Analysis of affected and non-affected sides of stroke hemiparalysis patients and correlations between rehabilitation therapy assessments using the bioelectrical impedance analysis method

CHANUK YOO1), SEONGKYO SUH2), YOUNGGYU KIM2)*

1) Department of Occupational Therapy, Hanlyo University, Republic of Korea
2) Department of Speech Therapy, Hanlyo University: 94-13 Hallyeodae-gil, Gwangyang-eup, Gwangyang-si, Jeollanam-do, Republic of Korea

Abstract. [Purpose] The purpose of this study was to demonstrate the use of bioelectrical impedance analysis as an appropriate rehabilitation therapy evaluation tool for stroke hemiplegic patients. [Subjects and Methods] A group of 20 stroke patients diagnosed with stroke hemiplegia who underwent stroke rehabilitation from October to November 2015 participated in this study. Using bioelectrical impedance analysis, stroke hemiparalysis patients were examined, and the affected and non-affected sides were compared. This correlation between impedance measurement values and rehabilitation therapy as an assessment tool was determined. [Results] According to the whole-body bioimpedance measurements, prediction markers, reactances, and phase angles, there were significant differences between the non-affected and affected sides, and bioimpedance had a positive correlation with hand grip power, manual dexterity of hand function, and ability to perform activities of daily living. [Conclusion] There were significant differences between the impedance values of the affected and non-affected sides of hemiplegic stroke patients. These results suggest that bioelectrical impedance analysis can be used as an assessment during the rehabilitation of stroke patients.

Key words: Bioelectrical impedance analysis, Affected side, Stroke

INTRODUCTION

A stroke is a neurologic disturbance caused by damage to the blood vessels that supply blood to the brain; it is one of the most common diseases in adults1). Many stroke patients have a number of serious disorders such as hemiplegia, motor disturbance, sensory disability, and cognitive impairment1). Dysfunction of upper and lower extremities impacts bodily function thereby degrading quality of life1). Due to these post-stroke disabilities, patients are subjected to long-term rehabilitation such as physical and occupational therapy4).

A bioelectrical impedance analysis (BIA), which is non-invasive, can easily measure the components of biological tissue and a biopsy specimen5–8). Whole-body BIA measurements have been increasingly applied within the medical field they have been utilized to diagnose diseases as well as assess the hydration status and nutritional condition of bodies9). Among impedance data, the indicators for determining bodily condition are prediction marker (PM), resistance (R), reactance (Xc), and phase angle (PA). The prediction marker (PM) is an indicator of body cell health, the resistance (R) is inversely related to fluid volume, the reactance (Xc) is a measure of cell membrane integrity and function, and the phase angle (PA) is a global indicator of health and nutritional status10,11).
In studies using BIA, Chumlea et al.\textsuperscript{12}) investigated the distribution of intracellular fluid (ICF) and extracellular fluid in cell tissues of the human body. Cho et al.\textsuperscript{13}) analyzed the limbs and thoracic impedance of patients with chronic heart failure and pulmonary edema by using a real-time body impedance measuring system.

However, examination of the physical characteristics of affected and non-affected sides of hemiplegic stroke patients undergoing rehabilitation therapy has yet to be done. Analysis of the affected and non-affected sides of stroke patients with hemiplegia may be applicable to the rehabilitation therapeutic assessment of stroke patients with hemiplegia, as well as the correlation between rehabilitation therapy assessments.

**SUBJECTS AND METHODS**

A group of 20 stroke patients who were diagnosed with stroke hemiplegia participated in this study. Impedance measurements and rehabilitation assessments were conducted in patients receiving rehabilitation therapy at Inje university Hospital in Korea from October to November 2015. The study objectives and methodology were explained to the patients, and their written consent was obtained. The study was approved by the ethics committee of the Inje University Institutional Review Board for Clinical Studies.

The bioelectrical impedance was performed using the MultiScan 5000 (Bodystat Ltd., Isle of Man, UK) in accordance with the recommendations in the The National Institutes of Health (NIH) Technology Assessment Statement. A specific Bodystat calibrator was used to confirm the reproducibility of the measurements\textsuperscript{14}). Experimental procedure was as follows: first, BIA was measured at 50 frequencies ranging from 5 to 1,000 kHz. When a current with a frequency larger than 50 kHz was applied to the body, the BIA was significantly decreased. The resistance and the reactance were also obtained in accordance with the applied frequency. Second, the relationship between reactance (Xc) and resistance (R) was determined, indicating a strong dependence of phase angle (PA) on the applied frequency.

For whole-body BIA measuring of the participants, the Tetrapolar BIA measurements of resistance (R) and reactance (Xc) were taken at 50 frequencies ranging from 5 to 1,000 kHz from the affected and non-affected sides of the subject, between the wrist and ankle, and while in the supine position on a nonconductive surface by using a multi-frequency bioelectrical impedance (Multi-Scan 5000, Bodystat Ltd., UK), which supplies an AC 600-A current. Four cutaneous electrodes, two on the wrist and two on the ankle, were applied with an inter-electrode distance of at least 5 cm to prevent interaction between electrodes.

Hand grip power was measured using a Jamar hydraulic hand dynamometer. During the maximum isometric contraction of hand power grip, all subjects were positioned with their shoulder adducted and neutrally rotated, their elbow flexed at 90°, and their forearm and wrist in the neutral position. The average value of three measurements was calculated, and expressed in pounds (lb)\textsuperscript{15}).

The manual function test (MFT), an upper limb function assessment measure for hemiparetic patients after stroke, developed by Sakai Rehabilitation Instruments, Japan, was used in this study. The time needed for evaluation in this test is short and it can be applied easily. This assessment of the affected body has a test-retest reliability of $r=0.994$ and an inter-rater reliability of $r=0.993$\textsuperscript{16}).

The ability to perform activities of daily living (ADL) was measured by using the modified Barthel Index (MBI). The MBI is a measure of ADL that shows the degree of independence of a patient. It covers 10 domains of functioning: bladder and bowel control, grooming, toilet use, feeding, transfers, walking, dressing, climbing stairs, and bathing\textsuperscript{17}).

The paired t-test was used for comparison of differences between the affected and non-affected sides in each test. The correlations of paretic side bio-impedance, hand grip power, manual dexterity of hand function, and the ability to perform activities of daily living were analyzed by using the Pearson correlation coefficient. The level of statistical significance was set as $\alpha=0.05$. The PASW Statistics for Window software (Version 18.0, SPSS Inc., Chicago, IL, USA) was used for statistical processing of data.

**RESULTS**

Four males and sixteen females with an average age of 75.9 years ($\pm$ 8.8 years), average height of 161.4 cm ($\pm$ 5.4 cm), and average weight of 53 kg ($\pm$ 8.1 kg) participated in this study. Ten patients had left-sided paralysis and ten patients had right-sided paralysis. Their average length of stay was 23.4 months (Table 1).

After conducting whole-body BIA measurements of participants, the prediction markers, reactances, and phase angles between non-affected and affected sides were found to be statistically significant ($p<0.05$). However, the resistance results showed no significant differences ($p>0.05$) (Table 2).

Bioimpedance had a positive correlation with hand grip power, manual dexterity of hand function, and ability to perform activities of daily living ($p<0.05$) (Table 3).

**DISCUSSION**

Patients with hemiplegia caused by a stroke show decreased limb sense and sensory movement due to weakening of the muscles; these problems cause difficulties in posture and tasks such as wearing clothes, eating and self-management\textsuperscript{18}). BIA
is reliable, non-invasive method, has high reproducibility, safe and easy-to-use.

In this study, prediction marker, resistance, reactance, phase angle of the affected and non-affected sides of hemiplegic stroke patients undergoing rehabilitation treatment were measured by using whole-body and segmental BIA. These results showed that prediction marker, reactance, and phase angle were significantly different when comparing the paralyzed and non-paralyzed sides of hemiplegic stroke patients. Our experimental results agree with Gupta et al.’s finding that lower phase angles increase the mortality of cancer patients. Prediction marker (PM): The prediction marker (or Impedance Ratio) is the ratio between the impedance measurement at 200 kHz and 5 kHz. The greater the variance between the two impedance values at 5 kHz and 200 kHz, the healthier the body cells. From our BIA measurements, the average prediction marker was 0.86 for the non-affected side and 0.88 for the affected side; the prediction marker of the affected side is larger than that of the non-affected side. Thus, healthy cells in the non-affected side have significantly lower PM than unhealthy cells in the affected side of hemiplegic stroke patients (p<0.05). Accordingly, BIA results showed that the non-affected side was significantly healthier than the affected side. Reactance: For whole body BIA measurement, the mean reactance was 43.5Ω for the non-affected side whereas it was 37.9Ω for the affected side (p<0.05). The low reactance can be regarded as deteriorated completion and function of cell membrane. Phase angle: The mean phase angle was 4.2° for the non-affected side whereas it was 3.7° for the affected side. Lower phase angles suggest cell death or decreased cell integrity; higher phase angles suggest large quantities of intact cell membranes. Phase angle has been found to be a prognostic marker in several clinical conditions (p<0.05). The resistances were not significantly different because the amount of an organism is inconsistent in each patient. It is difficult to evaluate the patient’s characteristics in terms of reactance relating to the total body water. Reactance relating to functionality and integrity of cell membrane is determined to represent significant differences.

For hemiplegic stroke patients, area-hand grip power, manual dexterity of hand function, and the ability to perform activities of daily living are used for evaluating rehabilitation in the clinical setting. For hand grip power, the paralyzed side measured 14.6 (lb) on average, and the non-paralyzed side measured 22.9 (lb), and thus the hand grip power between the paralyzed side and the non-paralyzed sides were significantly different (p<0.05). Accordingly, BIA results showed that the non-affected side was significantly healthier than the affected side. Reactance: For whole body BIA measurement, the mean reactance was 43.5Ω for the non-affected side whereas it was 37.9Ω for the affected side (p<0.05). The low reactance can be regarded as deteriorated completion and function of cell membrane. Phase angle: The mean phase angle was 4.2° for the non-affected side whereas it was 3.7° for the affected side. Lower phase angles suggest cell death or decreased cell integrity; higher phase angles suggest large quantities of intact cell membranes. Phase angle has been found to be a prognostic marker in several clinical conditions (p<0.05). The resistances were not significantly different because the amount of an organism is inconsistent in each patient. It is difficult to evaluate the patient’s characteristics in terms of reactance relating to the total body water. Reactance relating to functionality and integrity of cell membrane is determined to represent significant differences.

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In terms of a correlation between impedance, PA value, hand grip power, manual dexterity of hand function, and the ability to perform activities of daily living, a higher PA value correlated with an increase in hand grip power, manual dexterity of hand function, and the ability to perform activities of daily living; the correlation was positive. As the PA increases, hand grip power, manual dexterity of hand function, and the ability to perform activities of daily living also increase.

From our findings, the non-affected side was healthier than the affected side in hemiplegia stroke patients. Quantitative assessments are absolutely necessary in verifying treatment results in the rehabilitation. BIA research is essential for
quantitatively analyzing the status of rehabilitation of stroke patients with hemiplegia. Therefore, it is possible to use BIA as an objective assessment tool for rehabilitation of patients receiving rehabilitation therapy. Our data can be used in preparing evaluation programs for the physical aspects of rehabilitation therapy.

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