thus, the carpal tunnel (CT) volume is reduced, the intra-tunnel pressure is increased, while the RF to NM distance is decreased. On Phalen’s maneuver, the forced palmar hand flexion entails opposite consequences i.e. reduced RFT, relaxation of the finger long flexor muscle tendons, decreased pressure upon NM, slight increase in the CT volume, decreased intra-tunnel pressure and increased RF to NM distance. The hypothesis can be tested by a conductive NM study, preferably at three positions: mid-position (palmar/volar angle 180 degrees); forced dorsal flexion (palmar/volar angle about 270 degrees); and forced palmar (volar) flexion (palmar/volar angle about 90 degrees). Relative to mid-position, “deterioration” of electroneurography (ENG) finding is observed in dorsal flexion, whereas “improvement” of ENG finding is recorded in palmar flexion.

Keywords
carpal tunnel syndrome • median nerve • diagnosis • anatomy • electrophysiology

1. Introduction
Carpal tunnel syndrome (CTS), a symptomatic focal median neuropathy at the wrist, is the most common focal nerve compression and a frequent reason for electrodiagnostic consultation. In 1913, Marie and Foix [1] reported median nerve (NM) compression at the wrist observed in an autopsy study. Thousands of studies exploring the issue from various viewpoints (anatomic, pathophysiological, etiologic, diagnostic, therapeutic, etc.) have since been reported in the literature. The diagnosis of CTS is based on the clinical picture and is verified by electromyoneurography (EMNG). Clinically, CTS presents as a complex of symptoms that include pain, numbness, burning and/or tingling in the thumb, index finger, middle finger and radial half of the ring finger. The symptoms are frequently more prominent at night [2]. In CTS patients, hyperesthesia in the distal segment of NM innervation, weak thumb opposition and thenar hypotrophy can be found on examination. Many clinical tests and signs have been described in the literature as being more or less characteristic of the syndrome, e.g., Phalen’s sign [3], flick sign [4], Tinel’s sign [5], hyperextension test (reverse Phalen’s sign) [6], pressure provocation test [7], pneumatic-tourniquet test [8], hand elevation test [9], Semmes-Weinstein monofilament test [10], etc. Data on the validity of these tests are quite contradictory, indicating that “facts” need not always be taken as true facts when considering CTS. While it is clear that CTS is a chronic peripheral nerve compression phenomenon, the specific etiology and pathophysiology are less clear. Based on the anatomic considerations, clinical experience and electroneurophysiological (ENG) measurements, we propose a different approach to the clinical relevance of Phalen’s and reverse Phalen’s maneuvers in the diagnosis of CTS.

2. Hypothesis
From the anatomic, pathophysiological and electrophysiological viewpoints, forced dorsal flexion (hyperextension or reverse Phalen’s test) of the hand rather than the classic Phalen’s maneuver is a logical maneuver in the diagnosis of CTS.

3. Carpal tunnel anatomy
Carpal tunnel (CT) is an osteofibrous canal located on the palmar side of the hand root. CT is bound dorsally by carpal bones and volarly by flexor retinaculum (RF). The superficial aspect of RF is covered by the skin, while the deep aspect is turned towards anatomic structures passing through the tunnel. It is a fixed space that includes nine tendons (tendons of the four superficial flexor muscles of fingers, four deep flexor muscles of fingers and long flexor muscle of thumb) and the median nerve (NM). Tendons of these flexor muscles are lined with synovial sheaths. NM runs through the carpal canal superficially, that is immediately beneath RF and over tendons of the second and third finger flexor muscles [11].

4. Anatomic-pathophysiological approach to CTS
CT is a clearly demarcated space of a defined volume and intra-tunnel pressure. Changes in the intra-tunnel pressure can be transient (i.e. induced by certain wrist movements or...
by external pressure) or permanent (i.e. due to pathologic processes in the tunnel). All maneuvers that lead to transient reduction in the CT volume and consequential pressure increase are provocation methods in the diagnosis of CTS and make a basis of clinical tests for diagnosing CTS. With these maneuvers, anatomic relations among tendons, synovial sheaths filled with synovial fluid and RF, and indirectly NM, can be influenced, but not the wrist bones and fibrous tissue within the CT. On reverse Phalen's maneuver (Fig. 1, left), skin extension in the wrist area and increased RF tension (RFT) occur due to forced dorsal flexion of the hand, which in turn leads to an increase in the pressure within the CT. In addition, this maneuver results in extension of tendons of the long flexor muscles of fingers. As a consequence, NM is being entrapped between the tendons and RF. In this way, the distance between RF and NM is reduced. On classic Phalen's maneuver (Fig. 1, right), an inverse course is observed. The forced palmar (volar) flexion of the hand results in folding of the wrist skin, reduced RFT and relaxation of the finger long flexor muscle tendons. This in turn leads to a reduced pressure upon NM, slight increase in the CT volume and a decrease in the CT pressure, thus increasing the RF to NM distance and reducing the nerve pressure. As CT is bound from three sides by carpal bones, minimal changes in its volume and partial compensation for the increased intra-tunnel pressure can only be achieved through a decreased RFT and reduced synovial fluid volume within the tunnel. CTS can be compared with the elevated intracranial pressure syndrome and fascial compartment syndrome. Since CT, cranial cavity and fascial compartment are spaces of a clearly limited volume, any pathologic process in these spaces results in pressure elevation. Pressure elevation in the intracranial space manifests with headache, vomiting and arresting papilla; while in the fascial compartment it often presents with pain, ischemia, impaired sensations and muscular weakness [12], and in CT with sensory and motor symptoms of NM compression. There is no CTS without increased CT pressure; the only exception of systemic neuropathy of various etiologies.

This is the basis of CTS treatment with surgical NM decompression by cutting RF. In CTS patients, CT volume may be reduced due to carpal bone

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**Fig. 1** Effects of various hand positions on the anatomic-physiologic relations in the carpal tunnel and results of median nerve electroneurography finding.

d, distance; V, volume; p, pressure; S, volume of synovial fluid; NM, median nerve; RFT, flexor retinaculum tension; S1, distal stimulation site of NM; S2, proximal stimulation site of NM; DM, detection site of CMAP of NM; DS, detection site of SNAP of NM.
lesions (rheumatoid arthritis, osteoarthritis), tendon (tenosynovitis) and synovial sheath lesions (synovitis), edema (hypothyroidism, acromegaly, pregnancy), pathologic deposits (amyloidosis), and RF thickening. Also, NM can be hypersensitive to pressure (diabetic polyneuropathy, hereditary neuropathy with liability to pressure palsies) [11].

5. Electrophysiological approach to CTS

Based on the above considerations, we propose the classic ENG diagnosis to be extended by some modifications in patients suspected of having CTS. The median motor nerve conduction study (NCS) proposed is performed by placing the active recording lead on the midbelly of the thumb short abductor muscle over the thumb. The reference lead is placed 2 cm distally. The cathode for distal stimulation is placed at 7 cm proximally to the active recording lead, near the wrist crease. The proximal site is over the NM proximally to the antecubital fossa. In both instances, the anode is placed at 2 cm from the cathode. On median sensory NCS, recording is done from the fingers, with ring electrodes while stimulating 13 cm proximally, above the wrist crease. The method is modified by performing median NCS in three positions (Fig. 1): mid-position (palmar/volar angle about 90 degrees), forced dorsal flexion (palmar/volar angle about 270 degrees) and forced palmar (volar) flexion (palmar/volar angle about 90 degrees). The mid-position study is performed first, with determination of the following parameters: distal motor latency; motor conduction velocity, compound muscle action potential (CMAP) amplitude, distal sensory latency, sensory conduction velocity, and sensory nerve action potential (SNAP) amplitude. The study is then repeated in the position of dorsal flexion and the same parameters are recorded at 2 minutes. Finally, these ENG parameters are determined at 2 minutes in the position of palmar flexion.

Our clinical experience with ENG measurements performed to date indicate the position of dorsal flexion, which corresponds to the reverse Phalen’s maneuver, to “deteriorate” the ENG finding (prolonged distal motor and sensory latency and/or slowing down of motor and sensory NM conduction velocity relative to mid-position), as expected. In contrast, the position of palmar flexion, corresponding to the classic Phalen’s maneuver, surprisingly resulted in “improved” ENG findings, with reduced distal motor and sensory latency in almost all cases and quite frequently recorded an improvement of the NM motor and sensory conduction velocity. As reduction of the CAMP and/or SNAP amplitude is indicative of axonal lesion of the motor and sensory fibers, it would not be reasonable to expect that a 2-minute increase or decrease in RFT should influence their amplitude values during the maneuver performance.

6. Clinical significance or just delusion?

Considering the anatomic and physiologic relations within the CT, and the results of clinical observations and ENG studies, forced dorsal flexion (reverse Phalen’s maneuver) rather than the widely adopted Phalen’s maneuver is a logical method of choice in the diagnosis of CTS. This opinion is also supported by clinical observation of the characteristic discomfort of CTS typically occurring at night, as a consequence of excessive dorsal flexion of the hand, while being alleviated upon the flick maneuver performed in palmar flexion. CTS more commonly develops in individuals working on computers, with hands being in a position of slight dorsal flexion. Therefore, the main aim of conservative treatment using hand orthosis is to prevent dorsal but not palmar flexion of the hand. As paresthesias may occur as a neurogenic as well as vascular phenomenon, a positive classic Phalen’s sign may be a sequel of ischemia due to compromised radial artery circulation or of venous congestion due to the wrist joint compression. In case of latent CTS (i.e. positive clinical and history data but still negative ENG finding), we suggest additional neurographic analysis in the position of forced dorsal flexion of the hand, which can be used as a provocation test to obtain ENG finding characteristic of CTS.

References