Clinical Rehabilitation

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Clin Rehabil 2002; 16; 523

DOI: 10.1191/0269215502cr522oa

Clinical Rehabilitation 2002; **16**: 523–533

The Rivermead Assessment of Somatosensory Performance (RASP): standardization and reliability data

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Received 24th February 2001; returned for revisions 5th June 2001; revised manuscript accepted 17th July 2001.

Objective: To develop a standardized, clinically relevant, quantitative assessment of somatosensory performance in patients with stroke.
Design: Prospective observational study and test evaluation.
Setting: Local Oxford hospitals and a regional neurological rehabilitation centre.
Subjects: Stroke patients with a first, lateralized acute stroke in hospital, and age-matched control subjects.
Method: Each patient was assessed in a structured way using a new battery of formal tests of somatosensory performance.
Results: A total of 100 patients and 50 controls were fully investigated. Control subjects performed at or near ceiling on all tests, but patients showed impaired performance on all tests. The Rivermead Assessment of Somatosensory Performance (RASP) showed good intra-rater and inter-rater reliability for all subtests. There were however only weak relationships between scores of sensory impairment and scores of motor impairment or mobility and dependence.
Conclusions: The RASP provides a practical and reliable assessment of sensory loss, which provides the clinician with a comprehensive picture of the patient's performance and can be used to inform and monitor rehabilitation and recovery.

Introduction

Somatosensory assessment after stroke is often neglected, despite the fact that impairments of tactile and proprioceptive discrimination are found in over 50% of stroke patients.[1] Moreover, somatosensory impairments have a significant influence on everyday activities and rehabilitation outcome.[2–4] Patients with both sensory and motor loss show a worse prognosis than patients with motor loss only.[5] Accurate and reliable diagnostic instruments may help in establishing the effectiveness of clinical treatments.[6]

A recent survey of practising clinicians in the UK[7] found that over 80% routinely performed somatosensory assessment as part of their clinical assessment after stroke. The survey also confirmed that there was no single, generally

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accepted, standardized measure that was clinically applicable and capable of providing reliable and normative data over a range of submodalities. Furthermore, a comprehensive review by Carey[1] found that systematic investigations of sensory impairment following central nervous system lesions were often limited and largely subjective. Not surprisingly, many of the standard medical texts consider clinical testing procedures difficult to implement, tedious and unreliable, particularly when perceptual, comprehension and language problems coexist.

Although a few quantitative measures have been developed[8,9] these have been for the most part functionally orientated with few controlled or quantifiable tests of the underlying somatosensory impairment.[1] Poor reliability has been identified as the main problem in those few studies that have formalized the assessment of somatosensory impairment.[10–12] One reason for the low reliability may be the use of several different ad hoc, unquantifiable instruments, e.g. light touch tested using either cotton wool, the examiner's finger-tip or a feather, and the absence of a simple standardized procedure.

This study investigated the reliability and validity of a new clinically orientated test, the Rivermead Assessment of Somatosensory Performance (RASP).

Methods

The Rivermead Assessment of Somatosensory Performance (RASP) was designed to be a standardized test capable of providing a brief, quantifiable, modular and yet reliable assessment of somatosensory functioning that could be used in patients with a variety of different neurological disorders. Seven tests of sensation were chosen, covering the traditional range of somaesthetic modalities and major body parts (e.g. head, hands and foot). These were selected on the basis that (a) their established face validity (i.e. existing versions that had been in widespread clinical use for over a century), (b) they covered areas traditionally considered important in routine neurological assessment, and (c) it was possible to provide a user-friendly standardization.

The seven tests can be divided into five primary (sharp/dull discrimination, surface pressure touch, surface localization, temperature discrimination, movement and direction proprioception), and two secondary (extinction and two point discrimination) tests of sensation. In addition to a detailed standardized procedure, customized clinical instruments were developed to increase examiner reliability.

Description of new instruments

Three custom-designed quantifiable pieces of equipment were developed:

- *Neurometer* This pen-shaped instrument is used to test: (a) Sharp/dull discrimination, (b) Surface pressure touch, (c) Surface localization, and (d) Extinction. It has two distinct parts (Figure 1): a top half used for testing sharp/dull discrimination, and a lower half used for measuring surface pressure touch, surface localization and extinction.
- *Neurotemp* These are two paddle-shaped instruments with coloured plastic handles (one blue and one red) encasing copper discs used to provide a reliable discrimination between designated temperatures (cold = 6–10°C; hot = 44–49°C). The handles contain LCD (liquid crystal display) readout temperature displays (Figure 2).
- *Two-point neurodiscriminator* This is a four-pointed fixed distance discriminator (Figure 3) used to establish the extent of two-point discrimination on the finger pads. The three fixed distances are 3, 4 and 5 mm, together with a single point (Figure 3).

Brief descriptions of tests

All tests are administered with the subject's eyes closed. For the RASP, six trials are administered on each of 10 test regions. The 10 test regions (5 left and 5 right) represent areas on the face, hand and foot. The examination always moves from the unaffected side to the affected side. Just before each stimulus is given, the patient is asked what they feel. The patient is encouraged to only indicate what they feel and not to worry if they are unable to feel all the trials. This makes it clear to the patient that a stimulus is about to be presented, decreasing the element of surprise. For two of the tests 'sham' trials were given. Sham trials comprise tests where the examiner pretends to give the stimulus when in fact none is applied. These trials allow the examiner to evaluate the subject's inherent reliability.

1) Sharp/dull discrimination

Each Neurometer (one with sharp and one with dull Neurotip end showing) is applied to the test area in a pseudo-randomized order. A total of 60 trials are administered to 10 test regions. For this test, 20 'sham' trials are given, two for each area. The 'sham' consists of the examiner moving the Neurometer to within 6 in (15 cm) of the patient's skin surface and making the same audible sound with the instrument by applying it to his or her own hand.

2) Surface pressure touch

One Neurometer is set to level 1 (15.5 g pressure) and is applied to designated testing areas for a total of 60 trials. Twenty sham trials are also included.

3) Surface localization

Using one Neurometer (set to 15.5 g, i.e. setting 1), the subject is requested to identify designated areas on their body where they have

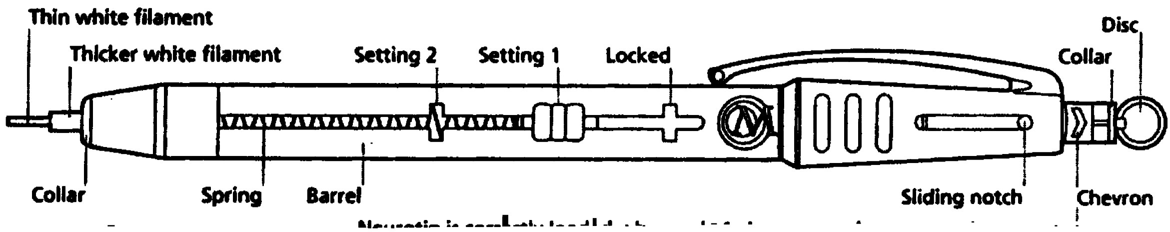

Figure 1 Neurometer. This has two distinct parts: a top half used for testing sharp/dull discrimination and a lower half used for measuring surface pressure touch, surface localization and extinction. To prepare for testing sharp/dull discrimination, two Neurometers are required, each loaded with a Neurotip in the special carrier located at the end of the instrument.

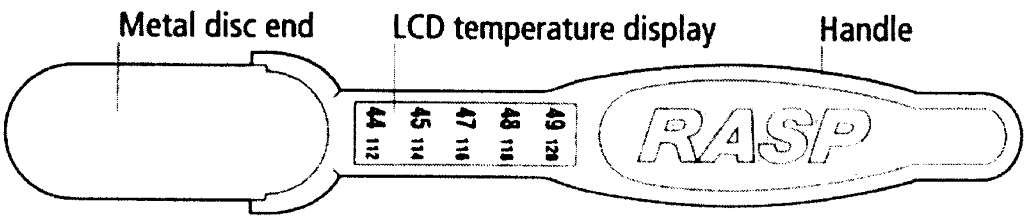

Figure 2 Neurotemp. This comprises two paddle-shaped instruments with plastic handles (one blue and one red) encasing copper discs. The handles contain linear LCD readout temperature displays. The drawing here shows a cold neurotemp. A similar but different instrument is used for determining hot temperatures. Each temperature display provides a specific range. The blue or cold Neurotemp reads temperatures from 6°C to 10°C; the red or warm Neurotemp reads temperatures from 44°C to 49°C, thus ensuring a minimum temperature range difference between the two Neurotemps of 34 and 43 degrees.

Subject samples

One hundred patients who had a stroke were used to standardize the complete battery. Fifty had left-sided lesions (right hemiplegia) and 50 had right-sided lesions (left hemiplegia).

Patients were recruited from three local Oxford hospitals (Rivermead Rehabilitation Centre, the Radcliffe Infirmary, the John Radcliffe Hospital) and Stoke Mandeville Hospital (in Aylesbury). Four hundred and sixty-five stroke patients were screened. Only patients with a diagnosis of first-ever unilateral stroke were tested in the development of the standardized version of the RASP. Patients were excluded if there was evidence of bilateral signs, they were unable or unwilling to participate, they had severe visual or hearing impairment, cognitive impairments and demonstrable comprehension difficulties, or they had a past medical history of another neurological condition or previous stroke. For the purposes of this paper, only performance related to the affected side is reported.

A control group of 50 non-brain-damaged subjects was also tested to obtain normative data and empirically establish impairment cut-off scores. These were recruited from several sources, including hospital employees and volunteers from the local community. Table 1 provides basic demographic details for these patients and the reference control group. The groups did not differ significantly with respect to age or time post onset.

The performance of the control group was used to establish normal performance for each of the seven subsets (Table 2). A subject was considered to show impairment on any of the tasks if they exceed the cut-off of two standard deviations from the respective mean, derived from normal performance.

Test–retest, intra-rater reliability was established by a single therapist assessing 12 patients on two separate occasions with an average interval of 30 days. Inter-rater reliability was established by comparing performance of 15 different patients scored independently but sequentially by two different raters and the original research therapist (CW). Assessments were approximately one week apart and the order of assessment was counter-balanced.

In addition all patients had their motor loss and functional performance measured using the Motricity Index,[14] Rivermead Motor Assessment (RMA)[15] and Barthel Activities of Daily Living Index.[16] This data was used to investigate validity of the RASP: we anticipated that greater sensory loss would be associated with greater motor impairment and greater dependence. This was investigated using correlation coefficients.

Results

The performance of the control subjects is shown in Table 2, where the cut-off scores defining 'normal' are shown. Control subjects performed at or about ceiling on most tests and there was no significant difference between performance on the left and right sides of the body. Normal performance in discriminating sharp from dull was the test that showed the greatest number scoring below maximum.

Patient performance was significantly worse than controls on every test (Mann–Whitney, $p < 0.001$). The mean scores for the respective groups are shown in Table 3. The frequency of patient

Table 1 Patient and reference control group demographic details

	Left brain damage	Right brain damage	Controls
No. of patients	50	50	50
Time post onset (mean, SD and range)	6.1 weeks (8.6) (0.2–35.5)	4.7 weeks (5.4) (0.2–26)	–
Age (mean, SD and range)	64.2 (15.6) 23–96	64.0 (15.4) 35–86	60.0 (12.7) 24–80
Sex ratio (M:F)	27:23	26:24	21:29

perature (0.84); proprioceptive movement (0.83); proprioceptive direction (0.50). This confirms that the RASP and its individual subtests showed good retest reliability.

Inter-rater reliability

The Pearson correlation coefficient for the scores between the research therapist and two independent raters for the total score on the five primary subtests (with an interval of no more than 5 days) was 0.92.

The range of disagreement between separate assessments done by the same rater and different raters is shown in Figure 4 which is a Bland and Altman plot of the difference in total there is no statistically significant consistent bias (confirmed on comparing the mean scores by *t*-test).

Patient reliability

Subjects are sometimes assumed to be 'unreliable' in reporting sensation, and hence sham tests were introduced to assess this phenomenon. Sham tests also help maintain the patient's interest.[17] In designing the RASP, we attempted to control for subject unreliability by employing six trials per test region for each of the seven objective subtests. Although multiple assessments may help reduce the danger of an unrepresentative trial, standardized tests *per se* cannot prevent unreliable performance in a patient. It is, however, possible to identify and exclude those patients whose performance might be considered affected by 'suggestibility', fatigue and mental confusion. One can 'control' for such effects by

Table 3 Performance of patient groups and numbers below impairment cut-off for affected side

RASP subtests	Max score	Right brain damage (left hemi) Mean (SD) Range	Below cut-off (n, %)	Left brain damage (right hemi) Mean (SD) Range	Below cut-off (n, %)
Sharp/dull	30	17 (8.2) 0–30 (n = 50)	33/50 66%	19.7 (6.3) 3–30 (n = 46)	25/46 54%
Surface pressure touch	30	21.2 (9.2) 0–30 (n = 50)	37/50 74%	23.2 (8.0) 2–30 (n = 50)	28/50 56%
Surface localization	30	21.7 (11.1) 0–30 (n = 50)	24/50, 48%	23.9 (10.0) 0–30 (n = 50)	17/50, 34%
Temperature	30	20 (7.7) 0–30 (n = 45)	30/45, 67%	22.4 (6.2) 0–30 (n = 44)	27/45, 60%
Proprioceptive movement	30	23.9 (9.2) 0–30 (n = 49)	21/49, 44%	24.3 (8.1) 0–30 (n = 47)	23/47, 49%
Proprioceptive direction	30	21.5 (10.0) 0–30 (n = 50)	27/49, 55%	21.8 (9.3) 0–30 (n = 50)	23/47, 49%
Sensory extinction	12 (2x6)	Face / Hand		Face / Hand	
Number of patients with		n = 44 / n = 38		n = 48 / n = 42	
Normal (6)		28 / 24		48 / 32	
Mild (4/5)		7 / 4		4 / 3	
Moderate (2/3)		2 / 0		1 / 2	
Severe (0/1)		7 / 10		2 / 5	
Two-point discrimination (index finger)					
3 mm		0		1	
4 mm		11		7	
5 mm		2		10	
Outside limits		19		10	
Untestable		18		22	
Total score (6 tests)	180				
Mean (SD)		122.4 (40.7)		128.3 (33.8)	
Median		130.5		141.5	
Range		19–175		27–174	
Percentiles 5%, 25%, 75%, 95%		44,103,155,168		60,110,151,166	

or equal to 2 false positive replies = normal; 3–5 false positives = mild; 6–8 = moderate and 8–10 = severe.

In the clinical patient group of 465 patients who were initially screened fr study, seven patients were specifically excluded because they pr5duced false many of which have been in clinical use for over a century. Furthermore the performance on the subtests were closely correlated (Table 4) suggesting that the battery was measuring a range of related phenomena.

Nevertheless, it was important to establish that performance on the RASP subtests discriminated significantly between brain-damaged patients and age-matched controls. Control performance was therefore compared directly with that of both left and right brain damaged groups. Using the Mann–Whitney test, patient groups were significantly (p <0.001) worse than age-matched control subjects on all tests.

We anticipated that patients with sensory loss would have more severe motor impairment, and so calculated the Spearman correlation coefficients between the Motricity Index scores and RASP item scores. The coefficients were nonsignificant for sharp/dull $r = 0.08$, surface pressure touch $r = 0.14$, surface localization $r = 0.21$, and temperature discrimination $r = 0.08$; but for proprioception movement ($r = 0.31$) and proprioception direction ($r = 0.36$) they were significant at the 0.01 level.

We also anticipated those patients with sensory loss would score lower on the Rivermead Mobility Index (RMI). The Spearman correlation coefficients between different item scored and the Rivermead Motor Assessment (RMA) were again low and nonsignificant for: sharp/dull discrimination ($r = 0.23$), surface pressure touch ($r = 0.21$), surface localization ($r = 0.25$), temperature discrimination ($r = 0.05$), and proprioception movement ($r = 0.25$); but it was significant for proprioception direction ($r = 0.32$.).

Lastly, we anticipated that patients with sensory loss would be more dependent, but again the Spearman correlation coefficients on the RASP item scores and the Barthel ADL Index score were similarly low and not statistically significant. Sharp/dull discrimination ($r = 0.27$), surface pressure touch ($r = 0.27$), surface localization ($r = 0.31$), temperature discrimination ($r = 0.09$); but again proprioception measures were statistically significant: proprioception movement ($r = 0.35$) and proprioception direction ($r = 0.41$). That said, these significant correlations only explain a small percentage of the total variance.

Clinical messages

- Sensory assessment after stroke can be made reliable by standardizing the process.
- Using specially developed test instruments may also help.
- Preliminary studies show the Rivermead Assessment of Somatosensory Performance (RASP) to be reliable.

Discussion

This study reports data on the reliability of a new standardized method for assessing the presence of sensory impairment shortly after stroke and also for measuring the severity and extent of any loss found. It finds reasonable reliability. Evidence on validity and sensitivity and on utility will need to be accumulated by others.

This study has some weaknesses. The patient population studied necessarily excluded patients who could not co-operate. It is therefore a selected group. However clinical assessment will always be restricted to patients who can co-operate. In other ways, the group was representative of those seen normally, in that they were seen within a few weeks of stroke rather than many months later.

Second, most of the data were collected by one individual with experience of and interest in sensory assessment using this procedure. Although the procedure was used by two other therapists, further studies will be needed to investigate reliability in normal clinical use.

Third, this study does not investigate whether all tests are necessary, or whether some are redundant. The high intercorrelation between individual test scores (Table 4) suggests that there might be scope for test reduction.

Fourth, the validity of any clinical sensory assessment is difficult to establish because perception of sensory stimulation by a patient is ultimately a subjective phenomenon. We did not compare the RASP with any electrophysiological measure such as somatosensory evoked potentials because it would be difficult both practically and ethically to carry this out in a large number of patients. There is no clinical (i.e. behavioural) 'gold standard' test for measuring sensation. Furthermore although somatosensory evoked potentials may demonstrate intact conductivity between peripheral receptors and cortical brain areas they are unable to indicate the patient's phenomenological experience or awareness to stimulation.

However, we believe that the RASP is valid. Face validity is obvious and the procedure tests sensory modalities that have been around for many years. The specific feature of the RASP is the standardization of the process of assessment and the development of customized test instruments. The weak relationship between sensory loss and motor loss or disability is surprising, but does not itself invalidate the procedure as there is little evidence on the relationship between sensory loss and motor loss. The validity of summing scores across items (sensory modalities) or body parts will need further investigation.

Fifth, although the sample sizes employed are comparatively small, reliability was established for one expert assessor, and good levels of inter-rater reliability were also determined. The problem of achieving reliability for somatosensory assessment was documented by Lincoln *et al.*[11] in developing the Nottingham Sensory Assessment (NSA) on a select group of patients admitted to a stroke rehabilitation unit. Their study found that while intra-rater reliability was good, inter-rater reliability was poor. In an attempt to address this weakness, Lincoln and colleagues[12] shortened the previous version of the NSA and re-evaluated the inter-rater reliability on 27 stroke patients 3–4 days apart. Despite two experienced research therapists familiar with the shorter version of the NSA, Kappa coefficients showed only acceptable agreement on 14% of test items.

Nonetheless, we believe that the RASP provides a practical and standardized instrument that addresses many of the established weaknesses of clinical testing reported in the past. The RASP score considers both the detection and extent of specific sensory impairments when compared with the performance of age-matched controls and provides a comprehensive picture of the patient's strengths and weaknesses. From a practical point of view, the test takes between 20 and 30 minutes to complete, and covers a representative range of body areas and sensory tests. Although the test employs newly designed instruments, all the subtests originate from established clinical practice and most have been used in a variety of unstandardized formats in medicine for well over a century. A reliable and sensitive diagnosis of somatosensory loss such as the RASP may help to establish the effectiveness of clinical treatments, and may explain why patients' neurological disabilities are not really detected by conventional neurological examinations.

Acknowledgements

We would like to thank Farida Barma, Maureen Bartley and Val Berry for helping with the reliability testing and Dr Mario Cortina Borja for statistical guidance. We would also like to thank Drs Winner, Hywel Jones, Durkin and Hillawi for permission to see their patients, Collette Keane and Dr Malar Hunt, the therapy departments at Rivermead and all the patients, controls who agreed to participate in the project. Finally, we acknowledge the support of the Stroke Association and MRC who funded CW and PWH respectively.

Competing interests

The authors have published the full testing manual and equipment commercially, and it is sold by: The Thames Valley Test Company, 7–9 The Green, Flempton, Bury St Edmunds, Suffolk IP28 6EL, UK (http://www.tvtc.com/tvtc/index.html)

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