Exp Brain Res (1999) 128:61–64

RESEARCH NOTE

Jean-Louis Thonnard · Pierre Saels
Peter Van den Bergh · Thierry Lejeune

Effects of chronic median nerve compression at the wrist on sensation and manual skills

Received: 25 September 1998 / Accepted: 10 December 1998

Abstract The aim of this study was to analyse the functional impairments caused by chronic median nerve compression at the wrist on hand sensation and manual skill. Hand function was assessed in 11 patients (8 women and 3 men) with severe carpal tunnel syndrome (CTS) and compared with that of an age- and sex-matched control group. Apart from CTS, the subjects were healthy and the electrodiagnostic examination was normal. The pressure and vibration detection thresholds of the index finger were partially impaired and statistically different ($P<0.05$) when compared with controls, suggesting a reduction of tactile acuity in the territory of the median nerve. The thermal thresholds were identical in both groups, suggesting that the small-diameter fibres were not affected. When a small object was lifted and positioned in space, the coordination between the grip force and the vertical lifting force did not seem to be affected in our patients. They were able to modify their grip force according to the friction between the fingertips and the object, i.e. the more slippery the object, the higher the grip force. The unimanual Purdue Pegboard subtest results suggest that digital dexterity was also not significantly perturbed in our sample of CTS patients when compared with controls. Despite the severe abnormalities of median nerve conduction, our results suggest that chronic median nerve compression occurring in CTS induces partial impairment of tactile sensibility with minor impact on grasp force regulation and digital dexterity.

Key words Hand · Sensation · Motor control · Precision grip · Friction · Median nerve

J.L. Thonnard (✉) · P. Saels · T. Lejeune
Unité de Réadaptation et de Médecine Physique,
Université catholique de Louvain, 53 Avenue Mounier,
Tour Pasteur, B-5375 Brussels, Belgium,
e-mail: thonnard@read.ucl.ac.be,
Tel.: +32-2-7645375, Fax: +32-2-7645360

P. Van den Bergh
Département de Neurologie, Université catholique de Louvain,
Brussels, Belgium

Introduction

Tactile sensory information from the skin of the fingertips plays a crucial role in the motor control of prehensile tasks. Johansson and Westling (1987, 1991) have demonstrated that during the precision grip-lift movement, the tactile receptors in the skin of the digits link the various phases of the lifting task by informing the central nervous system that discrete mechanical events have occurred, for example, that the digits have made contact with the object, or that the object has started to move.

The importance of tactile afferents in fine manipulative movements has also been clearly supported by data from reconstructive surgery (Moberg 1964, 1975) or anaesthetic experiments (Johansson and Westling 1984). In reconstructive surgery of the hand, all possible cutaneous innervation is preserved and it is widely accepted that the smallest grip with sensation is preferable to the best prosthesis.

Nevertheless, very few studies have analysed the manipulative capacity in patients with moderate sensory impairments. This can be addressed by studying the manual skills of patients presenting with degradation of tactile signals associated with median nerve compression. Median nerve compression within the carpal tunnel at the wrist is the best defined of entrapment neuropathies, which results in sensory loss in the fingers most often used in precision hand functions, i.e. the index finger, the long middle finger and the thumb.

The aim of this study was to analyse the functional impairments induced by chronic median nerve compression occurring in carpal tunnel syndrome (CTS) on sensation and manual skill.

Materials and methods

Eleven patients (eight women, three men, age 52±13 years), presenting the classical features of the CTS in 14 hands, were recruited from the electromyography laboratory when the nerve conduc-

Table 1 Results of the electrodiagnostic studies

Variable	Mean±SD	No response (*n*)	Norms
DML_m (ms)	6.9±1.5	2	<4.4
$CMAP_m$ (mV)	6.3±3.0	2	>4.0
DML_{m-u} (ms)	2.8±1.3	0	<0.4
DSL_m (ms)	5.3±0.6	6	<3.5
$SNAP_m$ (µV)	11.1±6.3	6	>20
DSL_{m-u} (ms)	1.8±0.8	9	<0.4
DSL_{m-r} (ms)	1.6±0.2	8	<0.4

tion studies had shown severe CTS (see Table 1). Severe cases of CTS were characterised by a very small or absent median sensory nerve action potential, prolonged distal sensory and motor latency (>5 ms), and evidence of denervation in the abductor pollicis brevis muscle (Smith 1998). Apart from CTS, the subjects were healthy and the electrodiagnostic examination was normal. An age- and sex-matched control group (eight women, three men, age 53±15 years) was used for comparison.

Electrodiagnostic Studies

The motor nerve conduction study was performed by surface-recording electrodes with the classical muscle belly tendon technique (Cantata Dantec, filter set 2–20000 Hz). The sensory nerve conduction study was performed by surface ring electrodes on the index finger and antidromic stimulation (Cantata Dantec, filter set 20–2000 Hz). The distal peak sensory latencies (DSL_m) and sensory nerve action potential amplitudes ($SNAP_m$) of the median nerve were recorded at the index finger after the stimulation 13 cm proximally at the wrist. The distal motor latencies (DML_m) and the compound muscle action potential ($CMAP_m$) of the median nerve were recorded from the abductor pollicis brevis muscle after stimulation 7 cm proximally at the wrist. The difference between the distal peak sensory latencies (DSL_{m-u}) was recorded at the ring finger after the stimulation of the median and the ulnar nerves 14 cm proximally at the wrist. The difference between the distal peak sensory latencies (DSL_{m-r}) was recorded at the thumb after the stimulation of the median and the radial nerves 10 cm proximally at the wrist. The difference between the distal motor latencies (DML_{m-u}) was recorded from the second dorsal interrosseous muscle and the second lumbrical muscle after stimulation of the ulnar and median nerves respectively, 10 cm proximally at the wrist. The skin temperature of the detection site was greater than 30°C (for references, details and discussion, see AAEM 1993).

Quantitative sensory testing

Quantitative sensory thermotesting was performed, on the pad of the index finger, using a Medoc TSA-2001 device (Medoc, Ramat Yishai, Israel). The method of limits was used according to Yarnitsky and Sprecher (1994) in order to obtain the warm detection threshold and the cold detection threshold. Quantitative sensory vibrametry was achieved using the vibratory sensory analyser (Model VSA-6003, Medoc, Ramat Yishai, Israel). The method of limits was used to obtain the vibration detection threshold (VDT), which was the average of four consecutive trials. The pressure detection threshold (PDT) was determined by using the Semmes-Weinstein aesthesiometer (Lafayette Instrument Company) according to the procedure described by Bell-Krotoski (1990).

Grasp force adjustment to different frictional conditions

Johansson and Westling (1987) have demonstrated that signals in tactile afferent units are utilised for adapting the grasp force to the friction between the object and the skin. The process of grasp force adjustment to different frictional conditions was tested by asking the subject to grip and lift an object, the friction of which at the skin-object interface was modified. The two parallel vertical grip surfaces, made of smooth brass, of the test object were spaced 30 mm apart. The coefficient of friction was reduced by applying talc to the brass grasp surfaces. The forces at the fingertips (normal and tangential, corresponding to the grip and load forces) were recorded as the subject lifted the object using the thumb and index finger. The subject was instructed to grasp the test instrument and to lift it approximately 5 cm above the table for about 10 s during which the static grip force was recorded. Then the subject was asked to slowly loosen his grip force and let the test instrument slide through his fingers. The grip force at which the object begins to slip is called the slip force and the safety margin is defined as the difference between the static grip force and the slip force. In addition, the grip force rate (dGF/d*t*) and the load force rate (dLF/d*t*) were computed using a ±5-point numerical differentiation. Two experimental conditions were carried out for each subject. In the first condition, each subject was asked to perform a series of five grip-lift movements with the grip surfaces coated with talc (the more slippery surface). In the second condition, each subject was requested to execute another series of five grip-lift movements when the object surface was dry brass. The subjects were instructed to wash and dry their hands before beginning the experiment and between the two experimental conditions. The signals were sampled at 400 Hz with a 12-bit resolution analogue-to-digital converter.

Digital dexterity

The digital dexterity was evaluated with the unimanual Purdue Pegboard subtest (Desrosiers et al. 1995). This task consists of picking up metal pegs from a cup and inserting a maximum number of them, one by one, into a row of holes within 30 s.

Results

The results of the QST and the Purdue Pegboard test are presented in Table 2. The index finger pressure and vibration detection thresholds were impaired and statistically different (Mann-Whitney Rank Sum Test, $P<0.05$) from controls, indicating a perturbation of tactile sensation in the territory of the median nerve. The thermal detection thresholds were similar in both groups with a trend toward a lower threshold for cold sensation in the CTS group. There was no significant difference for the Purdue Pegboard test between the two groups, suggesting that the digital dexterity was not impaired by CTS.

The results of the grip-lift task in two frictional conditions are shown in Fig. 1. In Fig. 1A, each trace represents averaged data from five consecutive trials executed by one patient. The load force, the grip force, and the ratio between the grip force and the load force are represented as a function of time during the lifting of the object. The load force rate, the grip force rate and the grip force are also represented against the load force in Fig. 1A. This patient presented with severe CTS; the $SNAP_m$ of the median nerve was absent and the DML_m was 7.4 ms; moreover, evidence of denervation was present on needle examination of the abductor pollicis brevis muscle, suggesting a component of axonal degeneration. Despite the significant deficit in median nerve conduction velocity, the patient adequately modulated the grip

Table 2 Results of the quantitative sensory testing and of the Purdue Pegboard test

Variable	Median (interquartile range)		
	Control	CTS	*P* value
Pressure detection threshold (g)	0.2 (0.07–0.41)	0.7 (0.41–0.7)	<0.001
Vibration detection threshold (μm)	1.2 (0.8–1.7)	2.1 (1.4–3.0)	0.024
Warm detection threshold (°C)	34.7 (34.0–35.4)	35.9 (34.5–38.9)	0.124
Cold detection threshold (°C)	30.4 (29.6–30.7)	28.4 (21.8–30.1)	0.046
Purdue Pegboard (*n*)	15.7 (14.7–16.7)	14.7 (13.4–17.2)	0.328

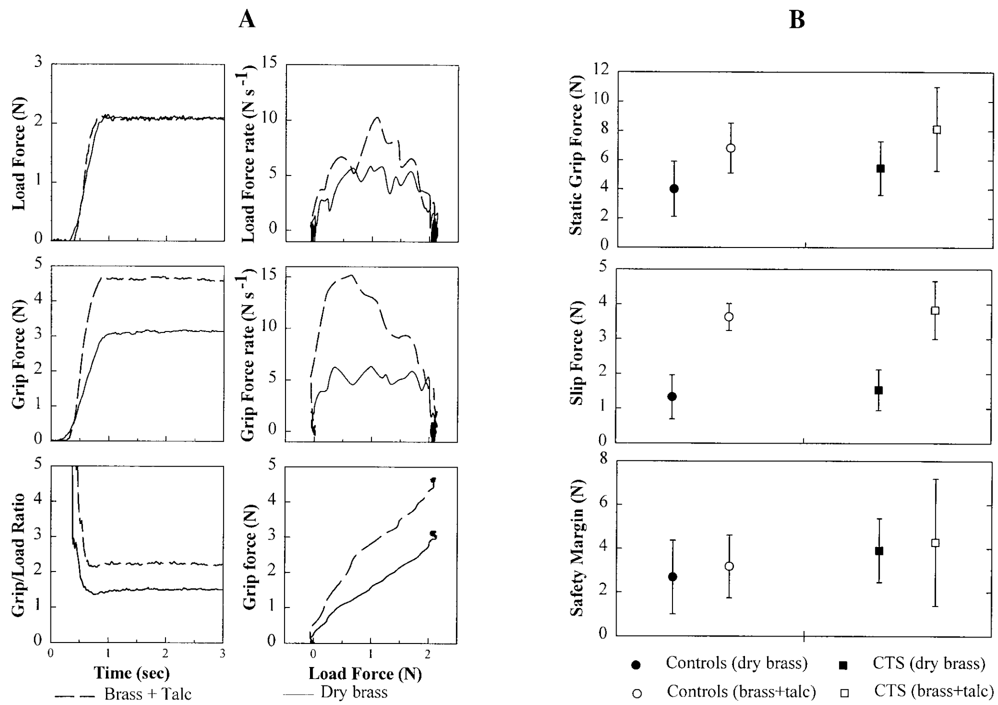

Fig. 1A, B Adjustment of the grasp force to the frictional changes: dry brass (less slippery) and talc-covered brass (more slippery). **A** Load force, grip force, and ratio between grip and load force shown as a function of time *on the left* and load force rate, grip force rate and grip force displayed against the load force *on the right*. *Each trace* represents averaged data from five consecutive trials executed by one patient with severe CTS ($SNAP_m$ of the median nerve absent and DML_m equal to 7.4 ms). A comparison between the force ratios employed for the two surfaces indicates that the grasp force was adjusted to the frictional changes. The higher force ratios with the more slippery conditions were produced mainly by higher rates of grip force increase during the loading phase. **B** Effect of friction on static grip force, slip force and safety margin in the CTS group and in the controls. *Symbols* represent mean values and standard deviations for each group with each surface contact

force to friction, giving a higher force ratio with more slippery conditions. This adjustment was reached mainly by higher rates of grip force during the loading phase.

Figure 1B displays the regulation of the grasp force in relation to the friction for the control subjects (circles) and CTS patients (squares). As is apparent, both groups modulated the grip force in relation to friction with an appropriate downgrading of the grip force during the less slippery condition. The static grip force and the slip forces were significantly higher with the talc-covered surface for both groups (Wilcoxon Signed Ranks Test, $P<0.001$), whereas the safety margins were not different.

Discussion

The present investigation demonstrates that chronic median nerve compression, as occurring in severe CTS, induces discrete, but significant abnormalities of finger tip sensation, whereas manual skills are not impaired.

Despite the severity of median nerve entrapment detected by nerve conduction studies, the patients report small but significant decreases in tactile sensation which are quantitatively demonstrated by QST. We noticed only a slight increase in both the VDT and the PDT, which is indicative of diminished light touch. These results seem surprising and suggest that the mechanical deformation of the nerve fibres and the induced ischaemia in the compressed segment does not lead to significant interference with the afferent signals from the mechanoreceptors, even in severe CTS. Standard nerve conduction studies assess function of conduction in the large myelinated fibres and therefore test only a minority of the fibres that constitute a peripheral nerve. Most of the fibres which constitute a peripheral nerve are of small diameter: A–δ or small myelinated fibres, and C or unmyelinated fibres. Dahlin et al. (1989) have shown that the A–δ and most particularly the C fibres had a much higher resistance to compression than the large myelinated fibres. They reported that a very high pressure (>400 mmHg) is needed to affect the C-fibres, which is far higher than the 30 mmHg intracarpal tunnel interstitial pressures (wrist in neutral position) and 90 mmHg (wrist in palmar flexion), measured in patients with CTS (Gelberman et al 1981). In our study, the thermal thresholds measured in the CTS group were normal, which indicates that the small-diameter fibres were not affected by the chronic median nerve compression. Interestingly, Schmidt et al. (1997) have observed responsiveness of C-fibres to mechanical stimuli. The thresholds (median 30 mN, range 3–750 mN) obtained with von Frey filaments in their study were much higher than the thresholds documented in our patients (median 7 mN, range 4–7 mN). Therefore, tactile sensation in our patients with severe CTS does not seem to be mediated by afferent C units. Further research is needed to explain the apparent discrepancy between the lack of correlation between the severity of nerve conduction study abnormalities and relatively well preserved tactile sensation in CTS patients.

A stable grasp while manipulating objects is ensured by the parallel coordination between grip and load forces. Tactile receptors in the fingertips are of crucial importance in adapting this relation between grip and load forces to the friction at the digit-object interface (Johansson and Westling 1984, 1987). The results of our experiments show that patients with chronic median nerve compression keep the ability to adapt the force ratio to the frictional conditions. They confirm that the mechanoreceptive afferent units provide the central nervous system with signals related to the frictional conditions between the skin and the object, in spite of median nerve compression. The impairments of tactile sensation must be more severe to degrade the frictional adaptation, for example in local finger anaesthesia (Johansson and Westling 1984) or in chronic sensory demyelinating neuropathy (Thonnard et al. 1997). In the latter conditions, the subjects use strong grip forces that are unnecessarily high and the frictional adjustment is disrupted. Our findings that manual skills were not impaired by chronic median nerve compression are confirmed by the Purdue Pegboard test scores showing that the patients are able to perform precision tasks rapidly and skilfully. This unimanual test involves a sequence of grip-lift movements, transfers, and positioning using a metal peg and measures unilateral fine manual dexterity (Desrosiers et al. 1995).

References

AAEM Quality Assurance Committee, Jablecki CK, Andary CMT, So YT, Wilkins DE, Williams FH (1993) Literature review of the usefulness of nerve conduction studies and electromyography for the evaluation of patients with carpal tunnel syndrome. Muscle Nerve 16:1392–1414

Bell-Krotoski JA (1990) Light touch-deep pressure testing using the Semmes-Weinstein monofilaments. In: Hunter JM, Schneider LH, Mackin EJ, Callahan AD (eds) Rehabilitation of the hand: surgery and therapy. Mosby, St. Louis, pp 585–593

Dahlin LB, Shyu BC, Danielsen N, Andersson SA (1989) Effects of nerve compression or ischaemia on conduction properties of myelinated and non-myelinated nerve fibres. An experimental study in the rabbit common peroneal nerve. Acta Physiol Scand 136:97–105

Desrosiers J, Hebert R, Bravo G, Dutil E (1995) The Purdue Pegboard test: normative data for people aged 60 and over. Disabil Rehabil 17:217–224

Gelberman RH, Hergenroeder PT, Hargens AR, Lundborg GN, Akeson WH (1981) The carpal tunnel syndrome. A study of carpal canal pressures. J Bone Joint Surg 63A:380–383

Johansson RS, Westling G (1984) Roles of glabrous skin receptors and sensorimotor memory in automatic control of precision grip when lifting rougher or more slippery objects. Exp Brain Res 56:550–564

Johansson RS, Westling G (1987) Signals in tactile afferents from the fingers eliciting adaptive motor responses during precision grip. Exp Brain Res 66:141–154

Johansson RS, Westling G (1991) Afferent signals during manipulative tasks in man. In: Franzen O, Westman J (eds) Somatosensory mechanism. Macmillan, London, pp 25–48

Moberg E (1964) Aspects of sensation in reconstructive surgery of the upper extremity. J Bone Joint Surg 46A:817–825

Moberg E (1975) Hand surgery and the development of hand prostheses. Scand J Plast Reconstr Surg 9:227–230

Schmidt R, Schmelz M, Ringkamp M, Handwerker HO, Torebjörk HE (1997) Innervation territories of mechanically activated C nociceptor units in human skin. J Neurophysiol 78:2641–2648

Smith SJM (1998) Electrodiagnosis. In: Birch R, Bonney G, Wynn Parry CB (eds) Surgical disorders of the peripheral nerves. Churchill Livingstone, pp 467–490

Thonnard JL, Detrembleur C, Van den Bergh PYK (1997) Assessment of hand function in a patient with chronic sensory demyelinating neuropathy. Neurology 49:253–257

Westling G, Johansson RS (1987) Responses in glabrous skin mechanoreceptors during precision grip in humans. Exp Brain Res 66:128–140

Yarnitsky D, Sprecher E (1994) Thermal testing: normative data and repeatability for various test algorithms. J Neurol Sci 125:39–45