International Journal of Advanced Culture Technology Vol.11 No.2 310-314(2023)
DOI https://doi.org/10.17703/IJACT.2023.11.2.310

IJACT 23-6-35

Detection of Arrhythmias by Holter Monitoring and Use of Wearable Electrocardiography Devices

Holter and wearable devices for arrhythmia detection

[1]Ji Yeon Chang, [2]Jae Kyung Kim*

[1]Master student, Department of Biomedical Laboratory Science, Dankook University College of Health &Welfare, Cheonan, Republic of Korea
*[2]*Prof., Dept. of Biomedical Laboratory Science, Dankook Univ., Korea*
jiyeonc7223@gmail.com, nerowolf@naver.com

Abstract

In this paper, we show that the limitations of Holter monitoring and Wearable Electrocardiogarphy Devices and their arrhythmia detection. Sudden death caused by cardiovascular disease, often referred to as the "silent killer" due to its unpredictable nature, is a major health concern. Electrocardiography (ECG) is a basic diagnostic tool for detecting heart disease, but its limitations make it difficult to detect arrhythmia, a significant indicator of an irregular heart state. To address this limitation, a long-term continuous ECG recording device has been developed, Holter ECG device and wearable device. A significant number of studies have focused on the differences between Holter monitoring and wearable devices. The Holter tests were useful for detecting regularly occurring arrhythmias, whereas wearable patches were better at detecting random and infrequent arrhythmias. Wearable patches were effective in detecting episodes of arrhythmia and myocardial ischemia. Despite the concern, wearable devices had less signal loss than Holter monitoring and patients also preferred wearable devices over Holter monitoring due to convenience. These results could mean that the wearable devices can perfectly replace the Holter test.

Keywords: *Arrythmia, Electrocardiography, Holter monitoring, Wearable device.*

1. INTRODUCTION

Sudden and unpredictable death caused by cardiovascular disease is a growing health concern. It is often the first sign of cardiovascular disease and is commonly known as a "silent killer." To prevent sudden death due to cardiovascular disease, it is necessary to permanently monitor heart activity, for which heart-related testing is necessary. Electrocardiography (ECG) is the most accessible diagnostic test for heart disease. ECG measures the electrical activity of the myocardium by recording it via electrodes placed on the thorax. The action potential from the contraction and relaxation of the myocardium is transmitted, and the potential difference is recorded by the electrodes depending on their position on the body. The waveform recorded based on the electrical changes that occur in cardiomyocytes is called an electrocardiogram.

Manuscript received: April 5, 2023 / revised: April 15, 2023 / accepted: May 20, 2023
Corresponding Author: nerowolf@naver.com
Tel: +82-41-550-1451, Fax: +82-41-550-1451
Professor, Dept. of Biomedical Laboratory Science, Univ., Korea

ECG is the simplest test used to detect heart disease, particularly arrhythmia, myocardial ischemia, angina pectoris, and myocardial infarction. However, arrhythmia is difficult to detect with a short ECG test. If not detected within 3–5 min of the test, the result may be read as normal sinus rhythm. Furthermore, if arrhythmia is not detected during the test despite the patient experiencing chest pain, it is difficult to determine the cause using only a short ECG test. To overcome this disadvantage, a long-term continuous ECG recording device was developed, called the Holter ECG device, which is used to measure the heart's electrical activity during the patients' daily activities for 24 or 48 h.

Arrhythmia is a very common phenomenon that occurs not only among patients with cardiovascular disease, but also among healthy people. Atrial fibrillation (AF) and malignant ventricular arrhythmia are typically associated with clinical symptoms. Early detection of AF is important for the effective treatment and prevention of complications, such as arrhythmia. Malignant ventricular arrhythmias account for 5% of all cardiac arrhythmias and are associated with serious clinical symptoms. Recent studies have shown that premature ventricular contractions (PVCs) play a role in inducing fatal ventricular arrhythmias, such as ventricular tachycardia or ventricular fibrillation.[1] Therefore, early diagnosis of PVC and AF is particularly important in patients with acute myocardial infarction and heart failure.

The Holter ECG device has the advantage of being portable but with many limitations, such as the inability to withstand water and that intense exercise can cause noise and affect its interpretation.[2] In addition, disposable silver chloride (Ag/AgCl) electrodes, which are most commonly used in Holter monitoring, detach frequently, thus rendering accurate measurements difficult. This constant detachment can cause discomfort to the user and may cause damage to the skin.[3] In recent years, waterproof smart watches and wearable patches with fewer activity restrictions were being released. Wrist-wearable devices are currently popular and provide heart rate monitoring through photoplethysmography (PPG) technology. By measuring the heartbeat signal, each peak of a pulse is interpreted as an R-wave, which represents a single heartbeat, which is then converted into the next heart rate. This PPG technology allows for the accurate measurement of heart rate and can also be used to diagnose AF.[4] Therefore, through this review, we aim to investigate the differences between hospital-prescribed Holter monitoring and wearable patches for long-term electrocardiogram (ECG) monitoring in South Korea. Additionally, we will present the limitations and potential improvements of wearable patches currently in use, based on various research examples.

2. THEORY

Rather than using only one method to monitor heart activity, it is necessary to use multiple types of ECG devices in combination. To understand the differences between Holter monitors and wearables, studies in which the same patient was simultaneously tested using both devices were searched. Among these, studies analyzing differences in activity restrictions perceived by the subjects were examined, as wearable ECG devices were developed to compensate for the lack of mobility of the Holter monitor. These differences in activity constraints were classified based on studies that investigated them through patient interviews and surveys. When the patient moves, noise and distortion can occur on ECG owing to changes in the electrode contact impedance with the skin. Studies analyzing the impact of noise on ECG interpretation and possibility of analysis errors were identified.

3. EXPERIMENTS

3.1 Study Subjects

Studies about the Holter examination method and wearable ECG patches were searched in PubMed, the National Assembly Library, the Dankook University Yulgok Library Database, and the *Journal of Alternative & Complementary Medicine*. The following search terms related to ECG examination were used: "ECG," "Holter," and "wearable ECG." Original papers that were not relevant to the purpose of this study were excluded. A total of 25 papers were selected.

3.2 Classification of Studies

Each study was classified according to the desired results of the Holter and wearable ECG examinations into one of three categories: artifacts, arrhythmia detection, or device features.

3.2.1 Artifacts

Because the development of technology and science has continued, studies on wearable ECG devices since 2013, including those that have examined wearable patches that have been released after that time, and studies that have compared Holter examinations with wearable ECG devices were included. A total of 23 studies were selected.

3.2.2 Arrhythmia Detection

As the purpose of this study was to analyze methods for detection of cardiac arrhythmia, studies analyzing devices from the perspective of detecting arrhythmia were examined. Ten studies were selected.

3.2.3 Device Features

As many wearable ECG-related devices are currently in the market, studies analyzing the advantages and disadvantages of each device according to their characteristics were included. A total of 20 studies were selected for this review.

4. RESULTS AND DISCUSSION

4.1 Artifacts

The main problem with ECG recordings is the extraction of high-resolution signals from the recordings with background noise.[5] This background noise is called an ECG artifact or artificial product. Unlike electrocardiograms that can be examined by removing artifacts, Holter and wearable electrocardiograms must be read when an artifact occurs; therefore, the presence or absence of artifacts is very important for interpreting electrocardiograms.[6][7] Artifacts were compared among the 23 studies. As a result, there were fewer artifacts in ECG tests using wearable patches than in Holter tests, and serious noise that interfered with appropriate interpretation was more common in Holter tests than in wearable tests.[8][9][10]

4.2 Arrhythmia Detection

Because the main purpose of both the Holter and wearable patch tests is to detect arrhythmias, it is important to determine how well arrhythmias detected during the test period can be interpreted. Studies on arrhythmia detection were selected from the 10 studies. The Holter tests were useful for detecting regularly occurring arrhythmias, whereas wearable patches were better at detecting random and infrequent arrhythmias.[11] Wearable patches were very effective in detecting episodes of arrhythmia and myocardial ischemia. The diagnostic accuracy of wearable patches was higher than that of Holter tests; however, for atrioventricular block and sinus pause, Holter tests were more accurate than wearable patches. AF diagnosis was more accurate with wearable patches than with Holter tests, and the ability to detect ST depression, a sign of ischemia, is still controversial for both Holter and wearable patch tests.[12]

4.3 Device Features

Signal loss, which means no recording owing to mechanical defects, occurred only with Holter tests,

resulting in a signal loss rate of 9.4%. All types of wearable ECG devices were more expensive than Holter tests. After completion of the 20 studies, patient satisfaction with the test was evaluated by conducting surveys and interviews with patients.[14][15][16][17][18] As a result, it was unanimous that wearable patches that were not connected by wires were more convenient than Holter tests. Patients preferred wearable patches that allowed bathing and imposed fewer restrictions on their daily lives.[19]

4.4 Discussion

Holter monitoring and the use of wearable ECG devices have advantages and limitations. When selecting a suitable heart monitoring method for a patient, it is important to consider these factors. Holter monitoring is still considered a gold standard for detecting and diagnosing arrhythmias, although wearable ECG devices have been developed as a convenient and practical alternative for long-term monitoring of heart activity. Nonetheless, wearable ECG devices are associated with certain risks and limitations. It is important to examine how a patient uses a specific device during the test because this is crucial for detecting arrhythmias. [20]

After examining the available literature on wearable ECG devices, we determined that the following research is needed in the future. In terms of accuracy and reliability, future studies should evaluate the sensitivity and specificity of the devices for detecting various types of arrhythmias and other cardiac abnormalities.[21] In terms of clinical usefulness, wearable ECG devices should be evaluated to determine their effectiveness in managing various cardiac conditions. Future studies should also evaluate the impact of using wearable ECG devices for patient outcomes, such as reduced hospitalization rates, improved quality of life, and reduced medical costs. Moreover, further research is needed to determine the potential benefits of combining the use of wearable ECG devices with other technologies, such as artificial intelligence and machine learning algorithms, to improve diagnostic accuracy and personalized treatment.

5. CONCLUSION

Holter monitoring is still considered a good standard for detecting and diagnosing arrhythmias, although wearable ECG devices have been developed as a convenient and practical alternative for long-term monitoring of heart activity. Comparing the use of a wearable ECG device with Holter monitoring should be performed in a larger number of people, particularly patients with a specific cardiac disease or a history of paroxysmal diseases, such as paroxysmal supraventricular tachycardia or paroxysmal atrial fibrillation.

Based on our review, it was concluded that the use of wearable ECG devices can sufficiently replace Holter monitoring. The long-term monitored content can be reviewed using computer-aided analysis.[22] However, computer-aided analysis algorithms are only capable of analyzing electrocardiograms without artifacts. Therefore, they are not suitable for handling artifacts caused by movement during wearable use. Hence, all the artifacts that may occur during movement must be learned.

REFERENCES

[1] Q. Shen, J. Li, C. Cui, X. Wang, H. Gao, C. Liu, and M. Chen, "A wearable real-time telemom nitoring electrocardiogram device compared with traditional Holter monitoring," *Journal of Biomedical Research*, Vol. 35, No. 3, pp. 238-246, Dec 2020.

[2] P. Kamga, R. Mostafa, and S. Zafar, "The use of wearable ECG devices in the clinical setting: a revie w," *Current Emergency and Hospital Medicine Reports*, Vol. 10, No. 3, pp. 67-72, Sep 2022.

[3] S. Ramasamy and A. Balan, "Wearable sensors for ECG measurement: a review," *Sensor Review*, Vol. 3 8, No. 4, pp. 412-419, Feb 2018.

[4] J. Hwang, J. Kim, K.J. Choi, M.S. Cho, G.B. Nam, and Y.H. Kim, "Assessing accuracy of wrist-worn w earable devices in measurement of paroxysmal supraventricular tachycardia heart rate,"*Korean Circulation Journal*, Vol. 49, No 5, pp. 437-445, May 2019.

[5] S. Chaudhuri, T.D. Pawar, and S. Duttagupta, Ambulation analysis in wearable ECG, Springer, 2009.

[6] W. Choi, S.H. Kim, W. Lee, S.H. Kang, C.H. Yoon, T.J. Youn, and I.H. Chae, "Comparison of continuo us ECG monitoring by wearable patch device and conventional telemonitoring device," *Journal of Korean Medical Science*, Vol. 35, No. 44, e363, Nov 2020.
[7] S. Majumder, L. Chen, O. Marinov, C.H. Chen, T. Mondal, and M.J. Deen, "Noncontact wearable wirele ss ECG systems for long-term monitoring," *IEEE Reviews in Biomedical Engineering*, Vol. 11, pp. 306-3 21, May 2018.
[8] M. Boszko, G. Osak, N. Żurawska, K. Skoczylas, B. Krzowski, G. Wróblewski, G., A. Maciejewski, J. S obiech, S. Ostrowski, M. Grabowski, and Ł. Kołtowski, "Assessment of a new KoMaWo electrode-patch configuration accuracy and review of the literature," *Journal of Electrocardiology*, Vol 75, pp. 82-87, No v-Dec 2022.
[9] K. Eguchi and R. Aoki, "Practical RR interval editing for heart rate variability analysis using single-chan nel wearable ECG devices," *IEEE Access*, Vol. 11, pp. 25543-25582, Mar 2023.
[10] H. Kamozawa, S. Muroga, and M. Tanaka, "A detection method of atrial fibrillation from 24 - hour Holt er - ECG using CNN," *IEEJ Transactions on Electrical and Electronic Engineering*, Vol. 18, No. 4, pp. 577-582, Apr 2023.
[11] M. Strik, S. Ploux, D. Weigel, J. van der Zande, A. Velraeds, H.P. Racine, F.D. Ramirez, M. Haïssaguer re, and P. Bordachar, "The use of smartwatch electrocardiogram beyond arrhythmia detection," *Trends in Cardiovascular Medicine*, Vol. S1050-1738, No. 22, 00153-0, Jan 2023.
[12] J. Hoevelmann, K. Sliwa, O. Briton, M. Ntsekhe, A. Chin, and C. Viljoen, "Effectiveness of implantable loop recorder and Holter electrocardiographic monitoring for the detection of arrhythmias in patients with peripartum cardiomyopathy," *Clinical Research in Cardiology*, Vol. 112, No. 3, pp. 379-391, Mar 2023.
[13] T. Todorov, G.T. Bogdanova, N. Noev, and N. Sabev, "Data management in a holter monitoring system," *TEM Journal*, Vol. 8, No. 3, pp. 801-805, 2019.
[14] S. Kwon, S.R. Lee, E.K. Choi, H.J. Ahn, H.S. Song, Y.S. Lee, and S. Oh, "Validation of adhesive singl e-lead ECG device compared with Holter monitoring among non-atrial fibrillation patients," *Sensors*, Vol. 21, No. 9, p. 3122, Apr 2021.
[15] S. Murali, N. Brugger, F. Rincon, M. Mashru, S. Cook, and J.J. Goy, "Cardiac ambulatory monitoring: n ew wireless device validated against conventional Holter monitoring in a case series," *Frontiers in Cardio vascular Medicine*, Vol. 7, 587945, Nov 2020.
[16] P. Vardas, M. Cowie, N. Dagres, D. Asvestas, S. Tzeis, E.P. Vardas, G. Hindricks, and J. Camm, "The electrocardiogram endeavour: from the Holter single-lead recordings to multilead wearable devices supporte d by computational machine learning algorithms," *EP Europace*, Vol. 22, No. 1, pp. 19-23, Jan 2020.
[17] Z. Cai, J. Li, X. Zhang, Q. Shen, A. Murray, and C. Liu, "How accurate are ECG parameters from wea rable single-lead ECG system for 24-hours monitoring," *2019 Computing in Cardiology*, pp. 1-4, Sep 201 9.
[18] K. Amami, A. Yoshihisa, Y. Horikoshi, S. Yamada, T. Nehashi, N. Hijioka, M. Nodera, T. Kaneshiro, T. Yokokawa, T. Misaka, and Y. Takeishi, "Utility of a novel wearable electrode embedded in an undershi rt for electrocardiogram monitoring and detection of arrhythmias," *Plos One*, Vol. 17, No. 8, e0273541, Aug 2022.
[19] Y.T. Tsukada, M. Tokita, H. Murata, Y. Hirasawa, K. Yodogawa, Y.K. Iwasaki, K. Asai, W. Shimizu, N. Kasai, H. Nakashima, and S. Tsukada, "Validation of wearable textile electrodes for ECG monitoring," *Heart and Vessels*, Vol. 34, No. 7, pp. 1203-1211, Jul 2019.
[20] M. Jacobsen, T.A. Dembek, A.P. Ziakos, R. Gholamipoor, G. Kobbe, M. Kollmann, C. Blum, D. Müller- Wieland, A. Napp, L. Heinemann, N. Deubner, N. Marx, S. Isenmann, and M. Seyfarth, "Reliable detecti on of atrial fibrillation with a medical wearable during inpatient conditions," *Sensors*, Vol. 20, No. 19, p. 5517, Sep 2020.
[21] A. Xintarakou, V. Sousonis, D. Asvestas, P.E. Vardas, and S. Tzeis, "Remote cardiac rhythm monitoring in the era of smart wearables: present assets and future perspectives," *Frontiers in Cardiovascular Medici ne*, Vol. 9, 853614, Mar 2022.
[22] P. Wang, Z. Lin, X. Yan, Z. Chen, M. Ding, Y. Song, and L. Meng, "A wearable ECG monitor for dee p learning based real-time cardiovascular disease detection," arXiv preprint arXiv:2201.10083, Jan 2022.