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INFLUENCE OF TEMPERATURE ON COMPARATIVE NERVE CONDUCTION TECHNIQUES FOR CARPAL TUNNEL SYNDROME DIAGNOSIS

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ABSTRACT - In this study we compared the effect of temperature variation (≥32°C to ≤27°C) on latency differences median to ulnar (ringdiff), median to radial (thumbdiff), palmar median to ulnar (palmdiff) and the sum of three, the combined sensory index (CSI), in 15 controls and 12 patients with carpal tunnel syndrome (CTS). After cooling, ringdiff was the most reliable technique with little variation in both controls and patients; thumbdiff decreased dramatically in controls and could even come within normal limits in patients; palmdiff increased only in patients; CSI decreased significantly in controls and showed a slight increase in patients with no loss in electrodiagnosis accuracy. The high increase of palmdiff in patients, and the high decrease of thumbdiff in controls, after cooling, could not be explained only for fiber size in the nerve trunks. We concluded that for CTS electrodiagnosis even latency differences in same person/same limb could be significantly modified after cooling not previously emphasized in literature.

KEY WORDS: carpal tunnel syndrome, median nerve, compressive neuropathy, nerve conduction study, temperature.

Influência da temperatura nas técnicas comparativas de condução nervosa para diagnóstico de síndrome do túnel do carpo

RESUMO - O objetivo do estudo foi comparar o efeito da variação de temperatura da mão (≥32°C e ≤27° C) no estudo das técnicas de diferenças de latências entre o nervo mediano e ulnar (MU4), mediano e radial (MR1), mediano e ulnar palmar (MUP) e índice sensitivo combinado (ISC) em 15 controles normais e 12 pacientes com síndrome do túnel do carpo (STC). Após resfriamento da mão, MU4 foi a técnica mais confiável com menor variação de latência tanto em controles como em pacientes; MR1 diminuiu dramaticamente nos controles e atingiu até valores normais em pacientes; MUP aumentou apenas em pacientes; ISC diminuiu significantemente em controles com leve aumento nos pacientes, porém sem perda da acurácia eletrodiagnóstica. O acentuado aumento de MUP em pacientes e a acentuada redução de MR1 em controles após o resfriamento não pôde ser explicado apenas pelo calibre das fibras nervosas nos diferentes troncos. Concluímos que mesmo quando se utilizam técnicas de comparação de latências entre dois nervos na mesma pessoa e no mesmo segmento, a redução da temperatura pode modificar de maneira significativa os resultados, dado não previamente relatado na literatura.

PALAVRAS-CHAVE: síndrome do túnel do carpo, neuropatia compressiva, nervo mediano, condução nervosa, temperatura.

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy in the upper limbs[1,2]. Prospective population-based studies have shown a prevalence of 5.8% in women and 0.6% in men in the Netherlands[3] and 2.7% in Southern Sweden[4]. Electrodiagnostic confirmation, particularly nerve conduction studies (NCS), are the most important, useful and quick tool for diagnosis, mainly in mild cases[5] .In the last two decades several new techniques of NCS have been incorporated for CTS electrodiagnosis. Comparison of median sensory or mixed latencies to ulnar or radial nerves in the same limb becomes a very common practice[6] .In theory, the biologic variation in conduction velocity from person to person due to age and genetic differences can be controlled by comparison of the speed of nerve conduction from one nerve to another in the same limb[7].

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Temperature is one of the most important factors influencing nerve conduction parameters[8-12]. Latency, amplitude, duration and area of the sensory nerve and compound muscle action potentials increase as the temperature falls. Electromyographers should maintain mid-palm temperature above 31 to 32°C to get a confident electrophysiological data. Lowering the temperature prolongs the open time of the voltage gated sodium channel, thereby generating a larger and longer action potential[13]. Robinson et al.[14] reported that a combined sensory index (CSI), the sum of three latency differences, is better than a single test in the diagnosis of median neuropathy at wrist. Their experience suggests that latency differences between nerves in the same digit or same hand are not markedly affected by cold. After that, Lew et al.[15] analyzed the effect of temperature on absolute latencies and latency differences and concluded that temperature had no significant effect in either the latency difference or the sum of latency differences, previously described as CSI.

The aim of this study was to determine if variation on hand temperature could modify the result of latency differences: sensory median to radial (thumb), sensory median to ulnar (ring), mixed palm median to ulnar, and, the sum of three, the CSI.[14].

METHOD

Subjects – From August to November 2003, we prospectively studied two groups of subjects. The first group (controls) was selected from medical students without any known systemic disease or symptoms of CTS. There were 15 subjects (15 hands) with a mean age of 22±1.6 years (20 to 25), 9 female and 6 male. The second group (patients) was selected from our EMG laboratory patients and was composed of 12 cases (12 hands) with an electrophysiologically confirmed diagnosis of symptomatic CTS including hand paraesthesia, numbness, and pain mainly at night; mean age was 45±10.6 years (31 to 62), 1 male and 11 female. Cases with previous CTS surgery and clinical or electrophysiologically evidence of polyneuropathy were not considered.

Nerve conduction studies – For all studies, a Cantata electromyograph (Dantec, Skovlunde, Denmark) was used. Mid palmar temperature was controlled using an infra-red thermometer (Infrascan, La Crosse Technology, USA) with resolution of 0.1°C and variation from -20°C to 300°C. Electrodiagnosis of CTS was based on data obtained from the second review of the American Association of Electrodiagnostic Medicine[7]. Median nerve distal sensory latency (wrist to index finger; 14 cm) was defined as abnormal when ≥3.7 ms, peak-measured. Sensory median/ulnar nerve difference (ringdiff; wrist to ring finger; 14 cm) was considered abnormal when ≥0.50 ms, peak-measured. Sensory median/radial nerve difference (thumbdiff; wrist to thumb; 10 cm) was considered abnormal when ≥0.50 ms, peak-measured. Mixed median/ulnar nerve palmar difference (palmdiff; palm to wrist; 8 cm) was considered abnormal when ≥0.40 ms, peak-measured. Median motor nerve distal latency (wrist to APB; 8 cm) was considered abnormal when ≥4.25 ms. We also used the CSI, as described by Robinson et al.[14], by adding palmdiff, ringdiff and thumbdiff, being abnormal if ≥1.10 ms. Nerve conduction was normal in all the other nerves studied, including sensory ulnar and radial, and ulnar motor.

Temperature control – Patients and controls were studied electrophysiologically utilizing all techniques described above. Palmdiff, ringdiff and thumbdiff were obtained after usual temperature for electrophysiological diagnosis (≥32°C) and after cooling wrist and hand in iced water for sufficient time the temperature dropped below 27°C. Absolute temperature was obtained in normal condition (≥32°C) and after hand cooling (≤27°C). Assuming a linear correlation between lowering temperature and increasing latencies, the mean latency increase (ms) for each degree Celsius reduced was calculated using the formula: latency obtained after hand cooling minus latency obtained after normal condition divided to temperature of mid-palm in normal condition minus temperature of mid-palm after hand cooling.

Data analysis – Latency differences above 32°C and below 27°C were compared using *t-tests* with $p \leq 0.05$ being considered significant.

Ethic – The local ethics committee approved the protocol and all studies were performed after informed consent had been obtained.

RESULTS

In spite of the use of two groups, CTS patients and normal controls, the main objective of this study was to compare latency differences after usual temperature for NCS (≥32°C) and after cooling (≤27°C) inside each group. Data, including means, standard-deviation and significance to all three latency differences and CSI, either peak (p) or onset-measured (o) are shown in Table 1.

The results showed a remarkable and striking thumbdiff (median latency minus radial latency) after cooling (o and p) in controls. The difference means dropped from 0.11 to -0.32 ms (o) and from 0.25 to -0.26 ms (p), being highly significant (p = 0.0006 and 0.0002 respectively). Ringdiff and palmdiff were not significantly modified, but there

Table 1. Summary of latency differences and CSI in usual temperature and after cooled hands.

Controls = 15		Usual temperature (≥32ºC)				Cooled hands (≤27ºC)				
		mean	SD	range	ULN*	mean	SD	range	ULN	P-value
Thumbdiff	o	0.11	0.09	0.28 to -0.08	0.29	-0.32	0.42	0.44 to -1.24	0.52	0.0006
	p	0.25	0.11	0.48 to 0.12	0.47	-0.26	0.44	0.48 to -1.16	0.62	0.0002
Ringdiff	o	0.12	0.10	0.28 to -0.08	0.32	0.20	0.23	0.64 to -0.24	0.66	0.2269
	p	0.11	0.07	0.20 to 0.00	0.25	0.16	0.29	0.60 to -0.52	0.74	0.5216
Palmdiff	o	0.15	0.12	0.36 to -0.08	0.39	0.24	0.19	0.76 to -0.08	0.62	0.1321
	p	0.13	0.10	0.32 to -0.04	0.33	0.25	0.24	0.88 to -0.12	0.73	0.0847
CSI	o	0.37	0.20	0.64 to 0.04	0.77	0.12	0.42	1.08 to -0.64	0.96	0.0467
	p	0.49	0.17	0.76 to 0.16	0.83	0.16	0.59	1.32 to -0.92	1.34	0.0466
CTS = 12		Usual temperature (≥32ºC)				Cooled hands (≤27ºC)				
		mean	SD	range		mean	SD	range		P-value
Thumbdiff	o	0.78	0.29	1.32 to 0.52		0.39	0.39	1.28 to -0.28		0.0109
	p	0.95	0.33	1.60 to 0.64		0.62	0.50	1.50 to 0.00		0.0695
Ringdiff	o	0.91	0.68	2.88 to 0.48		1.06	0.76	3.00 to 0.24		0.6155
	p	0.96	0.70	2.96 to 0.48		1.18	0.82	3.30 to 0.28		0.4871
Palmdiff	o	0.60	0.30	1.36 to 0.32		0.96	0.43	2.08 to 0.60		0.0265
	p	0.63	0.29	1.40 to 0.40		1.03	0.44	2.16 to 0.56		0.0153
CSI	o	2.29	1.17	5.04 to 1.44		2.41	1.38	5.40 to 1.08		0.8204
	p	2.54	1.24	5.44 to 1.60		2.83	1.60	6.20 to 1.16		0.6246

ULN, upper limit of normality; o, onset-measured; p, peak-measured; ringdiff, median/ulnar latency difference; thumdiff, median/radial latency difference; palmdiff, median/ulnar palmar latency difference; CSI, combined sensory index; CTS, carpal tunnel syndrome; o, onset-measured; p, peak-measured; m, mean.

Table 2. Variation of latencies (ms) per each degree (Celsius) reduced.

			Controls = 15		CTS = 12		
			mean	SD	mean	SD	P-value
Median II	o	sensory	0.08	0.02	0.09	0.02	0.2085
Median II	p	sensory	0.15	0.03	0.15	0.03	0.9999
Ulnar V	o	sensory	0.08	0.03	0.08	0.02	0.9999
Ulnar V	p	sensory	0.13	0.05	0.13	0.02	0.9999
Median IV	o	sensory	0.10	0.03	0.11	0.03	0.3976
Median IV	p	sensory	0.15	0.04	0.18	0.04	0.0642
Ulnar IV	o	sensory	0.09	0.04	0.10	0.03	0.4792
Ulnar IV	p	sensory	0.15	0.05	0.16	0.05	0.6101
Median I	o	sensory	0.08	0.04	0.10	0.03	0.1632
Median I	p	sensory	0.12	0.04	0.16	0.04	0.0161
Radial I	o	sensory	0.12	0.04	0.15	0.04	0.0642
Radial I	p	sensory	0.18	0.04	0.20	0.05	0.2587
Median palm	o	mixed	0.04	0.01	0.08	0.02	0.0001
Median palm	p	mixed	0.06	0.02	0.11	0.03	0.0001
Ulnar palm	o	mixed	0.03	0.02	0.04	0.01	0.1273
Ulnar palm	p	mixed	0.05	0.02	0.06	0.02	0.2085
Median DML	o	motor	0.20	0.10	0.29	0.06	0.0111
Ulnar DML	o	motor	0.18	0.08	0.21	0.08	0.3422
Ringdiff	o	sensory	0.01	0.02	0.01	0.03	0.9999
Ringdiff	p	sensory	0.00	0.03	0.02	0.03	0.0975
Thumbdiff	o	sensory	-0.05	0.03	-0.05	0.03	0.9999
Thumbdiff	p	sensory	-0.05	0.03	-0.04	0.03	0.3976
Palmdiff	o	mixed	0.01	0.01	0.04	0.02	0.0001
Palmdiff	p	mixed	0.01	0.01	0.04	0.02	0.0001

DML, distal motor latency; o, onset-measured; p, peak-measured; ringdiff, median/ulnar latency difference; thumdiff, median/radial latency difference; palmdiff, median/ulnar palmar latency difference.

was a tendency for increasing values instead of decline as found on thumbdiff. CSI significantly decreased and the means went down from 0.37 to 0.12 ms (o) and from 0.49 to 0.16 ms (p).

In CTS patients there was a significant decline of onset thumbdiff (0.78 to 0.39 ms, p = 0.0109), and a significant increased of palmdiff either onset (p = 0.0265) and peak-measured (p = 0.0153) after cooling. Thumbdiff (p) was not significantly modified but there was a tendency for decline. Ringdiff again was not significantly modified but there was a tendency for increasing values. In contrast to controls, CSI was also not significantly modified, although the value increased instead of decreasing; the means rose from 2.29 to 2.41 ms (o) and from 2.54 to 2.83 ms (p).

Data, including means, standard-deviation and significance to all distal absolute and comparative latencies (differences) showing the variation per each degree Celsius reduced are shown in Table 2. Regarding the increased sensory and mixed potential duration, all peak-measured latencies reached a higher variation when compared to onset-measured.

In controls, median sensory distal latencies to fingers I, II and IV increased 0.08 to 0.10 ms/ºC (o) and 0.12 to 0.15 ms/ºC (p). Ulnar sensory distal latencies to fingers V and IV increased 0.08 to 0.09 ms/ºC (o) and 0.13 to 0.15 ms/ºC (p) respectively. Radial sensory distal latencies to finger I increased 0.12 ms/ºC (o) and 0.18 ms/ºC (p). Median mixed palmar latencies increased 0.04 ms/ºC (o) and 0.06 ms/ºC (p). Ulnar mixed palmar latencies increased 0.03 ms/ºC (o) and 0.05 ms/ºC (p). Ringdiff increased 0.01 ms/ºC (o) with no variation to peak; palmdiff increased 0.01 ms/ºC (o and p); and thumbdiff decreased dramatically, 0.05 ms/ºC (o and p).

In CTS patients, median sensory distal latencies to fingers I, II and IV increased 0.09 to 0.11 ms/ºC (o) and 0.15 to 0.18 ms/ºC (p). Ulnar sensory distal latencies to fingers IV and V increased 0.08 to 0.10 ms/ºC (o) and 0.13 to 0.16 ms/ºC (p). Radial sensory distal latencies to finger I increased 0.15 ms/ºC (o) and 0.20 ms/ºC (p). Median mixed palmar latencies increased 0.08 ms/ºC (o) and 0.11 ms/ºC (p), being highly significant when compared to controls (P < 0.0001). Ulnar mixed palmar latencies increased 0.04 ms/ºC (o) and 0.06 ms/ºC (p). Ringdiff increased 0.01 ms/ºC (o) and 0.02 ms/ºC (p); thumbdiff decreased 0.05 ms/ºC (o) and 0.04 ms/ºC (p); and palmdiff increased dramatically 0.04 ms/ºC (o and p), being highly significant when compared to controls (P < 0.0001).

DISCUSSION

In this study we compared the effect of hand cooling on latency differences that became a useful and practical tool for mild CTS electrodiagnosis. It makes more sense to compare findings in the median nerve with those in the ipsilateral ulnar or radial nerve, so that the effects of hand temperature on nerve conduction velocity and latency can be reduced[15]. Intuitively we expected no significant latency differences variation after a comparison of two nerves in the same hand regardless temperature. However, our results showed that this claim was true only for ringdiff, either in controls or CTS patients, both presenting either slight or no significant increasing. In comparison to Lew et al.[15], the latency increase, peak-measured, after cooling in our CTS patients presented great difference in median sensory to thumb (0.16 ms/ºC versus 0.11 ms/ºC); radial sensory to finger thumb (0.20 ms/ºC versus 0.11 ms/ºC); and median palmar mixed, 8 cm (0.11 ms/ºC versus 0.06 ms/ºC).

Thumbdiff decreased significantly in both groups mainly in controls. Palmdiff presented either slight or no significant increasing in controls and a significant increase in CTS patients. The increase of latencies per each degree Celsius reduced (ms/ºC) was calculated assuming that there is a linear regression curve between these two variables as already demonstrated by others[11,13,16]. The most remarkable increase in latencies for each degree Celsius reduced had occurred in radial nerve, either controls or CTS patients, contributing to thumbdiff decrease. Median palm latencies, however, had a striking increase for each degree Celsius reduced in CTS patients, contributing to the significant palmdiff increase. These findings were responsible for maintaining CSI with a small and no significant variation in CTS patients but with a strong significant decline in controls. The results of Lew et al.[15] showed that temperature had no significant effect either on the latency differences or on the CSI, which was only partially confirmed by our findings.

The most striking variation on radial latencies certainly could be due to its superficial anatomy, being most reactive to cold. A decrease in temperature is found to alter conduction differently in nerves because of the wide variation on fiber diameters[13]. The large-diameter fibers comprising the A group require less of a drop in temperature to produce action potential blockade than in C fibers. They are, therefore, known to be more sensible to

cooling[13] and it could also explain a different increase in latencies for each degree Celsius reduced.

We could not explain why thumbdiff decreased dramatically and equally in controls and in CTS patients after cooling. We would expect that after median nerve compression in CTS there could be a loss of large fibers and as a consequence, the thumbdiff values would decline. On the other hand, palmdiff increased significantly only in CTS patients due to more sensitivity of median palm latencies for cooling. Again, we were expecting the opposite based on the premise that large fibers react more for temperature decline and they would be less in number in CTS.

We may suppose that in mild CTS, the compressive effect on median nerve could not be explained only by large fiber loss but also by a possible large fiber function abnormality that alters the sensitivity to cooling.

In conclusion, first, ringdiff was the most reliable technique to be used for CTS electrodiagnosis regardless usual (32°C) or reduced temperature, with narrow variations in controls and patients. Second, thumbdiff had a highly significant downward variation in controls, a less significant downward variation in patients, and was the only comparative technique that became "normal" in patients after cooling. Third, palmdiff had a significant upwardvariation after cooling just in patients. Fourth, the CSI decreased significantly after cooling in controls, but did not increase significantly in patients with any loss electrodiagnosis accuracy. Fifth, as already emphasized[17], we do not recommend using only one or even two latency differences for mild CTS electrodiagnosis and even using latency differences, the temperature must keep above 32°C. We could not confirm that latencies between two nerves in the same hand are less influenced by temperature as did Lew et al.[15]. We believe that thereare no ideal human models that could reflect exact limb temperature in NCS practice. Anxiety, ambient temperature or vascular problems could cause different temperatures in digit, palm and wrist leading to unusual findings. In other hand, our findings strongly supports a nerve diverse reaction for cooling that, at least put some doubt on claim that latency differences are not modified by temperature. Maybe a decrease (controls) or increase (CTS patients) on CSI values after cooling could be used to distinguish mild or incipient cases from normal but further studies should be designed for this purpose.

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