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ARTICLE

Sensory deficits in ipsilesional upper-extremity in chronic stroke patients

Déficit sensorial na extremidade superior ipsilateral em pacientes com AVE crônico

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ABSTRACT

Objective: To investigate somatosensory deficits in the ipsilesional wrist and hand in chronic stroke patients and correlate these deficits with contralesional sensorimotor dysfunctions, functional testing, laterality and handedness. **Method:** Fifty subjects (twenty-two healthy volunteers and twenty-eight stroke patients) underwent evaluation with Semmes-Weinstein monofilaments, the sensory and motor Fugl-Meyer Assessment, the Nottingham Sensory Assessment in both wrists and hands and functional tests. **Results:** Twenty-five patients had sensory changes in the wrist and hand contralateral to the stroke, and eighteen patients (64%) had sensory deficits in the ipsilesional wrist and hand. The most significant ipsilesional sensory loss was observed in the left-handed patients. We found that the patients with brain damage in the right hemisphere had better scores for ipsilesional tactile sensation. **Conclusions:** A reduction in ipsilesional conscious proprioception, tactile or thermal sensation was found in stroke subjects. Right hemisphere damage and right-handed subjects had better scores in ipsilesional tactile sensation.

Keywords: stroke, tactile sensation, proprioception, ipsilesional upper extremity.

RESUMO

Objetivo: Investigar déficits somatossensoriais no punho e mão ipsilesional em pacientes com acidente vascular encefálico (AVE) crônico e correlacionar esses déficits com disfunções sensório-motoras contralesional, testes funcionais, lateralidade e preferência manual. **Método:** Cinquenta indivíduos (vinte e dois voluntários saudáveis e vinte e oito pacientes com AVE) foram submetidos à avaliação com monofilamentos de Semmes-Weinstein, Avaliação Fugl-Meyer (sensorial e motora), Avaliação Sensorial Nottingham em punhos e mãos, e testes funcionais. **Resultados:** Vinte e cinco pacientes apresentaram alterações sensoriais no punho e mão contralateral ao AVE, e dezoito pacientes (64%) apresentaram déficits sensoriais no punho e mão ipsilesional. A perda sensorial ipsilesional mais significativa foi observada nos pacientes canhotos. Pacientes com lesão cerebral no hemisfério direito tiveram melhores pontuações para sensação tátil ipsilesional. **Conclusões:** A redução da propriocepção consciente ipsilesional, da sensibilidade tátil e térmica foi encontrada em indivíduos com AVE. Lesão no hemisfério direito e indivíduos destros apresentaram melhores pontuações na sensação tátil ipsilesional.

Palavras-chave: acidente vascular encefálico, sensação tátil, propriocepção, extremidade superior ipsilateral.

Dysfunction after a stroke in the ipsilesional body has been studied by neuroscientists in recent years[1,2,3,4]. However, in clinical practice, little or no attention has been given to ipsilesional neurological deficits. This is supported by the fact that the hemibody ipsilateral to the stroke has been named "healthy," "intact" or "unaffected," while the hemibody contralateral to the lesion has been named "affected" or "involved."

Clinical signs such as paresis, reduced dexterity, slow digital movements, impaired interarticular coordination and dysdiadochokinesia in stroke patients are widely listed in the literature[3,4,5,6], whereas the description of sensory changes is still limited. The involvement of sensory function in the ipsilesional hand may result in reduced manual task accuracy or impairment of motor function [7].

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Early studies, dating from 1960, showed ipsilesional sensory deficits in individuals with unilateral brain injury sequelae[8,9,10,11,12]. Baskett et al.[13] analyzed 20 subjects with acute stroke and found slow responses in tests that measured sensorimotor function of the ipsilesional hemibody. Kim and Choi-Know[14] found bilateral deficits in discriminative touch (17 of 39 patients) and astereognosis (7 of 38 patients) in subjects in the acute phase of stroke.

Previous studies have analyzed the presence of sensory deficits in the ipsilesional upper extremity (UE) in subjects with chronic sequelae of stroke[1,2,7] through a modified Von Frey device, joint position sense and scores of the Moving Touch-Pressure test position and found proprioceptive and tactile disturbances. Carey and Matyas[15] found that approximately 19% of chronic post-stroke patients showed alterations in conscious proprioception in the ipsilesional hand.

Given the functional importance of sensory loss after a stroke, the aim of this study was to investigate the somatosensory deficits in the wrist and hand ipsilateral to the chronic stroke and to correlate these deficits with contralesional sensorimotor dysfunction, scores on functional tests (with and without visual deprivation), laterality and handedness.

METHOD

This prospective clinical study was approved by the Ethics Committee of the State University of Campinas (number 697/2011). The study was conducted in the outpatient Physical and Occupational Therapy department of the hospital clinic of the institution. Participants and their families were informed about the study objectives and the procedures to be performed.

Participants

The control group consisted of twenty-two healthy volunteers. Exclusion criteria included the presence of cardiovascular or peripheral vascular disease, diabetes, neurological or musculoskeletal disease, recent trauma, reduced sensitivity in the hands, pregnancy and adverse reactions to cold, including Raynaud's phenomenon.

Twenty-eight male and female stroke patients were selected from a list of 41 outpatients. The individuals who were included could understand prompts and exhibited hemiparesis, which was secondary to a single stroke, for more than 1 year (chronic stage). Patients were included regardless of stroke cause (ischemic or hemorrhagic) and affected hemisphere. We used the following exclusion criteria: orthopedic and neurological comorbidities, Wernicke's aphasia, cognitive problems (Mini-Mental State Examination < 24 points), patients with wounds at the site of application test, individuals with hypertension uncontrolled by treatment, cardiovascular or peripheral vascular disease, diabetes, recent trauma, pregnancy and adverse reactions to cold, including Raynaud's phenomenon. All individuals who were invited to participate in the study signed an informed consent form.

Measures

An evaluation form addressing personal physiotherapy, clinical diagnosis, personal and family history and a history of present and past illnesses was completed. Measurement instruments were applied in a single day.

Sensorimotor evaluation

The sensory evaluation was performed using a Semmes-Weinstein kit (Smiles®). The kit contains a set of six nylon monofilaments (esthesiometry) of the same length, which exert force on the specific area tested. Each monofilament is represented by a color and diameter: Green (0.05 g), blue (0.2 g), violet (2 g), red (4 g), orange (10 g) and magenta red (300 g) [16]. The sensitivity test was performed on the C6, C7 and C8 dermatomes (end of the first, third and fifth fingers) of each hand. The scores ranged from seven (green monofilament) to 1 (magenta red monofilament). These scores were indicative of a normal range of sensitivity for each hand. A score of "no answer" was indicative of a loss of sensitivity to deep pressure where pain cannot be felt. Sensory evaluation using monofilaments was applied to both hands. The sum of the esthesiometry scores ranged from 21 to 3 points for each hand per patient, with higher scores representing better function.

The Fugl-Meyer Assessment (FMA)[17] measures sensorimotor recovery in patients. Each item was scored 0-2, with a higher score indicating better patient function. The following sections were used: exteroceptive and proprioceptive sensitivity of the wrist and hand of both upper extremities (UE) (maximum score for each UE, 8) and UE motor function, with a maximum score of 66. Mild impairment was represented by a score ≥ 50, a moderate to severe score was 50-20, and a severe score was < 20[18].

The Nottingham Sensory Assessment (NSA)[19] is an instrument that identifies sensory deficits after stroke and includes four subscales: tactile, conscious proprioception, stereognosis and two-point discrimination. A subset of the tactile sensation subscale was used (e.g., light touch, pressure, prick, temperature and location touch). The items were scored 0, 1 or 2, which represented the absence of sensation, altered sensation and normal sensation, respectively. Tactile sensation was tested in wrist and hand of ipsilesional and contralesional hemibodies. The materials used included a pin, blindfold, flannel and cup of ice. The sum of the wrist and hand NSA score was ranged 0 to 20, with a higher number reflecting better function.

Sensory-motor function was tested using a modification of functional tests described by Smania et al.[20]. The functional tests (FT) included seven consecutive tasks: (1) closing a zipper, (2) unbuttoning a button, (3) opening and fastening a velcro strip, (4) using a fork, (5) sharpening a pencil, (6) pouring water into a glass and (7) putting on a glove with the paretic hand. One point was awarded for each task if it was completed within 15 seconds. The score (maximum, 7) was obtained by summing the points obtained in each trial. FT tests were initially performed with the aid of vision (with vision - WV), but patients were subsequently blindfolded and assigned scores for each condition.

Procedures

The subjects underwent evaluation and treatment from January 2012 to March 2012 between 14:00 and 18:00 hours.

The control and stroke subject groups were assessed by FMA sensory scale, esthesiometry and the NSA items light touch, pressure, prick, temperature and location touch in both wrists and hands. The FMA motor scale (contralesional UE) and functional tests were applied only to stroke patients.

Statistical analysis

Data were analyzed using SAS (Statistical Analysis System) for Windows, v. 9.2, SAS Institute Inc, 2002-2008, Cary, NC, USA and GraphPad Prism for Windows v. 5.0, Inc, CA, USA. There was no normal sample distribution (Kolmogorov-Smirnov's test). A descriptive analysis was performed. Frequency tables for categorical variables are presented, while measurements of location and dispersion are represented by numeric variables. We used a Spearman's correlation to compare different variables. To verify an association or to compare frequencies between groups of subjects, the chi-square test or Fisher's exact test was used. The Mann-Whitney test was used to compare numerical measurements between the two groups. The significance level for all statistical tests was set at 5%.

RESULTS

No significant differences were observed between the control and stroke groups in terms of distribution of sex, age and hand dominance. The results indicate that measurements in the stroke group (ipsilesional side) were significantly different ($p < 0.05$) from those in the control group (dominant side), except for the NSA ipsilesional UE scores. There was no association between the scores on the measurement instruments, age and time post-stroke.

Table 1 shows the demographics data and measurement scores of the stroke group, and Table 2 summarizes the measurement scores. Table 3 shows the scores of monofilaments, and Table 4 summarizes the FMA sensory score and the sum of NSA scores for each stroke patient.

All participants in the control group showed a maximum score (7) in the dermatomes C6, C7 and C8 of both hands, a maximum score on the sensory scale and on the FMA and NSA items in both wrists and hands. One or more instruments detected sensory changes in the wrist and hand contralateral to the stroke in twenty-five (89%) stroke patients, and eighteen subjects (64%) had sensory deficits in the ipsilesional wrist and hand.

According to the sum of the scores for esthesiometry, 60% showed ipsilesional and 85% showed contralesional sensory loss. Approximately 10%, 14% and 14% of subjects had a score ≤ 5 on the ipsilesional dermatomes C6, C7 and C8, respectively.

Table 1. Demographic characteristics of healthy and stroke subjects.

Variables	Stroke subjects (n = 28) Median (1st Q; 3rd Q) or n	Healthy subjects (n = 22) Median (1st Q; 3rd Q) or n
Age (years)	58 (49.5; 66.5)	45.5 (37.7; 51.6)
Sex (F/M)	10/18	7/ 15
Lesioned hemisphere (R/L)	18/10	---
Dominant hand (R/L)	26/2	21/1
Time after stroke (months)	64 (20.3; 102)	---
Stroke type (H/I)	8/20	---
FMA contralesional EU motor score	26.5 (8.5; 50.8)	---
≤ 20	13	---
20-50	9	---
≥ 50	6	---
Affected artery		
Middle cerebral	24	---
Anterior cerebral	4	---

F: female; M: male; R: right; L: left; I: ischemic; H: hemorrhagic; Y: yes; N: no; FMA: Fugl-Meyer Assessment; UE: upper extremity; Q: quartile.

Table 2. Measurement scores of healthy and stroke subjects.

	Stroke subjects (n = 28)		Healthy subjects (n = 22)	
Variables	Contralesional UE Median (1st Q; 3rd Q)	Ipsilesional UE Median (1st Q; 3rd Q)	Non dominant UE Median (1st Q; 3rd Q)	Dominant UE Median (1st Q; 3rd Q)
Sum of esthesiometry score	11.5 (6.25; 18)	20 (18; 21) §	21 (21; 21)*	21 (21; 21)**
Sum of NSA score	20 (20; 20)	18 (7.25; 20) §	20 (20; 20)	20 (20; 20)
FMA sensory score	6 (4; 7.75)	8 (8; 8) §	8 (8; 8)*	8 (8; 8)
Functional tests with visual guidance	2 (0; 7)		---	
Functional tests without visual guidance	1 (0; 4)		---	

NSA: Nottingham Sensory Assessment; FMA: Fugl-Meyer Assessment; UE: upper extremity; Q: quartile; *p-value < 0.05 for comparison of non-dominant UE and contralesional UE; § p-value < 0.001 comparing contralesional and ipsilesional UE's in stroke group; **p-value < 0.05 comparing dominant UE and ipsilesional UE values.

Table 3. Esthesiometry scores of stroke patients (n = 28).

Case	C6 IL	C6 CL	C7 IL	C7 CL	C8 IL	C8 CL	Total Score IL	Total Score CL
Case 1	7	3	7	4	6	4	20	11
Case 2	6	4	7	4	7	4	20	12
Case 3	6	4	6	4	6	4	18	12
Case 4	6	1	6	2	6	2	18	5
Case 5	7	7	6	7	7	6	20	20
Case 6	6	5	6	2	6	4	18	11
Case 7	7	6	7	6	7	6	21	18
Case 8	6	6	6	6	7	6	19	18
Case 9	7	2	5	3	4	5	16	10
Case 10	5	3	5	2	5	2	15	7
Case 11	7	1	7	1	6	1	20	3
Case 12	7	1	7	1	7	1	21	3
Case 13	6	4	6	3	6	1	18	8
Case 14	7	7	7	7	7	7	21	21
Case 15	6	6	6	5	6	6	18	17
Case 16	7	7	7	7	7	7	21	21
Case 17	7	1	6	1	6	1	19	3
Case 18	7	5	7	5	7	5	21	15
Case 19	6	1	6	1	6	1	18	3
Case 20	7	3	7	3	7	3	21	9
Case 21	7	7	7	7	7	7	21	21
Case 22	7	5	7	6	7	7	21	18
Case 23	7	6	7	6	7	6	21	18
Case 24	5	5	5	5	5	5	15	15
Case 25	7	7	7	7	7	7	21	21
Case 26	7	1	7	4	7	1	21	6
Case 27	7	1	6	1	6	1	19	3
Case 28	1	2	1	3	1	3	3	8

IL: ipsilesional upper extremity; CL: contralesional upper extremity. The scores ranged from 7 (green monofilament) to 1 (magenta red monofilament).

According to the FMA scores, 75% of the stroke patients had light touch and hand conscious proprioceptive deficits on the contralesional wrist and 17% showed these characteristics on the ipsilesional side. With regard to the sum of the scores on the NSA, 7% had sensory changes only in the ipsilesional wrist and 64% had sensory changes in the wrist and hand contralateral to the lesion.

Approximately 78% of the subjects had mild or moderate motor impairment, according to the FMA score. The comparison of the scores for the sensory FMA, NSA and esthesiometry assessments between the ipsilesional and contralesional limbs showed significant differences ($p < 0.001$ for the three measuring instruments), while no correlation between the ipsilesional and contralesional sensory deficits was found. The ipsilesional sensory deficits showed no significant correlation with the contralesional motor deficits. There was no correlation between the scores for esthesiometry, the NSA and the ipsilesional sensory FMA with the performance on functional tests (with and without visual guidance). We found a significant difference between functional tests with and without visual orientation scores ($p = 0.002$).

Table 4. FMA sensory scores and sum of NSA scores in stroke patients (n = 28).

Case	FMA sensory score Ipsilesional UE	FMA sensory score Contralesional UE	ASN Score Ipsilesional UE	ASN score Contralesional UE
Case 1	8	8	20	20
Case 2	4	4	20	6
Case 3	7	6	20	19
Case 4	8	4	20	7
Case 5	8	7	20	20
Case 6	8	7	20	8
Case 7	8	8	20	19
Case 8	8	8	20	20
Case 9	6	6	20	8
Case 10	8	7	20	11
Case 11	8	2	20	4
Case 12	8	2	20	3
Case 13	8	2	20	10
Case 14	8	6	20	20
Case 15	8	8	20	20
Case 16	8	7	20	20
Case 17	8	2	20	5
Case 18	8	4	20	20
Case 19	8	0	20	0
Case 20	8	4	20	6
Case 21	8	8	20	20
Case 22	8	0	20	18
Case 23	8	6	20	20
Case 24	7	6	16	11
Case 25	8	8	20	20
Case 26	6	7	20	16
Case 27	8	4	18	18
Case 28	8	8	20	19

NSA: Nottingham Sensory Assessment; FMA: Fugl-Meyer Assessment; UE: upper extremity.

Table 5 shows the difference in esthesiometry scores (ipsilesional UE) in right and left lesions; no significant differences between lesion laterality and other measuring instruments were found. The most significant ipsilesional sensory loss was observed in the 2 left-handed patients ($p = 0.05$), according to NSA (one subject had right hemispheric damage and the other had left neurologic damage).

DISCUSSION

In the present study, the reduction of conscious proprioception, tactile sensation (light touch, pressure or location) or thermal sensation was found in the wrist and hand ipsilateral to neurological injury in 64% of subjects after a stroke.

In this study, ipsilateral sensory deficits showed no significant correlation with contralesional motor deficits, confirming the findings of Brasil-Neto and Lima[1]. The authors

Table 5. Lesioned hemisphere and esthesiometry score of ipsilesional upper extremity.

Lesioned hemisphere	Score 3 (n)	Score 15 (n)	Score 16 (n)	Score 18 (n)	Score 19 (n)	Score 20 (n)	Score 21 (n)
Right (n = 18)	0	0	0	6	3	2	7 *
Left (n = 10)	1	2	1	0	0	2	4

*p-value = 0.011 comparing distribution of esthesiometry scores for right and left lesions.

analyzed a sample of 25 chronic post-stroke patients and observed a reduction in tactile sensation of the ipsilesional hand through the Moving Touch-Pressure test in comparison with normal subjects. However, Son et al.[2] found a positive correlation between the sense of position of the metacarpophalangeal joint ipsilesional with contralesional tracking task.

No correlation between ipsilesional and contralesional sensory deficits was found in contrast to the Essing et al.[7] study. Essing et al.[7] evaluated 30 subjects post-stroke and found 30% of them with bilateral tactile hypoesthesia. The authors noted that there was a correlation between the degree of sensory loss in the ipsilesional and contralesional limb, so that individuals with tactile anesthesia in the hand contralateral to the stroke were more likely to exhibit ipsilateral sensory deficits.

The finding of reduced conscious proprioception in the ipsilesional upper limb replicates the results found by Sartor-Glittenberg and Powers[21] and Son et al.[2]. Son et al.[2] investigated joint position sense in 50 stroke subjects. The tests were conducted in the hand ipsilateral to the damaged hemisphere. Higher error scores were found in the joint reposition test in the stroke group. The authors suggest that it is possible that the transcallosal transfer disturbance after unilateral brain damage may lead to ipsilateral sensory deficits.

Dannenbaum et al.[22] indicated that the tactile sensory evaluation using the Semmes-Weinstein test is not related to normal function. However, we found a maximum score (normal function) in all healthy subjects and sensory changes in the upper limb in post-stroke subjects. In this study, over 10% of the post-stroke sample exhibited a score less than or equal to 5 for esthesiometry in the ipsilesional hand, which indicates a reduced protective sensation, difficulty with the discrimination of shape and temperature, vulnerability to skin lesions and, in some cases, loss of hot/cold discrimination.

In the present study, it was found that the subjects with brain damage in the right hemisphere exhibited better scores in ipsilesional tactile sensation (verified by esthesiometry), confirming the findings of Vaughn and Costa[8]. Boll[11] found worse sensory function in patients with brain damage in the right hemisphere. According to Desrosiers et al.[23], subjects with lesions in the left hemisphere have a double disadvantage: in addition to higher contralesional UE deficits, they are obliged to use their non-dominant UE (ipsilesional).

There are justifications for the existence of ipsilesional sensory disturbances. Sherwood[24] noted that there are few afferent neuronal fibers following the ipsilateral cerebral cortex. Another plausible explanation is the existence of a bilateral representation of the body in the secondary somatosensory area, in contrast to the representation of the contralateral primary somatosensory area[25].

A third justification for the existence of ipsilesional sensory loss is the activation of both cerebral hemispheres during unimanual motor tasks, considering the contribution of interhemispheric interactions with excitatory or inhibitory effects of a cerebral hemisphere on the opposite hemisphere[26]. In turn, the posterior parietal cortex is connected with the frontal motor areas and the primary somatosensory area ensuring a close relationship between sensory and motor function[27]. Moreover, it is speculated that there can be problems with the corpus callosum after a stroke, leading to issues with neural information transfer across hemispheres[1].

The findings of this study reinforce the need, as revealed by other researchers, to not consider the ipsilesional upper extremity as "unaffected" or "normal" [1,7,28]. Kitsos et al.[28] conducted a review of the scientific literature on the sensory-motor deficits in ipsilesional UE after stroke and recommended the use of the terms "most affected" for the contralesional upper limb and "less affected" for the ipsilesional upper limb.

In conclusion, reduction of conscious proprioception, tactile sensation or thermal sensation was found in the wrist and hand ipsilateral to neurological injury in 64% of subjects after stroke. The esthesiometry through the monofilament was a more sensitive tool for detection of sensory disturbances in the ipsilesional wrist and hand.

We found that the subjects with brain damage in the right hemisphere exhibited better scores on the ipsilesional tactile sensation assessment (verified by esthesiometry). The most significant ipsilesional sensory loss was observed in the 2 left-handed patients.

Comparisons of scores of the sensory FMA scale, the NSA and the esthesiometry between ipsilesional and contralesional extremities showed significant differences, and no correlation between ipsilesional and contralesional sensory deficits was found. Ipsilesional sensory deficits showed no significant correlation with contralesional motor deficits.

There was no correlation between the scores of ipsilesional esthesiometry, NSA and sensory FMA scale with the performance on functional tests. We found significant differences between functional tests with and without visual orientation scores.

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