

A precision neurorehabilitation using SSEP for early detection of sensory deficit and restoration of the motor recovery in balance, gait and activities of daily living in acute stroke

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Abstract.

BACKGROUND: Impaired sensory in acute stroke patients results in dynamic balance, gait and activities of daily living (ADL) impairment.

OBJECTIVE: The aim of present study was to examine the correlation between somatosensory-evoked potential (SSEP) parameters and motor recovery in balance, gait and ADL performance in hemiparetic stroke survivors.

METHODS: One hundred and one participants with hemiparetic stroke (43 males, 58 females; mean age, 6538 ± 1222 years; post-stroke duration, 199 ± 0.74 month) participated in this study. The Electro Synergy system (Viasys Healthcare; San Diego, CA, USA) was applied to measure SSEP measurement. The 101 stroke survivors were divided into three groups consistent with their SSEP results: sensory normal group; sensory impaired group; sensory absent group. All the subject participated the inpatient rehabilitation intervention for 4 weeks. Analyses of variance (ANOVA) were used to verify the group difference among the three groups after the treatment.

RESULTS: ANOVA revealed the significant difference ($p < 0.01$). The Scheffe test demonstrated that the sensory normal group showed greater increase in Modified Barthel Index (MBI), Fugl-Myer Assessment (FMA), Trunk Impairment Scale (TIS), Berg Balance Scale (BBS) and Functional Ambulation Category (FAC) scores than the sensory impaired and absent group ($p < 0.05$).

CONCLUSIONS: Our research provides therapeutic evidence that correlation of somatosensory functions on motor recovery, balance, gait, and ADL in patients with hemiplegic stroke.

Keywords: Somatosensory-evoked potential, neurorehabilitation, balance, gait, ADL

1. Introduction

The integrity of the sensory function is an important biomarker for prediction of the motor recovery

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and associated balance, gait, and activities of daily living (ADL) after hemiparetic stroke. The extent of initial sensory impairment was closely correlated with motor and functional recovery [1]. Furthermore, proprioception deficit was the strongest determinant factor for balance, ambulation, and ADL in stroke patients. Neurophysiologically, the proprioceptive information includes kinaesthesia, joint movement and joint position sense to maintain the center of mass (COM) within the base of support (BOS) during standing and dynamic walking as well as during ADL. Such sensory inputs are transmitted via the medial lemniscus and the ipsilateral dorsal column tracts to the frontoparietal sensory-motor cortex [2], which in turn executes accurate motor commands for optimal balance and locomotor movement to occur during ADL.

Conventionally, clinical sensory tests include joint position, kinesthetic senses, and tactile senses. However, such sensory tests are not sensitive, but qualitative, and difficult to administer to the acute stroke patients with cognitive impairment. To overcome the shortcoming of the qualitative clinical sensory tests, the somatosensory evoked potential (SSEP) has recently gained a widespread acceptance as a powerful clinical decision-making test to determine the reliability of sensory related to proprioceptive function more precisely than the current clinical tests. SSEP allows detecting the electrophysiological reaction of the central nervous system (CNS) in response to stimulate an electrical sensory of posterior tibial nerve [3]. In fact, recent SSEP studies showed that SSEP provided accurate prognostic appraisal for motor recovery in dynamic standing balance, gait, ADL in acute stroke patients [4–6]. Nevertheless, it remains unknown that the degree or severity of the sensory impairment function is associated with clinical outcomes of functional motor recovery in sitting balance and postural control in acute stroke patients. Certainly, a precision rehabilitation medicine involves early detection of sensory deficit, which help clinicians to specifically target the sensori-motor integration to better improve sensory function during the acute phase of the neurorehabilitation process, thereby enhancing postural control in sitting and standing position as well as dynamic walking and ADL. Hence, the purpose of the current study was to determine the correlation between the degree of sensory impairment and functional motor recovery in balance (TIS, BBS), gait (FAC), and ADL (Barthel index) in acute stroke patients. The hypothesis was that the degree of sensory impairment affects the prognostic to functional outcome measures in acute stroke patients. In addition, there is a correlation between degree of sensory impairment and functional motor recovery.

2. Methods

2.1. Subjects

Eleven participants with hemiparetic stroke (mean age = 65.27 ± 12.36 ; 54 males) were recruited from a rehabilitation hospital. The inclusion criteria entailed a first-ever stroke (mean onset duration 1.69 ± 0.71 month) and a supratentorial lesion which was confirmed by diagnostic CT or MRI. The exclusion criteria included severe cognitive or visual hemianopsia, quadriplegia, infratentorial lesion, coma, stupor or previous surgical history. Out of 332 patients, 101 subjects who met the inclusion criteria underwent the baseline somatosensory evoked potential test and classified either into SNG, SIG, or SAG.

2.2. Somatosensory evoked potential test

Electrophysiological SSEP testing of the central nervous system (CNS) was measured with the Electro Synergy system (Viasys Healthcare; San Diego, CA, USA) to provide real-time information about changes in brain electrical activity in response to therapeutic interventions. Specifically, SSEP measures evoked

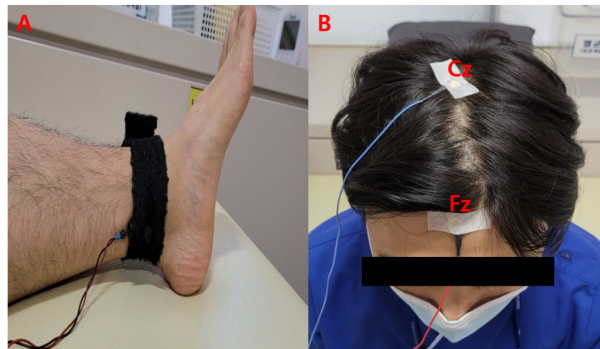


Fig. 1. A: Bar-electrodes, B: reference electrodes (Fz, Cz).

conduction of an electrical stimulus along the posterior tibial nerve, which is considered an important prediction biomarker to estimate the potential balance, gait, ADL, and lower extremity motor recovery. A bar-electrode was stimulated the posterior tibial nerve. The cathode was placed in the middle position between the achilles tendon and medial malleolus. The cathode was stimulated the posterior tibial nerve with a current of 30 mA [5].

The anode was attached 2 cm distally from the cathode. The signal was recorded by attaching the electrode guidelines into the Fz and attaching the electrode into the Cz as per the 10–20 system (Fig. 1) [7]. The bandpass filter was from 20 to 2000 Hz. The SSEP was measured sensory normal if P37 was more than 41.7 ms, it is normal conversely, if P37 is less than 41.7 ms, sensory impairment, the absence of signal was classified as sensory absent group [8]. According to the standard SSEP data, 33 stroke patients were allocated into the sensory normal group; 36 stroke individuals into the sensory impaired group; 32 stroke individuals were categorized into the sensory absent group.

2.3. Clinical tests

All participants underwent standardized clinical tests including MBI, FMA, TIS, BBS, and FAC before and after intervention.

2.3.1. MBI

MBI is a performance measure to examine an ability to perform ADL, functional mobility; gait in stroke patients. The MBI test is comprised of 10 items, with each item score ranging from 1 to 5 levels (1: Total dependence, 2: Severe dependence, 3: Moderate dependence, 4: Slight dependence, 5: Independence). The maximum score is 100 points [9]. The validity and reliability are reported to be good in stroke patients, $r = 0.849$ and $r = 0.88$, respectively [10].

2.3.2. FMA

The FMA is a quantitative measure of motor recovery after stroke, which includes the five domains measured as follows: motor function (upper extremity 66 point; lower extremity 34 point), sensory function (24 point), balance (14 point), joint range of motion (44 point), joint pain (44 point). However, in the present study, the lower motor function domain was tested only to determine the relationship between the lower extremity motor recovery function and SSEP in the posterior tibial nerve. Each domain is classified on a 3 point scale (0 = cannot perform; 1 = performs partially; 2 = performs fully). The lower extremity section is further subdivided into hip, knee, and ankle motor function tests and the total score is 34 points. The validity and reliability are reported to be good in stroke patients, $r = 0.96$ and $r = 0.88$, respectively [11].

2.3.3. TIS

TIS is a performance measure which includes the motor impairment of the trunk related with balance on sitting, and trunk movement coordination in hemiparetic stroke patients. The evaluation domain consists of sitting balance on static (3 items), sitting balance on dynamic (10 items), and coordination (4 items), and the total score is 23 points. This scale proved to be excellent reliability for stroke patients ($r = 0.99$) [12].

2.3.4. BBS

BBS is a performance evaluate which is designed to assess standing balance in stroke population [13]. This clinical outcome measure consists of a total of 14 items. Each item is to be given scores ranging from 0 point (cannot perform) to 4 points (normal performance) and the full score is 56 points this scale proved to be excellent reliability for stroke patients (ICC = 0.95) [14].

2.3.5. FAC

The FAC is categorized patients according to motor abilities necessary for functional ambulation. The FAC has six levels ranging from 0 (non-functional ambulation) to 5 (independent). FAC has excellent reliability in patients with hemiplegia after a stroke (Kappa = 0.90) [15].

2.3.6. Intervention

All participants underwent conventional neurodevelopmental rehabilitation intervention for 30 minutes per a day, 5 days a week over a 4 weeks period were recruited for the present study.

2.4. Data analysis

The parametric tests included paired t-tests to analyze intervention-related changes before and after the treatment in each group. Analyses of variance (ANOVA) were applied to verify the group difference among the three groups after the treatment. Post-hoc analyses (Scheffe test) were used if significant change was obtained. The Kolmogorov-Smirnov test was analyzed to test for normal distribution. Levene's test was performed to analyze the homogeneity of variances. The collected data were statistically analyzed using the SPSS Window 25.0 program (SPSS Inc., Chicago, IL, USA). Statistical significance level α was set to 0.05.

3. Results

Table 1 presents the clinical characteristics of the subjects. The Levene's test didn't show a significant difference in the baseline characteristics of the subjects, supporting the group homogeneity.

Table 2 shows the comparative clinical data across the three groups pre and post intervention. That all the three groups showed significant differences between before and after the study ($p < 0.01$). ANOVA were used to verify the group difference among the three groups after the treatment. ANOVA showed statistically significances in the MBI, FMA, TIS, BBS, and FAC posttest scores across the three groups ($p < 0.01$). The Scheffe test showed the MBI score of SNG were significantly different between SAG and SIG ($p < 0.05$). But SIG and SAG was not statistically significant difference. Also, BBS score of SNG were significantly different between SAG and SIG ($p < 0.05$). But SIG and SAG was not statistically significant difference. However, FMA, TIS, FAC, score was significantly different among the SNG and SIG and SAG. FMA, TIS, FAC score of SNG were significantly higher than SIG and SAG, and SIG was significantly higher than SAG score ($p < 0.05$).

Table 1
Clinical characteristics of the subjects

	Sensory normal group (n = 33)	Sensory impaired group (n = 36)	Sensory absent group (n = 32)	p
Sex				
Male	12	16	15	0.18
Female	21	20	17	
Lesion				
Cortex	22	26	22	0.60
Subcortex	11	10	10	
Stroke type				
Infraction	19	18	18	0.68
Hemorrhage	14	18	14	
Paretic side				
Right	23	21	20	0.13
Left	10	15	12	
Age	64.36 ± 12.74	68.63 ± 11.16	62.78 ± 12.38	0.78
MMSE	20.36 ± 6.72	21.83 ± 5.29	21.93 ± 5.60	0.49
Onset (month)	2.18 ± 0.72	1.86 ± 0.68	1.93 ± 0.8	0.52

Table 2
Comparison of clinical tests (n = 101)

	Sensory normal group (n = 33)	Sensory impaired group (n = 36)	Sensory absent group (n = 32)	ANOVA (F)
MBI (score)				
Before	47.30 ± 22.33	36.5 ± 19.73	30.25 ± 19.19	9.84**
After	61.96 ± 23.05 [†]	46.5 ± 20.8	37.84 ± 22.99	
Paired t-test	6.46**	5.25**	3.71**	
FMA (score)				
Before	21.78 ± 8.19	15.75 ± 7.85	11 ± 7.08	31.49**
After	27.36 ± 6.24 [†]	20.33 ± 5.96 [†]	14.31 ± 7.66 [†]	
Paired t-test	5.04**	6.59**	3.74**	
TIS (score)				
Before	13.51 ± 5.62	11.05 ± 6.26	8.75 ± 6.64	14.68**
After	19.66 ± 2.80 [†]	16.13 ± 5.4 [†]	12.28 ± 7.36 [†]	
Paired t-test	9.46**	7.89**	6.92**	
BBS (score)				
Before	23.57 ± 14.24	11.38 ± 11.02	10 ± 10.65	26.68**
After	42.03 ± 14.87 [†]	23.25 ± 13.9	16.87 ± 14.77	
Paired t-test	9.22**	7.38**	6.08**	
FAC (grade)				
Before	2 ± 1.17	1.19 ± 1.03	0.71 ± 0.95	29.57**
After	3.51 ± 1.27 [†]	2.25 ± 0.87 [†]	1.31 ± 1.3 [†]	
Paired t-test	10**	10.86**	5.46**	

Note. Mean ± standard deviation (SD), *p < 0.05, **p < 0.01, [†]significant difference compared with other both groups (p < 0.05).

4. Discussion

The current research indicated a correlation of the effects of baseline somatosensory functions in the individuals who had the acute stroke patients to their motor recovery and associated balance, gait and ADL after stroke rehabilitation. As anticipated, Clinical evaluation demonstrated that NSG in acute stroke patients exhibited grater improvements in motor function, sitting balance, standing balance, gait performance and ADL than those who had impaired somatosensory function. These results are consistent

with previous researches [16,17] that participants with normal somatosensory functions examined greater improvement of motor recovery function evaluated by BBS, FAC and MBI score compared to participants with impaired somatosensory function after stroke inpatient rehabilitation. Other study [18] were reported that improvement of lower limb motor function (FMA) when somatosensory evoked potential is normal. Dynamic standing balance, gait, ADL in patients with acute stroke has been due to various variables, including sensory impairment, muscle weakness, movement coordination and dexterity deficit. These problems were eventually caused by sensory dysfunction. In case, impaired sensory ability didn't transfer precise information to primary motor cortex. Inadequate input of sensory information leads to inefficient and uncontrolled movements. These results have affected for motor performance, standing balance, gait, and ADL. However, there was no study effect of sitting position on postural control according to the severity of lower extremity sensation in SSEP. In the present study, there was a significant difference in the postural control of sitting position among the groups according to degree of sensory impairment. The spine of the body consists of active and passive structures: the passive structures of the pelvis and thoracolumbar spine and the active parts of the trunk muscles [19]. Akuthota and Nadler [20] portrayed the core with the abdominals in the front, the paraspinals and gluteus in the behind, the diaphragm as the roof and the pelvic floor and hip girdle musculature as the bottom side. The hip girdle musculature plays an essential role within the kinetic chain, especially for all movement, in stability of the trunk and pelvis and in shifting force from the lower extremities to the pelvis and spine. Most stroke patients had a decreased sensory ability. Thus, altered somatosensory input spread from the included limb to the primary motor cortex by ascending pathways could be generated unacceptable motor output to the spinal cord by descending pathways in SIG and SAG [21]. Incorrect motor output of the lower extremity leads to changes in the CNS, resulting in decreased dynamic balance, postural regulation, and increasing postural sway [22]. Hence, meaningful sensory input provides valuable feedback to the dynamic balance control making it an important mechanism in supporting the function of the somatosensory system overall [23]. These results of study indicate that the level of posterior tibial nerve impairment can provide to motor function, balance, gait and ADL after stroke. Clinically, this study presents insights into improving functional ability in acute stroke survivors.

5. Conclusions

The current study suggested a correlation of baseline somatosensory functions in the individuals who had an acute stroke patient to their motor recovery and associated balance, gait and ADL after stroke rehabilitation. As anticipated, the normal sensory function group showed superior improvements in motor recovery, balance, gait and ADL than patients with impaired and absent somatosensory function group.

Conflict of interest

None to report.

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