감성과학, vol. 11, No. 3 pp.419-426. september 2008

섬유전극을 기반으로 한 라이프스타일 모니터링용 ECG-센싱의류의 프로토타입 연구*

A Study on a Prototype of ECG-Sensing ClothingBased on Textile Electrode for Lifestyle Monitoring

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Abstract: In order to develop "textile electrode - sensing clothing" which is a sort of smart clothing to measure electric activities of heart, we propose possible ways to develop textile electrode and design of sensing clothing, ultimately aiming to develop "ECG sensing clothing for lifestyle monitoring". Conventional sensors for measuring typical electric activities of heart keep certain distance between measuring electrodes to measure signals for electric activities of heart, but these sensors often cause inappropriate factors (e.g. motional artifacts, inconvenience of use, etc) for monitoring natural cardiac activities in our daily life. In addition, most of textile electrodes have made it difficult to collect data due to high impedance and unstable contact between skin and electrodes. To overcome these questions, we minimized distance between electrodes and skin to maximize convenience of use. And in order to complement contact between skin electrodes, we modified textile electrode's form and developed ways to design clothing. As a result, we could find

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* 본 연구는 지식경제부 전략기술개발사업의 일환으로 수행되었음.

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out clinical significance by investigating possible associations of clinical electrocardiogram (ECG) with variation of distance between electrodes, and could also demonstrate clinically significant associations between textile electrode developed herein and clothing.

Keywords: Textile electrode, ECG monitoring, sensing clothing design, distance between electrodes

1. Introduction

With the beginning of latest ubiquitous era we face now, everyone has a wish to check their health online anytime and anywhere. So there are more public interests focused on preventing diseases, rather than treating diseases. While living daily life, people want to rely on healthcare services at the same time. It is expected that health will be very crucial issue of interests from people in future society and technological breakthrough will contribute to more interests in health and more expectations for various technical supports than before. These health concerns and technological expectations will possibly come true with a combination of various technologies beyond certain limited sphere.

Owing to fusion of up-to-date textile and IT technologies, there have been recently positive activities for developing smart clothing based on body health monitoring technology. Over last 5 years, there have been many projects conducted to develop various types of vital monitoring smart clothing. In particular, cardiac and ECG sensing clothing have been developed on a full scale.

Currently developed electrodes have good adhesive strength and have no problem with impedance characteristics and noise. But they have been considered inappropriate for long-term using worn on human body, because they may cause skin rash with long-term adhesion on skin and also require cumbersome replacements for each measurement. Long-term collection of vital sign data requires development of electrodes that can work for long hours. Moreover, typical electrodes measuring cardiac electric activities adopt keeping certain distance between electrodes to catch cardiac electric activity signals, but involve many inappropriate factors (e.g. motional artifacts, inconvenience of use, etc) for monitoring natural cardiac activities in our daily life. To overcome these setbacks, we adopted minimization of distance between electrodes to maximize their convenience of use.

This study came to development of textile electrodes by complementing limitations of conventional electrodes, and also sought to minimize distance between electrodes in favor of reducing motional artifacts. With textile electrodes attached to clothing, they show inherent characteristics of dry electrode, such as unstable contact with skin and high noise level caused by body motions.

To improve these disadvantages, we developed a new textile electrode in modified form to improve skin contact, and also developed a clothing design method to minimize possible effects of muscular variations following body motion upon the position of electrodes.

2. Methods

2.1 Development of Textile Electrode

In this study, a sort of silver-coated yarn was used to develop textile electrode. The silver-coated yarn was made in filament form on nylon base in accordance with specification of 40denier/10filament(40de/10f). Denier is a unit that indicates thickness of thread or fiber. Filamentary silver-coated yarn may be accidentally cracked and cannot be used for embroidery machine. To improve these disadvantages, silver-coated yarn was further treated with covering process. Silver-coated yarn treated with covering process had specification of 100de/21f. First, 700TM of 40de/10f silver filament yarn was intertwined with 20de/1f polyester core yarn, in parallel with 600TM of silver filament yarn intertwined with polyester core yarn in its S(right) and Z(left) winding direction respectively for covering process. Here, TM refers to the number of intertwined yarns within the length of 1 meter.

In order to minimize potential resistance resulting from transformation, mechanical embroidery should be made circlewise so that a series of silver filament yarns can be regularly arranged after processing with non-elastic core, polyester 100% (See Fig. 1). With minimized distance among three electrodes in a square area of 4*4cm, the embroidery should be made in a circle with diameter of 1.7cm on each apex of equilateral triangle (area = 2 cm2)(SeeFig.2).

One layer should be embroidered in a circle with diameter of 1.7cm, and another layer should be embroidered in a doughnut-like circle with diameter of 1.7cm, while a round clearance of 0.2cm should be left in the center of the latter layer so that it can be connected with snap button to be in contact with transmitter (See Fig. 3).

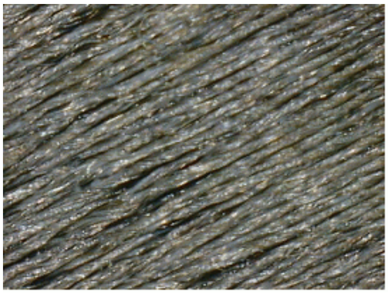

Figure 1. Surface of mechanical embroidery with processed silver thread

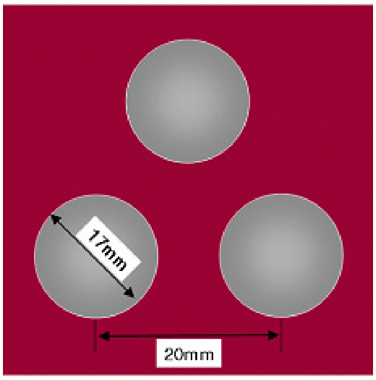

Figure 2. Distance among three textile electrodes embroidered within area of 4x4cm

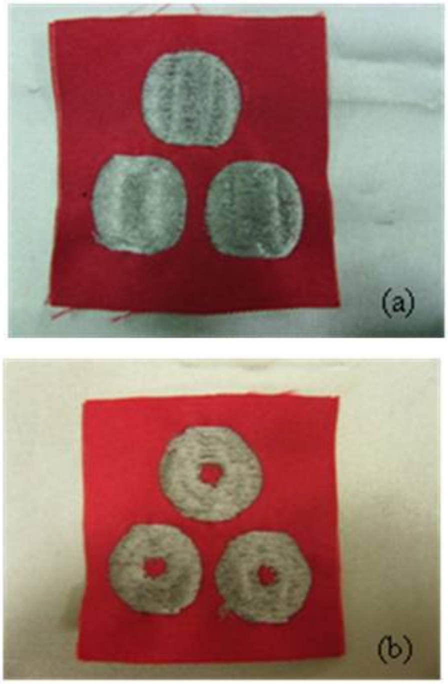

Figure 3. Original photograph of mechanical embroidery (a) Embroidery on surface in contact with skin, (b) Doughnut–like embroidery to be connected to snap button

For the embroidery, non–woven fabric with thickness of 0.1cm should be embroidered along with cloth. For embroidery works with embroidery machine, it is required to line cloth with stiff nonwoven, so that embroidery can be finished smoothly without any seam. We adopted thickest one of all nonwoven types available to create a feeling of solidity. Next, silicon insertion (diameter = 0.6cm, thickness = 0.3cm) and part 'a' (in Fig. 4) of snap button should be inserted between these two layers, so that part a can be protruded through the center of doughnut–like circle and can be connected with part 'b' (in Fig. 4) of snap button on the outer surface of layer. Here, conductive adhesive should be applied to inner hole side of doughnut–like circle for pinching snap button. The round girth of two layers should be connected with each other using zigzag stitching, so that they can touch silver filament yarns except silicon insertion (See Fig. 4 and 5).

Then, textile electrode creates a sense of solidity (0.7cm) and touches skin surface effectively for minimized contact resistance.

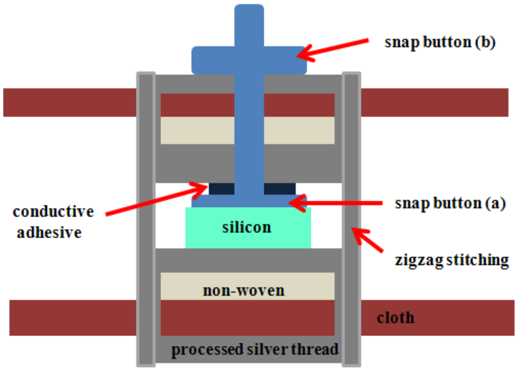

Figure 4. Figural cross-section of finished electrode

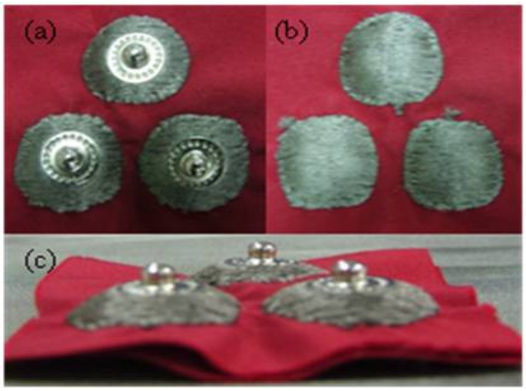

Figure 5. Original photograph of finished electrode. (a) Surface having snap button to be attached with transmitter, (b) surface to touch skin, (c) inflated surface of electrode

2.2 Remodularization of Clothing to Minimize Potential Movement of Electrodes

In order to minimize potential changing positions of electrodes, it is favorable to use sleeveless T-shirt to reduce effects of electrode movement. Neck circumference and armhole should not be extra exposed so that they can be stably adhered to trunk as closely as possible. Zipper should be attached to the rear center for wearing. Based on measurement results of elongation for skin, it was estimated that 4-way stretchy materials with 20% elongation would be appropriate for making. Base should be made of nylon 80%/polyurethane 20%, and band line should be made of nylon 92%/polyurethane 8% to reduce motional effects on band line as the position of electrode. Zigzag stitching was adopted to sewing so that base and band line can be stably connected with each other to overcome difference in elongation between them. As shown in Fig. 6 and 7, a cross-shaped band line was arranged, avoiding muscles on shoulder and back region. Here, the intersection of band lines should be positioned at 18cm down to the center of front neck and at 4cm leftward from the center front. When making up ECG sensing clothing, this position becomes that of electrodes where crosswise part of cross-shaped band lines passes 3rd and 4th sternum and trunk tightly adhered on clothing turns tipped a little leftward to facilitate ECG measurement. The size of electrode positioned at intersection of cross-shaped band lines falls within the area of 4*4cm, so the length of band lines should be not more than 4cm.

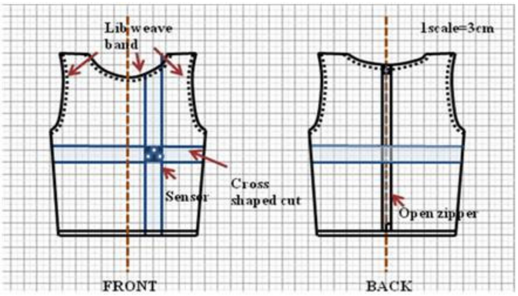

Figure 6. Design drawing on cross-shaped ECG sensing clothing

Figure 7. Original photograph of ECG sensing clothing

3. Experimentation

Textile electrodes were applied to aforementioned clothing as developed for experimental purpose herein.

For application, inflated section of electrode was placed to touch the surface of skin, and the surface of snap button was designed to go outside 3-point holes from electrode position of clothing. Next, NORDIC nRF24L01 wireless transmitter was attached to surface of snap button where it amplified signal before transmission to computer (See Fig. 8). ECG level was measured in two modes, i.e. static and dynamic mode for data comparison to examine if textile electrodes devised herein could meet the requirements and purpose of ECG monitoring in our daily life. Static ECG level was measured on standstill sitting condition, while dynamic ECG level was measured on active walking condition (See Fig. 9). Each of ECG experiment was conducted for 3 minutes up to 4 periods under respective conditions. And 10-minute recess was applied to intermission between 4 experiment periods. ECG signals ranging from 0.5Hz to 50Hz were filtered in band pass mode before data analysis.

Figure 8. View on transmitter attached to clothing with electrodes

Figure 9. View on ECG measurement. (a) Upon standstill sitting, (b) upon active walking

4. Results

In this study, we measured ECG level using inflated textile electrodes with cross-shaped clothing design. As a result, it was found that stable measurements were obtained under standstill sitting condition over all 4 periods of experiment, and ECG waves detected with the electrodes were in similar forms as clinical ECG waves (See Fig. 10).

In addition, it was found that there were relatively stable ECG waves detected from all 4 periods of experiment under active walking condition. Thus, these findings imply that clothing design with minimized motion artifacts and inflated electrode structure with minimized contact resistance contribute to very effective ECG measurement (See Fig. 11).

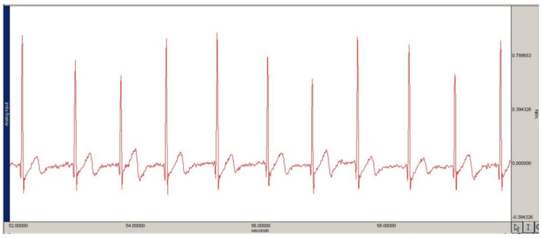

Figure 10. Results of ECG measurement upon standstill sitting

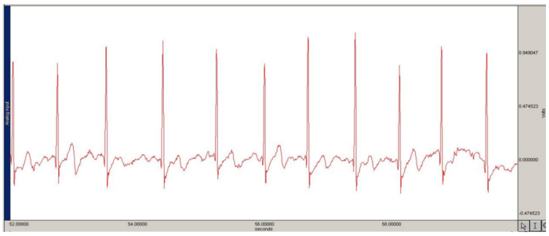

Figure 11. Results of ECG measurement upon active walking

5. Discussions

Both of contact resistance and motional noise were minimized owing to the combination of inflated textile electrodes and cross-shaped cut clothing design, developed in this study. And it was found that ECG waves under standstill sitting condition were detected in similar forms as clinical ECG waves, and ECG waves could be also measured under active walking condition. Thus, it was demonstrated that ECG levels can be possibly monitored in daily life, which we sought to find out in this study. The inflated textile electrode belongs to dry electrode and is also available without any inconvenience in our daily life, as compared to current clinical electrodes. Moreover, we reduced motion artifacts successfully by closing distance between electrodes and also maximized convenience of use. And it was found that the development of clothing design insusceptible to potential muscular motions contributed to very effectively fixing electrode positions.

6. Conclusion

In this study, it was found that ECG measuring experiments with inflated textile electrodes applied to cross-shaped patterned clothing allowed us to measure ECG levels under both static and dynamic condition. In follow-up studies, it is expected that dry textile electrode will be possibly developed to obtain higher accuracy of ECG wave measurement using solid textile electrode. Furthermore, it will be necessary to investigate in muscular motions or equivalent variables for clothing design and thereby develop clothing design to fix absolute position of electrodes.

References

[1] Aarts, E., Marzano, S. (2003), The New Everyday ; Views on Ambient Intelligence,Philips,Rotterdam,Netherlands.

[2] F. Axisa, P. M. Schmitt, C. Gehin, G. Delhomme, E. McAdams, and A. Dittmar, (2005), Flexible technologies and smart clothing for citizen medicine, home healthcare, and disease prevention, IEEE Trans Inf Technol Biomed, vol. 9, pp. 325-336.

[3] J. M. Auger and A. Lymberis, (2004), Current and future R&D activities of the EC-IST programme in eHealth, Stud Health Technol Inform, vol. 108, pp. 81-87.

[4] Lim, Y. (2007), ECG Recording on a Bed During Sleep Without Direct Skin-Contact, IEEE.

[5] Nakamura, H. (2007), A Comparative Evaluation Between Conditions of the Wrist Band Capatively-Coupled ECG Recording through Signal-to-Noise Ratio, IEEE EMBS.

[6] Rita P., Giannicola L., Nicola T. (2005), A Wearable Health Care System Based on Knitted Integrated Sensors, IEEE, vol. 9, No.3.

[7] Tao, X. (2005), Wearable electronics and photonics, Woodhead Publishing Limited, Abington,UK.

원고접수 : 08/07/28
수정접수 : 08/09/16
게재확정 : 08/09/19