ISB2011 Brussels

CAN WE DETERMINE THE LEVEL OF SPINAL CORD INJURY IN A QUANTITATIVE MANNER?

[1]Yunus Ziya Arslan, [2]Deniz Palamar, [3]Safak Sahir Karamehmetoglu, and [4]Mukden Ugur
[1]Department of Mechanical Engineering, Faculty of Engineering, Istanbul University, Avcilar, Istanbul, Turkey; yzarslan@istanbul.edu.tr
[2] Physical Medicine and Rehabilitation Department, Kars State Hospital, Kars, Turkey
[3] Physical Medicine and Rehabilitation Department, Cerrahpasa Medical Faculty, Istanbul University, Cerrahpasa, Istanbul, Turkey
[4]Department of Electric-Electronics Engineering, Faculty of Engineering, Istanbul University, Avcilar, Istanbul, Turkey

SUMMARY
The clinical neurological examination depends heavily on the experience of the medical doctor and hence it is a relatively subjective method. Thus, a quantitative and objective assessment way of the level of spinal cord injury (SCI) is required. In this study, we investigated whether the electrical conductivity of skin tissue was affected by SCI. If so, a method which could be used for quantitative determination of the level of SCI would be developed. We measured skin impedance of controls and patients. We found that the level of injury was intuitively related to the distribution of magnitudes of the impedances along the spinal nerves. After analyzing the impedances by using the polynomial curve fitting method, strictly similar curve profiles were observed in paraplegics. Curves of the impedances of the paraplegics had an increasing inclination from the level of cervical nerves to the level of lumbar and sacral nerves. A certain curve profile could also be seen in tetraplegics, so that the impedance values changed slightly throughout all dermatomes. In the control group, a typical inclination was not observed. These meaningful characteristic curve profiles of the paraplegics and tetraplegics can be used to distinguish these two patients group and may lead us to determine the level of injury.

INTRODUCTION
The diagnosis and determination the level of spinal cord injury (SCI), and also monitoring the effect of rehabilitation process on spinal cord injured patients by clinical neurological examination depends heavily on the experience of the medical doctor which consequently leads to a highly non-objective way of assessment [1]. Furthermore, especially for non-cooperative and unconscious patients, this technique has more limitations since it requires patient’s feedback. Thus, it is clear that a quantitative and more objective way of assessment without requiring patient’s feedback is needed for clinical applications, such as diagnosing SCI, determining the level of injury, and quantitative monitoring of the effects of treatment and rehabilitation processes on patients following surgery, if any.

In recent years, some encouraging investigations have been carried out for the purpose of quantitative assessment by evaluating the thermal and electrical perception thresholds [2]. However, these perception threshold techniques require patient’s feedback, thereby precluding their applications for non-cooperative and unconscious patients.

In this study, we investigated whether the electrical conductivity of skin tissue was affected by SCI. If so, a method which could be used to determine the level of SCI in a quantitative manner would be developed.

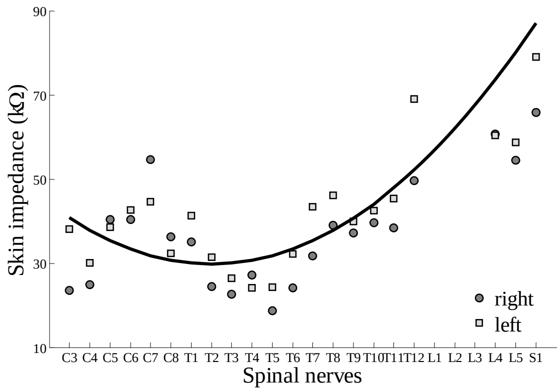
METHODS
Patients with traumatic SCI and control subjects aged between 18 and 55 years were included into the study. They were all evaluated by history and physical examination according to The International Standards for Neurological Classification of SCI, American Spinal Injury Association (ASIA), and International Spinal Cord Society (ISCoS) [1]. All procedures were approved by the Ethical Committee of Cerrahpasa Medical Faculty, Istanbul University.

Skin impedance of the left and right side key points according to sagittal plane was measured in 15 control subjects and in 15 patients with SCI (13 paraplegics and 2 tetraplegics), between C3 and S1 bilaterally [3]. The impedances were measured in all dermatomes except C2 (because of hair), L1-3 and S2-5 (because of the refusal of the control subjects). According to the aforementioned booklet of ASIA and ISCoS, 10 pairs of key muscles and 28 pairs of key points were evaluated and the neurological level, completeness and the classification of SCI were determined. For the patients, inclusion criteria were determined as traumatic SCI and both gender; however the exclusion criteria were determined for patients with any other neurological disorder than SCI and also non-traumatic SCI.

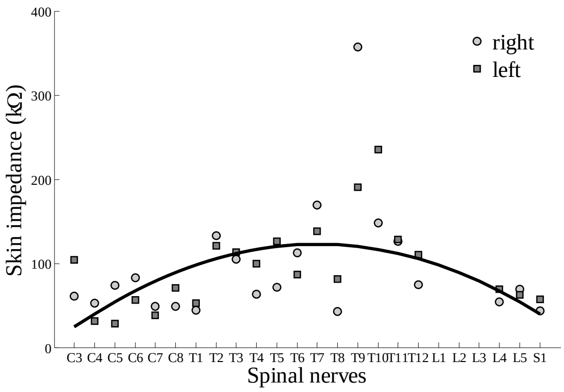
Two self adhesive electrodes were placed on both side of the key points and an AC signal (2V, 200Hz) was applied by means of a signal generator. A portable multi-meter was situated between one of the electrodes and signal generator, and the current level was recorded. The other output of the signal generator was connected to the electrode which was not fixed to the multi-meter. The type of the electrodes was electrocardiography (ECG) electrodes. The distance between the centers of the electrodes was 3 cm.

RESULTS AND DISCUSSION

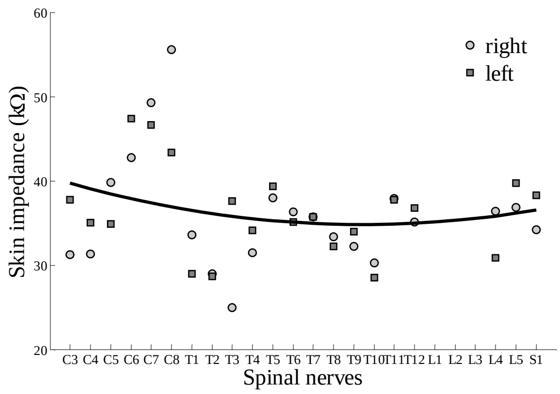
By analyzing the impedance values in qualitative manner, a certain correlation between corresponding right and left dermatomes and repeated assessments were not found. In addition, at first sight, distributions of the magnitudes of the impedances measured from C3 to S1 were irrelevant in patient and control groups. However, after analyzing the distribution of magnitudes of the skin impedances by using a second order polynomial curve fitting method, strictly similar curve profiles were observed in paraplegics. It could be seen from Figure 1a that the curves of the impedances of the paraplegic patients had an increasing inclination beginning from the level of cervical nerves to the level of lumbar and sacral nerves. In addition to paraplegics, a certain curve profile could be seen in tetraplegics, namely the impedance values changed slightly throughout all dermatomes (Figure 1b). In the control group, a typical inclination that could be classified was not observed (Figure 1c). The impedance values of the both sides of the representative subjects' bodies could also be seen in Figure 1.



(a)



(b)



(c)

Figure 1: Distribution of the magnitudes of skin impedances along the spinal nerves and second order polynomial fitted curves for representative (a) paraplegic (b) tetraplegic, and (c) control subjects. Circular and square markers represent the impedances of the right and left side dermatomes, respectively.

Due to the inconvenient and difficult situations in measuring the skin impedances of tetraplegics, number of tetraplegics included in the study was insufficient, thereby precluding the assessment of this group adequately. To increase the number of tetraplegics would be considered in future studies. Another future aim would be to include acute patients in the subject group and to validate the proposed test in such patients. Since, in Turkey, there is not an organization such as National Spinal Cord Injured Database which captures data from new SCI cases in the U.S., we have not been able to measure skin impedances from acute patients, and hence we could not evaluate the validity of the proposed technique in acute patients. If the skin impedance technique can be confirmed for acute patients, in case of emergency such as following an accident, a spinal cord injury would be detected if any and a special care would be taken in transferring the injured people to the hospital.

CONCLUSIONS

Since the present clinical techniques to determine the level of SCI and monitor the effect of rehabilitation and treatment processes on patients are mostly subjective, a quantitative and objective assessment test would be a very important improvement for clinical applications. The suggested quantitative method in which the skin impedances were analyzed is non-invasive and non-expensive. Moreover, this technique does not require patient's feedback which ensures to be applicable as a more objective method, especially for unconscious and non-cooperative SCI patients.

REFERENCES

1. Maynard FM Jr, et al., *Spinal Cord.* **35**:266-274, 1997.
2. Savic G, et al., *J Rehabil Res Dev*. **44**:77-82, 2007.
3. Karamehmetoglu SS, et al., *Eur Spine J.* **18**:972-77, 2009.