Unrestrained Diastolic Blood Pressure Estimation Method Using Heartbeat during Sleep

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***Abstract*—Monitoring blood pressure during sleep is essential to detect nocturnal hypertension. However, measuring the blood pressure using a cuff during sleep without awaking the sleeping person by the squeezing of the cuff is difficult. Therefore, we propose an unrestrained diastolic blood pressure estimation method that uses heartbeat during sleep. We defined 12 features on the basis of measured heartbeat signals and applied the 12 features in a multiple regression analysis. Then, we estimated blood pressure during sleep. To validate our proposed method, we conducted a validity experiment. As a result, the mean error was −0.38 mmHg; standard deviation, 6.50 mmHg; and correlation coefficient, 0.70.**

I. Introduction

As hypertension is a serious mortality factor in the elderly, early detection of high-blood pressure is essential. However, masked hypertension that causes high blood pressure only under limited conditions is difficult to detect. Especially in the case of nocturnal hypertension, although blood pressure monitoring during sleep is necessary, measuring blood pressure without awaking the elderly patient by squeezing the upper arm with the cuff is difficult. Hence, in this study, we propose an unrestrained diastolic blood pressure estimation method that uses heartbeat signal.

II. Proposed Method

In the proposed method, we measured heartbeat signal by using the pneumatic method [1], which could unconstrainedly detect heartbeat and respiration signal during sleep. By using the heartbeat signal, we calculated the following 12 features from $x1$ to $x12$: Features $x1$–$x6$ are defined on the basis of the seven waves (H, I, J, K, L, M, and N) obtained from the heartbeat signal. Each feature from $x1$ to $x6$ was calculated as amplitude ratio between H and J ($x1$), I and J ($x2$), K and J ($x3$), L and J ($x4$), M and J ($x5$), and N and J ($x6$). Features $x7$ and $x8$ were defined as heart rate and variance of heart beating. Features $x9$–$x12$ were defined on the basis of the five waves (a, b, c, d, and e) obtained from the second-order differentiated waveform for the heartbeat signal. Each feature from $x9$ to $x12$ was calculated as the amplitude ratio between b and a ($x9$), c and a ($x10$), d and a ($x11$), and e and a ($x12$). By applying the 12 features in the multiple regression analysis, we estimated blood pressure during sleep.

III. Validity Experiment

To validate our proposed method, we performed a validity experiment with six healthy men in their twenties. We asked the subject to sleep on an ordinary bed equipped with a pneumatic device to measure heartbeat signal for the whole night. We estimated the blood pressure per minute. In addition, the subject attached the sphygmomanometer (HEM-7252G-HP: OMRON Corporation) on the upper arm to obtain the correct blood pressure as reference. As the correct blood pressure was measured every 10 minutes, we compared the estimated and correct blood pressures measured every 10 minutes.

IV. Results

Fig. 1 shows examples of estimated and correct blood pressures measured for one night. The blue and red lines represent the estimated and correct blood pressures, respectively. The mean estimated blood pressure was 61.37 mmHg, and the reference blood pressure was 61.66 mmHg as shown in Fig. 1. The correlation coefficient was 0.49, and the mean error was 0.29 mmHg. In this result, the correlation coefficient was not so high. However, we can recognize from it the tendency of the transition of blood pressure throughout the night as shown in Fig. 1.

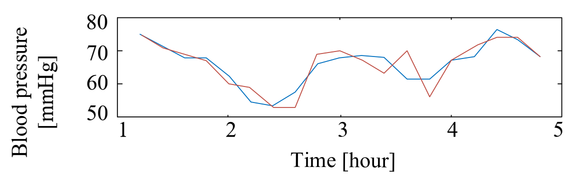

Fig. 1 comparison between estimated and correct blood pressure

For all the results, the mean error was −0.38 mmHg; standard deviation, 6.50 mmHg; and correlation coefficient, 0.70. The mean error and standard deviation satisfy the JIS and ANSI/AAMI standards.

V. Conclusion

In this paper, we described an unrestrained diastolic blood pressure estimation method that uses heartbeat signal. The experiment results showed a mean error of −0.38 mmHg, standard deviation of 6.50 mmHg, and correlation coefficient of 0.70. For our future work, we consider incorporating the time-varying dynamics in the analysis.

Reference

[1] Y. Kurihara, and K. Watanabe, “Suppression of Artifacts in Biomeasurement System by Pneumatic Filtering,” *IEEE Sensors Journal*, vol.12, no.3, pp.416-422, 2012.