

REDUCTION OF SKIN IMPEDANCE BY THE IMPROVEMENT OF THE BLOOD CIRCULATION

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Abstract-When biopotentials are recorded from the surface of the skin, the skin impedance will usually influence the measurement. We minimized the skin impedance by improving the blood circulation. The skin impedance may be reduced maximally by more than 50% after soaking in the warm water for 5 minutes. This method can be applied in all the measurement used surface electrodes so as to get highly resolution, especially getting better results for the patients with bad blood circulation.

Keywords - Skin impedance, blood circulation, electrode, double layer

I. INTRODUCTION

Surface electrodes are widely used in the measurement of bioelectric events, such as EKG, EEG or EMG. In the measurement of using the surface electrodes, there are two components – the electrode impedance and skin impedance, which will influence biopotential recording. There have been many studies and designs focused on the electrode impedance to see how the electric properties of the interface between the electrode and the electrolyte influence the measurement. In order to diminish the artifact resulting from the polarizable electrode, silver-silver chloride electrodes is the most popular type, and the proper thickness of the AgCl layer has been studied [1]. In regard to the skin impedance two practical methods are used to reduce the effect of epidermis: abrading the stratum corneum with fine sandpaper or rubbing with a pad soaked in acetone.

In this study we can minimize the skin impedance by improving the blood circulation of the skin in place on which the surface electrodes are attached.

II. METHODOLOGY

Two stainless boxes with $25 \times 20 \times 10 \text{ cm}^3$ were filled with 0.9% saline. Two hands of the subject were immersed into the solution in the boxes separately. One box was connected to the positive output of a constant voltage power supply via an analog switch, which could be switched in 10^{-6} sec, and the other box was connected to the negative output. We applied a constant voltage (in switch ON) across the two boxes at ≥ 0 . The resistance of the switch is less than 10 ohm (at ON state). All the arrangement formed a close loop circuit as shown in Fig. 1. The hand electrode impedance comes from the interface between the electrode and the electrolyte. The skin impedance of hand results from the interface between the solution and the skin. The current passing through the “circuit” was analyzed on a personal computer through A/D converter with sampling rate 20kHz. The hands immersed in the solution in the metal boxes

are similar to the metal-plate electrodes with gel attached to the surface of the skin. The applied step potential was 0.8 volt.

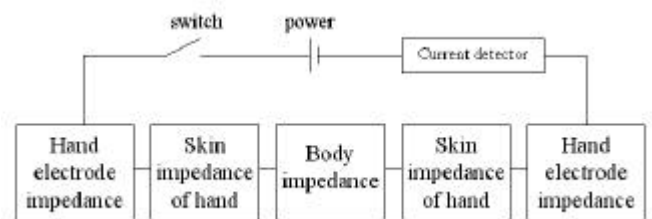


Fig. 1. Block diagram of the system in this study. The lower five blocks contribute to the measured impedance.

We took three measurements as the control data. After the measurement the participants soaked their hands in the cleanly warm water of 40 degrees centigrade for 5 minutes. The immersed area was the same as that immersed in the solution in the boxes. After soaking, the participants dried their hands and we took three measurements again. Eight volunteers from age 20 to 45 participated in the testing.

III. RESULTS

Fig. 2 shows the electric current responses while applying the step potential on Subject 1 before and after soaking. The transient current was highly enhanced after soaking, especially for the dc current (about after 15 msec). It revealed that the impedance was decreased for the low frequency. Fig. 3 shows the DC resistance of eight subjects before and after soaking respectively. The DC resistance was calculated from the DC current response measured at 100msec, and was defined according to (1).

$$\text{DC resistance} = \text{applied voltage} / \text{DC current} \quad (1)$$

The DC resistance was clearly decreased after soaking except for the Subject 6. All the data showed is the average of the three measurements for canceling white noise.

IV. DISCUSSION

From the study of electrode kinetics [2][5], the electrode-electrolyte interface equivalent circuit is a series half-cell potential and a series resistance combined with a parallel RC circuit. Because the metal boxes are larger enough, the capacitance in the equivalent circuit is short in our measuring period. If we control the concentration and temperature of the electrolyte, the hand-electrode-impedance part in the Fig. 1. will not influence our measurement before

Report Documentation Page

Report Date 25OCT2001	Report Type N/A	Dates Covered (from... to) -
Title and Subtitle Reduction of Skin Impedance by the Improvement of the Blood Circulation	Contract Number	
	Grant Number	
	Program Element Number	
Author(s)	Project Number	
	Task Number	
	Work Unit Number	
Performing Organization Name(s) and Address(es) Department of physics, National Taiwan University, Taipei, Taiwan, R.O.C	Performing Organization Report Number	
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	Sponsor/Monitor's Acronym(s)	
	Sponsor/Monitor's Report Number(s)	
Distribution/Availability Statement Approved for public release, distribution unlimited		
Supplementary Notes Papers from the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.		
Abstract		
Subject Terms		
Report Classification unclassified	Classification of this page unclassified	
Classification of Abstract unclassified	Limitation of Abstract UU	
Number of Pages 2		

and after soaking. All the parts, which will affect the measurements, are the two skin-impedance parts and body-impedance part.

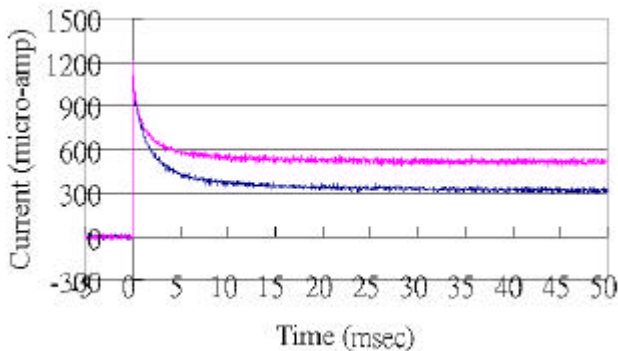


Fig. 2. The transient electric current response for the subject 1 before and after soaking. The current was clearly enhanced due to the decrease of the impedance. The larger response was the result after soaking while the other was the result before.

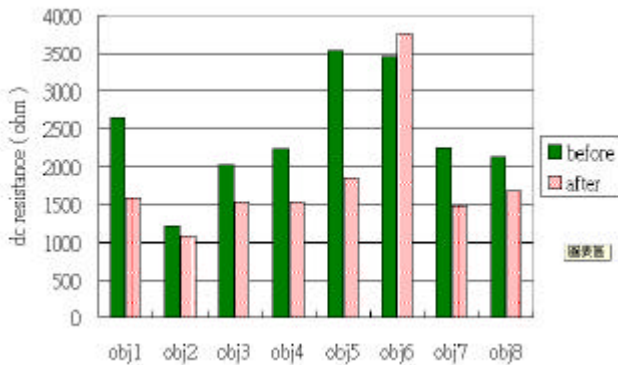


Fig. 3. The DC impedance before and after soaking. Solid column represent the impedance before soaking, and broken column represent the impedance after soaking.

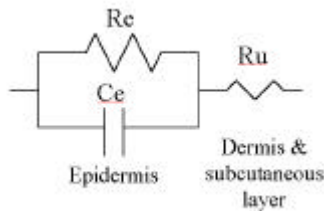


Fig. 4. The skin impedance equivalent circuit.

After the soaking in the warm water, the skin impedance of hand will change more than other parts of the system, and results in the different current response.

Because the blood circulation in the dermis will be increased after soaking in the warm water, the dermis will be nourished and therefore the skin impedance is decreased. Beside, after the long soak, the epidermis will have better permeability for the fluid, and this will also eliminate the skin impedance.

In the studies of the skin impedance [3][4], the skin impedance equivalent circuit, shown in Fig. 4, is a series resistance, R_u , which represents the dermis and subcutaneous layer, combined with a parallel RC circuit, R_e and C_e , which represents the epidermis. The peak current in Fig. 2 is determined by the body impedance and R_u , while

the steady-state current (after 15 msec) is determined by the body impedance, R_u and R_e . The impedance calculated from Eq. (1) is just the sum of the R_u , body impedance and the R_e in the equivalent circuit above. Our results in Fig. 3 show that the R_e could be reduced to less than 50% while the R_u and the body impedance did not change for Subject 5. On the other words, the elevation of the dc current should be due to the reduction of the leakage resistance R_e while the peak current almost does not change after soaking. The change of the parallel RC circuit after soaking should be due to the improvement of the blood circulation and the induced perspiration [3]. The sweat glands and ducts could be induced after soaking and change the equivalent circuit.

V. CONCLUSION

The skin impedance of hand was clearly reduced for most of the subjects. We can apply the warm-soaking method in all the measurement used surface electrodes so as to reduce the impedance and get highly resolution, especially for the subjects with bad blood circulation [6].

REFERENCES

- [1] L. A. Geddes, "Electrodes and the Measurement of Bioelectric events", John Wiley & Sons, Inc., Ch1, 1972
- [2] Albery, Electrode Kinetics, 1st ed., Clarendon Press, Oxford, 1975 Ch 1.
- [3] J. G. Webster, "Medical Instrumentation – Application and Design", third ed. John Wiley & Sons, Inc., Ch5, 1998
- [4] J. Rosell, J. Colominas, P. Riu, R. Pallas-Areny, and J. G. Webster, "Skin impedance from 1Hz to 1MHz", IEEE Trans. Biomed. Eng., 1988, 35, 649-651.
- [5] J.G. Bau, H. Hsiu, Y. Chiang, YY.L.Wang, W.K. Wang, "Different Response from Different Electrodes – An Application in Composition Analyzing of Solution", Proceedings of the 20th Annual International Conference of IEEE EMBS, Vol.20, No 3, 1998
- [6] W. K. Wang, G. C. Wang, H. Hsiu, J. G. Bau, M. Y. Jan, "The Relationship between the Bio-impedance of the Body and the Blood Circulation", Proceeding of the EMBEC '99, J.G. Bau, H. Hsiu, Y. Chiang, YY.L.Wang, W.K. Wang, Part I p.110-111, 1999.