Functional prognosis in stroke: use of somatosensory evoked potentials

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SUMMARY   Median nerve somatosensory evoked potentials (SEPs) were performed on 35 patients with acute stroke and correlated with functional outcome as measured by placement, length of stay and an activities of daily living index (Barthel Index). There was a statistically significant correlation of both SEP and sensory examination at the 0·05 level to eventual functional outcome. SEPs were better than age, sex and side of CVA in predicting functional outcome as measured by these scores. SEPs and sensory examination are interrelated but SEPs offer the advantages of objectivity, the ability to quantify results and the use in unconscious or dysphasic patients.

The ability to predict functional outcome in stroke patients has great importance in developing effective forms of therapy, in resource allocation and in individual consequences. Although functional outcome can be predicted to a certain extent with clinical examination, age, sex, side and site of stroke,[1–4] these factors are not sensitive enough and are only suitable for large groups of patients.

There are no universally accepted measures of functional outcome, so a number of indirect measures can be used. Placement (that is, return home or to a nursing home) and length of hospital stay are frequently used as indirect measures of functional outcome. Many indices of activities of daily living (ADL) have been developed to give approximations for selected activities.

The Barthel Index[5] is a well recognised and accepted index of ADL. It scores functional outcome out of a possible score of 100. Being independent although possibly still having neurological deficits is scored 100.

Since Dawson in 1947[6] described the technique of somatosensory evoked potentials (SEPs), there have been many publications about their use in various neurological conditions. These include multiple sclerosis, head injuries, brachial plexus injuries, spinal injuries etc.[7–9] Short latency somatosensory evoked potentials are those with a latency of less than 100 ms. They most accurately reflect proprioceptive pathways and their direct synaptic connections including posterior and posterolateral columns.

Although there have been studies on the use of SEPs

in stroke, most have concentrated on the correlation with the neurological examination, few have looked at function and none have used an accepted index of function and ADL. In addition, there have been various design limitations. Some studies have looked at only small numbers of patients,[10–12] and others have included a range of pathological conditions.[13–15] Frequently, there were large time variables between stroke and SEP testing.

It has been established that multimodality evoked potentials can predict outcome in head injuries[16 17] and more recently Cant et al[18] proposed that SEPs alone can predict short term outcome in head injuries. There is some suggestive evidence that they may be a useful prognostic indicator in stroke.[10–12 19] It was felt therefore that SEPs might be useful in predicting functional outcome in stroke.

The aim of this study was specifically to look at the usefulness of SEPs in predicting outcome as measured by placement, length of stay and Barthel Index. In addition, its practical application is compared with current other methods of prognostication.

Materials and methods

(a) Patients
The patient population consisted of acute stroke patients referred to the rehabilitation period from May 1985 to May 1986 and also included a small number of patients who had been used as a pilot programme over a 10 week period in 1984. The criteria for referral to the rehabilitation unit were all acute strokes admitted to Westmead Hospital under the age of 72 years with a neurological deficit. Patients with TIAs, multiple infarcts and peripheral neuropathies were excluded. There were no exclusions for the study on the basis of rapid recovery or very poor outcome. Four patients were excluded because of peripheral neuropathy as evidenced by abnormal brachial plexus potentials. In the remaining 35

patients the mean age was 56·4 years; the range 15 to 72 yrs and the median age was 62 years. (There were 18 men and 17 women). All patients who were given a rehabilitation programme, had this by therapists who were not aware of the SEP result.

Patients had the test explained and permission was given before testing. All patients had CT examinations. Twenty nine had CT evidence of infarction; six patients had normal CT scans (all of these were repeated and still showed no abnormality). There were two patients with brainstem infarcts (one haemorrhagic), 11 patients had subcortical infarcts (basal ganglia, corona radiata or internal capsule) and 16 patients with cortical infarcts. Fifteen of these were in the distribution of the middle cerebral artery and one in the distribution of the posterior cerebral artery.

(*b*) *Controls*
SEPs were performed on 26 normal controls (age range 19–83 years); mean age 50–65 years. There were 14 women and 12 men.

(*c*) *SEP method*
SEPs were performed using a similar technique to that previously described by Chiappa.[8] Recording was performed using surface silver chloride electrodes overlying Erb's point, the upper cervical vertebrae (C2) and the contralateral cortex overlying the primary somatosensory area (CC) with a common mid frontal reference electrode (Fz: 10–20 system). An electrode was also placed over the ipsilateral cortex. All four channels were recorded simultaneously. In selected patients an additional non cephalic reference site was used.

The stimulus was a square wave of $100 \, \mu s$ duration delivered to the skin with the cathode overlying the median nerve at the wrist and proximal to the anode. The stimulus strength was adjusted to produce a twitch of the appropriate muscles at a frequency of 2 Hz. Subjects sat in an armchair and were instructed to relax and to sleep if they wished. The recording electrodes were connected to a Digitimer D200, 256 stimulations were performed and repeated for reproducibility. The bandpass used was 16 Hz to 3 KHz. Each sweep was from 0 ms to 52 ms. The digital averaging system sampled 256 points per ms. The procedure was performed on both arms for comparison purposes. Final results were plotted on paper with a Hewlett Packard 7470A plotter.

Lower limb evoked potentials were performed on some patients as it was intended to correlate these with outcome but technical difficulties in performing this and in particular obtaining the lumbar potential to determine latencies meant that only a small number of patients could be examined and so this was abandoned for the study.

Latency and amplitude were measured of the first negative peak over Erb's point (N9), cervical spine (N13) and contralateral cortex (N20). Interpeak latencies were calculated from these points. In addition, amplitude of the positivity following N20 (P23/P30) was compared to the opposite side.

An abnormal SEP was judged as having any of the following: An absent N20; an amplitude of N20 less than 50% of the unaffected cortex or less than the lowest value in the normal range; a prolonged latency of N20 (more than 2·5 times the standard deviation of controls); a reduction in amplitude of the following positivity of greater than 50% of the unaffected side.

(*d*) *Functional outcome*
Decisions for discharge, placement and scoring of Barthel Index were done independently of the treating clinicians. Decisions for discharge were determined uniformly by whether the patient could manage at home and not for other reasons such as pressure from hospital bed shortages.

The patients were all examined by a neurologist and a rehabilitation specialist and a standard neurological examination was performed at the time of testing and at follow up. Follow up ceased when patients had plateaued neurologically and functionally. A score of 100 meant they were able to perform these selected activities but that they still may have neurological impairment.

(*e*) *Statistics*
Statistical analysis was performed to determine the level of significance. "z" values were derived using the formula:

$$z = \frac{(x - a)}{b} \text{ multiplied by the square root of n.}$$

where x is the mean of the sample size n; a is the mean of the total group and b is the standard deviation of the total group. The level of significance was then derived from tables using a one-tailed normal curve.

Results

One patient died from bacterial endocarditis after open heart surgery prior to his stroke and was excluded from length of stay and placement but was included in Barthel Index because he had plateaued.

All other patients went home except for three who were placed in a nursing home. Two others went home against advice and were expected to be placed in a nursing home eventually. Four of these five patients with very poor outcome had abnormal SEPs and severe sensory loss. The small numbers involved preclude using place of discharge as a useful measure of outcome but these results indicate that those with an abnormal SEP are more likely to require placement in a nursing home.

There were 19 patients with abnormal SEPs (henceforth referred to as Group I) and 16 patients with normal SEPs (henceforth referred to as Group II). They were comparable by age and sex. SEPs were performed between 4 and 34 days after the stroke (average 12·14 days). Those patients with an abnormal SEP result had the test performed 14·63 days after their stroke compared to 9·18 days for those with normal SEP results. This is insufficient time for there to be any differences in SEP result due to retrograde degeneration.

Results are summarised in tables 1, 2. Normal SEP correlates highly with a good functional outcome as measured by length of stay and Barthel Index. An abnormal SEP correlates with a longer length of stay

Table 1 *Length of stay in days*

Group	Average	No	SD	z	Level of significance
Total	51·14	34	42·61		
I (Abnormal SEP)	70·30	18	38·86	1·79	0·037*
II (Normal SEP)	29·56	16	36·66	1·82	0·034*
Group A & B (Sensory loss)	70·93	16	42·80	1·85	0·032*
Group C (Normal Sensation)	33·35	18	34·77	1·77	0·038*
Male	52·23	17	47·54	0·10	0·460
Female	50·00	17	38·50	0·11	0·460
Left CVA	48·23	13	43·67	0·24	0·405
Right CVA	65·46	15	44·45	1·27	0·102
62 yrs and over	60·18	16	45·67	0·84	0·200
Under 62 yr	43·11	18	39·33	0·79	0·215
Both Abnormal SEP & Sensory loss	83·46	13	37·11	2·72	0·003*
Both Normal SEP & Normal sensation	32·5	13	38·6	1·57	0·058

*Indicates a level of significance below 0·05.

and a lower Barthel Index but with a much wider variation. The results also show that SEP abnormality is a better predictor of outcome than age, sex, and side of stroke but that sensory impairment correlates with outcome as well as SEP. Examples of SEP abnormalities are illustrated in figs 1 and 2.

There were 16 patients with sensory impairment; nine with severe sensory loss involving light touch, stereognosis and pinprick (henceforth referred to as Group A) and seven patients with mild to moderate sensory impairment with decreased but not absent either light touch, stereognosis and pinprick (henceforth referred to as Group B). The sensory loss was assessed on both upper and lower limbs and graded on a scale using normal, mild, moderate and severe gradings. It did not differ between upper and lower limbs in the group of patients studied. There were 19 patients with normal sensation (Group C). There were 13 patients with both abnormal SEP and sensory impairment (68% of abnormal SEPs had sensory loss). There were 13 patients who had both a normal SEP and normal sensation (81% of normal SEPs had normal sensation). A closer association between SEPs

and specific sensory pathways could not be determined in these groups as those with sensory loss usually had all modalities affected to various degrees.

Preliminary findings suggest that the relationship of SEP abnormality to the outcome measures may be dependent on the site of the infarct; an absent SEP response in a cortical infarction having a much poorer outcome than a subcortical lesion. However a larger study is required to confirm the relationship of the SEP, outcome and the site of the stroke. The size of the stroke in cortical infarcts will also have an effect on the outcome and perhaps the SEP reflects this, but much larger number of patients with cortical infarcts would be required to draw any statistically significant conclusions.

There were 11 patients with a low amplitude response (either N20, P30 or both) and/or a delayed N20. Of these, five had cortical infarcts and five were subcortical (basal ganglia). One patient had a normal CT scan. The outcome in nine of the 11 was good (mean Barthel of 90·5). In two patients the outcome was poor (mean Barthel of 32·5) and both these patients had frontoparietal infarcts. This could

Table 2 *Barthel index*

Group	Average	No	SD	z	Level of significance
Total	85·57	35	22·58		
I (Abnormal SEP)	76·84	19	24·50	1·65	0·049*
II (Normal SEP)	95·93	16	14·96	1·82	0·034*
Group A & B (Sensory loss)	74·37	16	24·13	1·97	0·024*
Group C (Normal Sensation)	95·00	19	13·74	1·62	0·053
Male	82·7	13	24·92	0·52	0·300
Female	88·52	17	20·13	0·53	0·298
Left CVA	81·92	13	30·03	0·57	0·284
Right CVA	82·66	15	18·79	0·48	0·316
62 yrs and over	80·29	17	26·24	0·95	0·171
Under 62 yr	90·55	18	17·81	0·92	0·179
Both Abnormal SEP & Sensory loss	68·46	13	25·52	2·71	0·003*
Both Normal SEP & Normal sensation	95·00	13	16·58	1·49	0·068

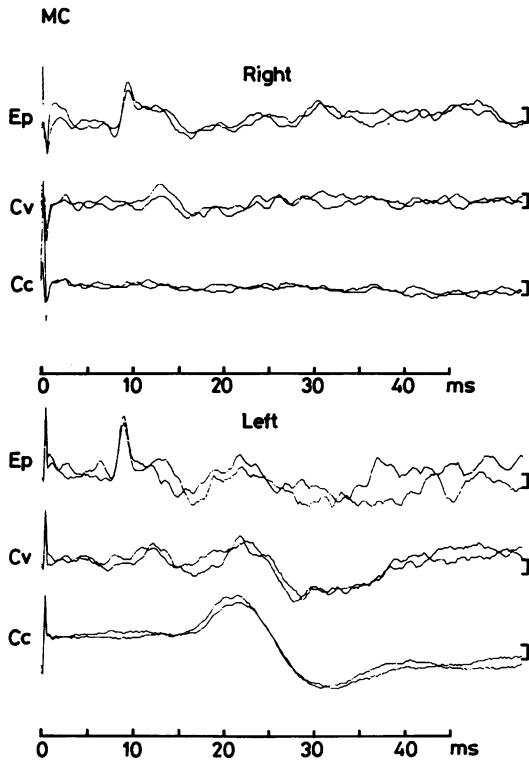*Indicates a level of significance below 0·05.

MC

Fig 1 *Median nerve SEPs from MC, 72 yr old woman with a left temporoparietal infarct. Recordings were made from electrodes at Erb's point (Ep), Second cervical vertebrae (Cv) and contralateral cortex (Cc). The trace shows an absent N20 and its following positivity from the appropriate side. The scale at end of each trace equals 2 μV.*
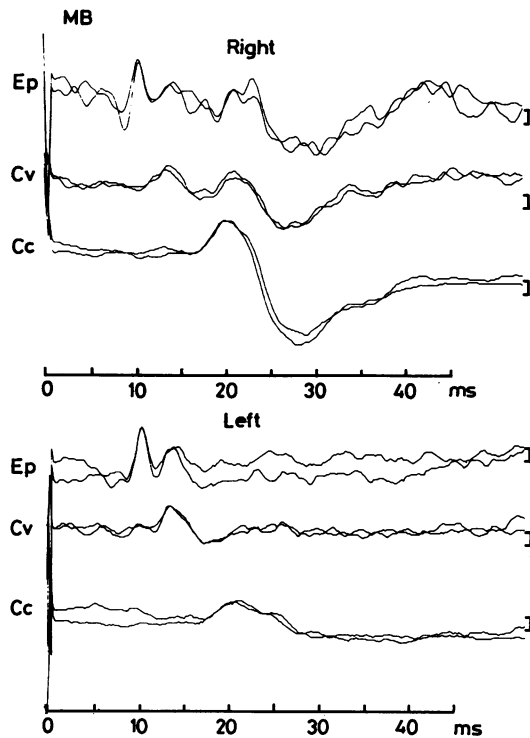
MB

Fig 2 *Median nerve SEPs from MB, 66 yr old woman with a right internal capsule infarct. Recordings were made from electrodes at Erb's point (Ep), Second cervical vertebrae (Cv) and contralateral cortex (Cc). The trace shows an absent positivity following a low amplitude N20 on left median nerve stimulation. The scale at end of each trace equals 2 μV.*

indicate that delayed or low amplitude responses have a similar outcome to those with a normal SEP. It would be difficult to attribute the relevance of these findings to the site of the lesion as these numbers are too small. In the group with absent SEPs (eight patients) the outcome was variable depending on the site of the infarct. An absent SEP with cortical infarction had a poor outcome in the five cases (mean Barthel Index of 65) whereas with subcortical or brainstem infarction this correlated with a better outcome in the four cases (mean Barthel Index of 92). These numbers however are too small to draw statistical conclusions.

Discussion

According to the WHO classification of Impairments, Disabilities and Handicaps,[20] a stroke will cause a specific neurological loss called an impairment with a resultant functional loss called a disability. In the

rehabilitation of stroke patients, a functional loss (disability) is more important than neurological signs (impairment).

SEPs have been used previously in the assessment of stroke patients and their functional outcome however there was little distinction made between impairment and disability.

Liberson in 1966[11] studied 15 aphasic patients. He concluded that severe dyphasia correlated with "suppression" of the SEP in eight out of 10 patients. Two had SEP "suppression" without severe dysphasia and one severe dysphasia without SEP "suppression". However, functional outcome was not considered.

Kusoffosky *et al*[2] studied 16 hemiplegic patients and concluded that there was a good correlation between early SEPs and the subsequent development of motor activity especially in the upper limb. The small numbers made it difficult to draw statistical conclusions.

La Joie[19] indicated a use in prognosis for mobility by using SEPs to determine proprioceptive loss in aphasic patients. Other studies[21 22] proposed that SEPs could

be correlated with anosognosia using bilateral stimulation but no assessment of functional outcome was made.

Our study shows that there is a good correlation between SEP and functional outcome measured by length of stay and Barthel Index. The average length of stay was 29·56 days in those with normal SEPs, compared to 70·3 in those with abnormal SEPs. The Barthel Index was 95·93 in those with normal SEPs and 76·84 in those with abnormal SEPs. All of these results were significant at the 0·05 level.

Mortality figures obviously do not give a reflection of functional outcome but merely the disease state. Both length of stay and return home, have long been used as crude indirect measures of functional outcome. However, they both may be influenced by factors other than functional outcome such as family situations, other illnesses, availiblity of community resources and criteria for discharge. For populations within a certain community, these will tend to be evenly distributed, so that other influences can be measured. Therefore, as the measurement of functional outcome depends on multiple factors, a statistically significant number of patients are required and no single factor will reliably predict functional outcome in an individual.

Placement at home or in a nursing home was found not to be sensitive enough as a measure of outcome in our group of patients on statistically significant level. It tends to reflect extremely poor functional outcome whereas the majority of survivors of stroke nowadays go home.

Length of stay, although a coarse measure of outcome is easily understood and has direct practical significance. In different hospitals, different outpatient and inpatient services and policies will cause different lengths of stay for patients with similar disabilities.

The Barthel Index may differ between institutions and scorers depending on a number of variables. It has been found that measurement of specific activities in a clinic setting may not accurately reflect the ability to perform that task outside the clinic. There has been a gradual acceptance that measures of functional outcome can only be correct for groups of patients who have wide variations in performance of measured activities. Anecdotal experience in this circumstance is apt to be misleading as outcome may depend on a large number of variables that are not measured or are difficult to measure, such as social support.

Allowing for the difficulties with outcome measures, the conclusion that lengths of stay and functional outcome as measured by the Barthel Index correlate with somatosensory evoked potentials results on a statistically significant level is valid. By providing a practical, early and objective prediction of outcome, they can be used to assess the effectiveness of different

treatments which minimise disability.

Preliminary findings suggest that the relationship of SEP abnormality to the outcome measures may be dependent on the site of the infarct; an absent SEP response in a corticol infarction having a much poorer outcome than a subcorticol lesion. However a larger study is required to confirm the relationship of the SEP, outcome and the site of the stroke. The size of the stroke itself will also have an effect on the outcome and perhaps the SEP reflects this, but more patients and a more detailed assessment of the CT would be required to draw any statistically significant conclusions. As all but one patient had his stroke in the distribution of the middle cerebral artery after patients with normal CT and brainstem strokes were excluded, no conclusions can be drawn about the value of SEP in those patients with lesions in say the posterior circulation or anterior cerebral artery territory.

It has been suggested that the SEP reflects conduction in various sensory pathways. In our study, 68% of patients with abnormal SEPs had sensory loss and 81% of patients with normal SEPs had abnormal sensation. A closer association between SEP and sensory pathways could not be determined in our study as those with sensory loss usually had all modalities affected to various degrees. Our study confirms other studies that have found a strong association between SEP and sensory examination.

Giblin[2] found that out of 42 stroke patients, SEPs correlated with clinical abnormalities in only 34 patients. Larson[10] looked at six patients sequentially and found that clinical improvement correlated with improvement in SEP in four, but in two patients they improved clinically but not in SEP. In 1970, Williamson *et al*[22] looked at 42 stroke patients. They excluded severe dysphasics and in addition excluded three as technically unsatisfactory results because of lack of cooperation. They found that the SEP correlated best with sensory impairment. Despland and Regli[15] in 1985 investigated 70 patients with clearly defined cortical or subcortical vascular lesions confined to the post central gyrus. They used SEPs within one week of the CVA, and compared the site of the lesion with the clincal examination and SEP result. They found that a normal N20 component correlated with mild to moderate tactile or vibration deficit. The abolition of N20 always correlated with severe lemniscal dysfunction and astereognosis. Follow up after many months in 17 patients showed that the SEP may change. Functional outcome was again not looked at.

Since Van Buskirk and Webster in 1955[23] described the prognostic value of sensory impairment in the functional outcome of hemiplegic stroke, many others have confirmed this, but is is rarely emphasised in clinical practice or in the literature. It may be there is an overemphasis on motor recovery or that the

measurement of sensory deficit is not as obvious and is more subjective and less quantifiable than the motor deficit.

Our study confirms that sensory impairment is a statistically significant measure of functional outcome. SEPs can offer the advantages of subjectivity and quantification over standard sensory examination, and appear as accurate as sensory examination in predicting functional outcome. There is some indication that specific SEP abnormalities may be a better indicator of ultimate prognosis but more detailed examination of the SEP and larger numbers would be necessary to do confirm this.

Combining SEP abnormality and sensory disturbance shows an even better correlation with poor outcome than either factor alone, but only when brainstem and CT negative strokes are included. (Length of stay was 83·44 days and Barthel Index 68·46 at a 0·003 level of significance). However, combined normal SEP and normal sensation did not correlate significantly (0·058) with a good outcome probably as a result of some patients with normal sensation having a poor outcome. This may be related to insufficient numbers.

In clinical practice, SEPs will continue to be used for diagnostic purposes, for example in brainstem strokes and pure sensory disturbances where other tests may be normal. Although SEPs will not replace the clinical examination they can provide a more objective measure of sensory pathways and are particularly useful in patients with dysphasia, inattention or a decreased level of consciousness. They also provide a statistically significant method of determining outcome as measured by length of stay and Barthel Index. It remains to be seen whether specific SEP abnormalities will be a better predictor of outcome than a good clinical examination and further studies are needed. Like other methods of determining outcome, they are more suitable for cohorts and groups of patients than individuals.

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