Postprint: Applied Research on Mobile Intelligent Healthcare for Cardiovascular Disease Prevention and Control in Elderly Chronic Disease Patients at the Primary Care Level

Authors: Yu Xinyan 1, Zhao Jun 2, Zhao Xiaoye 3, Jiang Qingru 1, Chen Yatian 4, Wang Yan 5, Zhang Haicheng 6*

Date: 2023-07-25T00:00:00+00:00

Abstract

Background In recent years, the advantages of mobile smart healthcare in the screening, intervention, treatment, and management of cardiovascular diseases have become increasingly prominent. Specifically, the application value of single-lead wearable electrocardiogram (ECG) devices for out-of-hospital early screening and diagnosis of arrhythmia patients has been recognized by scholars and clinicians. However, the simplicity of its lead configuration and the limited functionality of its associated cloud platform restrict its application in risk screening and long-term follow-up management of chronic disease patients in primary-level medical institutions.

Objective This study, grounded in the hierarchical diagnosis and treatment system and from the perspective of chronic disease prevention and control, utilizes single-lead wearable ECG devices as a vehicle to explore the application value of mobile smart healthcare in cardiovascular disease risk prevention and control among elderly chronic disease patients at the primary level.

Methods A total of 3,000 chronic disease patients aged 65 years and above, admitted to 20 primary-level medical institutions in Ningxia from January to August 2022, were selected as study subjects, including 1,202 males and 1,798 females; the mean age was (71.3$±$5.0) years. Primary-level physicians used a mobile APP and a patient management cloud platform to input patient information, provided patients with single-lead wearable ECG devices to collect 72-hour ECG data, and uploaded the data to the patient management cloud platform. Professional ECG physicians separately performed arrhythmia, heart rate variability (HRV), and obstructive sleep apnea hypopnea syndrome (OSAHS) analyses and risk stratification on the data. The stratification results

from the three analysis methods were integrated, and data corresponding to low, medium, and high comprehensive cardiovascular disease risk were marked with appropriate identifiers on the cloud platform. The cloud platform notified primary-level physicians of high- and medium-risk patients via text messages to manage patients according to different protocols. The numbers of patients detected with different risk stratifications by the three analysis methods, the numbers of patients with low, medium, and high cardiovascular disease risk, and the protocol-based management rates were statistically analyzed.

Results The numbers of patients with arrhythmia results classified as normal, positive, and critically positive were 1,526 (50.86%), 1,349 (44.97%), and 125 (4.17%), respectively; those with HRV classified as mildly, moderately, and severely reduced were 2,330 (78.5%), 630 (21.21%), and 8 (0.27%), respectively; and those with OSAHS classified as mildly, moderately, and severely abnormal were 1,769 (65.57%), 573 (19.31%), and 626 (21.09%), respectively. The numbers of patients with low, medium, and high comprehensive cardiovascular disease risk were 744 (24.80%), 1,640 (54.67%), and 616 (30.53%), respectively. The protocol-based management rates for high-, medium-, and low-risk patients were 94.49% (703 cases), 88.10% (1,445 cases), and 100.00% (616 cases), respectively.

Conclusion The combined application of mobile smart healthcare technology with arrhythmia, HRV, and OSAHS analysis methods in the prevention and control of cardiovascular disease among elderly chronic disease patients at the primary level can not only improve the detection rate of cardiovascular disease risk in patients, but also enhance their management rate, which is conducive to establishing a cardiovascular disease prevention and control system for elderly chronic disease patients at the primary level.

Full Text

Application of Mobile Smart Healthcare in the Prevention and Control of Cardiovascular Diseases in Elderly Patients with Chronic Diseases in Primary Care

YU Xinyan[1], ZHAO Jun[2], ZHAO Xiaoye[3], JIANG Qingru[1], CHEN Yatian[4], WANG Yan[5], ZHANG Haicheng[6]*

[1]Health Management (Physical Examination) Center, the First People' s Hospital of Yinchuan, Yinchuan 750001, China
[2]Jiangsu Taixing People' s Hospital, Taixing 225400, China
[3]School of Electrical and Information Engineering, Northern Minzu University, Yinchuan 750021, China
[4]Damiao Community Health Station, the First People' s Hospital of Yinchuan, Yinchuan 750001, China
[5]Xinhua Street Community Health Station, the First People' s Hospital of Yinchuan, Yinchuan 750001, China

[6]Department of Cardiology, Peking University People's Hospital, Beijing 100044, China

*Corresponding author: ZHANG Haicheng, Chief physician; E-mail: haichengzhang@bjmu.edu.cn

Funding: Major Project of National Social Science Fund (18ZDA086-4); Key Major Special Project of Yinchuan Science and Technology Innovation (2021-SF-009)

Abstract

Background: The advantages of mobile smart healthcare in screening, intervention, treatment, and management of cardiovascular diseases have become increasingly prominent in recent years. The application value of single-lead wearable electrocardiogram (ECG) devices for out-of-hospital screening and diagnosis of arrhythmias has been recognized by scholars and clinicians. However, the limited lead configuration and the monofunctional nature of associated cloud platforms restrict their utility for risk screening and long-term follow-up management of chronic disease patients in primary care settings.

Objective: Based on the hierarchical medical system and from the perspective of chronic disease prevention and control, this study explores the application value of mobile smart healthcare in cardiovascular disease risk prevention and control among elderly chronic disease patients in primary care, using single-lead wearable ECG devices as the carrier.

Methods: A total of 3,000 chronic disease patients aged over 65 years admitted to 20 primary care institutions in Ningxia from January to August 2022 were selected as study subjects, including 1,202 males and 1,798 females with an average age of (71.3$±$5.0) years. Primary care physicians used a mobile phone APP and patient management cloud platform to record patient information and fitted patients with single-lead wearable ECG devices to collect 72-hour ECG data, which were uploaded to the patient management cloud platform. Professional ECG physicians performed arrhythmia, heart rate variability (HRV), and obstructive sleep apnea-hypopnea syndrome (OSAHS) analyses and risk stratification. Based on the combined stratification results from these three analytical methods, data corresponding to low, medium, and high comprehensive cardiovascular disease risk were marked with appropriate identifiers in the cloud platform. The platform notified primary care physicians of high- and medium-risk patients via text message for management according to different protocols. The number of patients detected across different risk stratifications by the three analytical methods, the number of patients with low, medium, and high cardiovascular disease risk, and the management rates according to protocol were statistically analyzed.

Results: Arrhythmia analysis identified 1,526 (50.86%) normal cases, 1,349

(44.97%) positive cases, and 125 (4.17%) major positive cases. HRV analysis showed mild, moderate, and severe reduction in 2,330 (78.5%), 630 (21.21%), and 8 (0.27%) cases, respectively. OSAHS analysis revealed mild, moderate, and severe abnormalities in 1,769 (65.57%), 573 (19.31%), and 626 (21.09%) cases, respectively. Comprehensive cardiovascular disease risk stratification identified 744 (24.80%), 1,640 (54.67%), and 616 (30.53%) patients as low, medium, and high risk, respectively. The protocol-based management rates for high-, medium-, and low-risk patients were 94.49% (703 cases), 88.10% (1,445 cases), and 100.00% (616 cases), respectively.

Conclusion: The combined application of mobile smart healthcare technology with arrhythmia, HRV, and OSAHS analytical methods for cardiovascular disease prevention and control in elderly chronic disease patients at the primary care level not only improves the detection rate of cardiovascular disease risk but also enhances management rates, thereby facilitating the establishment of a cardiovascular disease prevention and control system for elderly chronic disease patients in primary care settings.

Keywords: Mobile health; Telehealth; Single-lead wearable ECG equipment; Aged; Chronic disease; Cardiovascular diseases

---

Introduction

With rapid socioeconomic development, chronic non-communicable diseases (hereafter referred to as "chronic diseases") have become a major public health threat to Chinese residents. Cardiovascular disease (CVD) not only ranks first in incidence and mortality among all chronic diseases but also serves as the primary complication of other chronic diseases and the leading cause of death. The strategic policy for chronic disease prevention and control in China emphasizes "focusing on primary care and prioritizing prevention." However, primary care institutions currently lack simple, efficient, and low-cost appropriate technologies for preventing and controlling cardiovascular disease risks associated with chronic diseases and their complications.

Meanwhile, as population aging accelerates in China, the growing number of elderly chronic disease patients places higher demands on the cardiovascular disease risk prevention and control capabilities of primary care institutions. In recent years, driven by new technologies such as cloud computing, the Internet of Things, big data, and artificial intelligence represented by 5G, and accompanied by the widespread adoption of smartphones and continuous improvement of wearable ECG device functionality, the advantages of mobile smart healthcare in screening, intervention, treatment, and management of cardiovascular diseases have become increasingly prominent.

Our research team has been committed to continuous research on the application of single-lead wearable ECG devices in primary care in recent years, with pre-

vious studies focusing on their role in improving diagnosis and treatment of arrhythmia patients. Building upon this foundation, the current study, grounded in the hierarchical medical system and from the perspective of chronic disease prevention and control, uses single-lead wearable ECG devices as a carrier to combine arrhythmia analysis with heart rate variability (HRV) and obstructive sleep apnea-hypopnea syndrome (OSAHS) analysis for cardiovascular disease risk assessment in elderly chronic disease patients at the primary care level. By leveraging the high degree of informatization, speed, efficiency, massive connectivity, and flexible data routing advantages of mobile smart healthcare, this study explores the application value of mobile smart healthcare in cardiovascular disease risk prevention and control among elderly chronic disease patients in primary care.

Methods

1.1 Study Subjects A total of 3,000 chronic disease patients aged over 65 years admitted to 20 primary care institutions in Ningxia Hui Autonomous Region from January to August 2022 were selected as study subjects. The cohort included 1,202 males and 1,798 females, with an average age of (71.3$±$5.0) years. Among them, 2,760 patients were aged 65–80 years and 240 were $ $80 years; 1,241 had BMI < 24 kg/m^{2}$ and 1,759 had BMI $ $24 kg/m^{2}$; 2,070 were urban residents and 930 were rural residents; 1,543 had a single chronic disease and 1,457 had multiple chronic diseases; 2,028 presented with symptoms such as chest tightness, palpitations, and shortness of breath while 972 were asymptomatic; 399 were smokers and 2,601 were non-smokers. Primary care physicians used a mobile phone APP and patient management cloud platform to record patient baseline information and fitted patients with single-lead wearable ECG devices to collect 72-hour ECG data, which were uploaded to the patient management cloud platform. This study was approved by the hospital ethics committee, and all subjects or their families provided informed consent.

Inclusion criteria: Patients aged $ $65 years with chronic diseases who were able to cooperate with the study.
Exclusion criteria: (1) Patients with cognitive impairment or inability to cooperate; (2) Patients with incomplete clinical data; (3) Patients with skin allergies; (4) Patients with effective ECG recording duration <24 hours.

1.3.1 Single-Lead Wearable ECG Device and Mobile APP The study employed a smart wearable single-lead ECG device produced by Chengdu Xinhuijuyuan Technology Co., Ltd. (Medical Device Registration Certificate No.: Chuanxiezhun 20182210026). The device measures 6 mm thick, weighs 9 g, samples at 256 Hz/s, has a battery life of 3–7 days, stores 72 hours of internal data, features a built-in rechargeable lithium battery, and supports Bluetooth 5.0 and USB data transmission. It is paired with a physician version of the Guanxin

mobile APP for entering patient basic information and collecting/uploading 72-hour ECG data.

1.3.2 Patient Management Cloud Platform The study utilized a web-based patient management cloud platform jointly developed by the First People' s Hospital of Yinchuan and Chengdu Xinhuijuyuan Technology Co., Ltd. The platform consists of an analysis and diagnosis system, patient management system, and triage and referral system, which can automatically link with each other and extract data from the mobile APP. It is used for ECG data analysis, diagnosis, labeling, and report printing; entry, summary, calculation, and classification of patients' first-visit detailed clinical data, follow-up results, and treatment opinions; and two-way referral management.

1.3.3 Data Collection and Upload Method Primary care physicians powered on the single-lead wearable ECG device by long-pressing the switch button, activated mobile phone Bluetooth, connected the device by scanning the QR code on the device through the mobile APP, removed the sticker from the disposable flexible sensor, aligned the sensor contacts on the device with the conductive sponge on the flexible sensor, and pressed firmly to adhere. After removing the protective film from the back of the sensor, they applied it along the patient' s sternal direction. Following connection, they clicked the "Start Measurement" button on the mobile APP. After confirming interference-free waveforms, patients left the clinic. After 72 hours, patients returned to the primary care institution, where physicians clicked the "Stop Measurement" button on the mobile APP to end the measurement and remove the device. Physicians then connected the device to the mobile phone via a data cable to upload data to the patient management cloud platform.

1.3.4 Data Analysis, Stratification, and Labeling Method ECG physicians retrieved ECG data from the analysis and diagnosis system to perform arrhythmia, HRV, and OSAHS analyses. Risk stratification was performed based on the results of each of the three methods (normal, positive, and major positive for arrhythmia; mild, moderate, and severe HRV reduction; and mild, moderate, and severe OSAHS). Based on the combined stratification results from these three methods, data corresponding to low, medium, and high cardiovascular disease risk were marked with appropriate identifiers in the cloud platform. The platform matched high- and medium-risk data with patient names and affiliated primary care physician information and notified primary care physicians via text message. The text message format was: "High/Medium risk, patient name, affiliated institution."

1.3.5 Diagnostic Criteria

1. **Arrhythmia results:** Major positive arrhythmia criteria referenced the "Shanxi Province Dynamic Electrocardiogram Major Positive Value

Prompt Recommendations." Normal was defined as no arrhythmia or only "occasional ventricular and/or supraventricular premature contractions." Arrhythmia types not meeting major positive or normal criteria were classified as positive.

2. **HRV analysis results:** HRV was classified as mildly, moderately, or severely reduced based on standard deviation of all normal-to-normal RR intervals (SDNN) values of >100 ms, 50–100 ms, and <50 ms, respectively.
3. **OSAHS analysis results:** OSAHS was classified as mild, moderate, or severe based on apnea-hypopnea index (AHI) values of <15 events/h, 15–30 events/h, and >30 events/h, respectively.
4. **Comprehensive cardiovascular disease risk stratification:** High risk was defined as meeting at least one of the following criteria: major positive arrhythmia, severe HRV reduction, or severe OSAHS. Low risk was defined as simultaneously meeting all three criteria: normal arrhythmia, mild HRV reduction, and mild OSAHS. Medium risk included all cases not meeting low- or high-risk criteria.

1.4 Management Pathway Process for High-, Medium-, and Low-Risk Patients Primary care physicians notified patients via text message or phone call. **High-risk patients:** Based on patient preference and proximity, primary care physicians selected a specialist from a higher-level hospital in the triage and referral system, after which the platform automatically sent a text message to the selected specialist with content: "High risk, patient name, affiliated institution." Upon receiving the message, the specialist reviewed the patient' s ECG and other clinical data in the patient management system, conducted a preliminary assessment, selected the appointment time and location in the triage and referral system, and the primary care physician could then view this information synchronously and notify the patient.

Medium-risk patients: Primary care physicians assisted patients in registering through the WeChat public account of the higher-level hospital based on patient preference, selected the specialist and date in the triage and referral system, and the physician received an automatically sent text message. After high- and medium-risk patients visited the specialist, the specialist logged into the patient management platform to fill in treatment measures and follow-up recommendations, which primary care physicians could view synchronously to conduct follow-up and management according to specialist advice.

Low-risk patients: Combined with patients'underlying diseases, follow-up was conducted at 3 months and results were entered into the patient management system. (Note: High- and medium-risk patients who refused referral management were managed according to the low-risk patient follow-up process.) See Figure 1 [Figure 1: see original paper].

1.5 Statistical Methods Data were extracted from the cloud platform and analyzed using SPSS 20.0 software. Count data were expressed as relative frequencies, and normally distributed measurement data were expressed as ($\bar{x}\pm s$).

Results

2.1 Risk Stratification Results from Three Analytical Methods Among the 3,000 patients, arrhythmia stratification identified 1,526 (50.86%) normal cases, 1,349 (44.97%) positive cases, and 125 (4.17%) major positive cases. A total of 32 (1.07%) patients had persistent atrial fibrillation and could not undergo HRV and OSAHS analysis. Among the 2,968 analyzable patients, HRV was mildly, moderately, and severely reduced in 2,330 (78.5%), 630 (21.21%), and 8 (0.27%) cases, respectively. OSAHS was mild, moderate, and severe in 1,769 (65.57%), 573 (19.31%), and 626 (21.09%) cases, respectively.

2.3 Comprehensive Cardiovascular Disease Risk Stratification Results Comprehensive cardiovascular disease risk stratification identified 616 (20.53%), 1,640 (54.67%), and 744 (24.80%) patients as low, medium, and high risk, respectively. Among high-risk patients, 729 (97.98%) met one of the criteria (major positive arrhythmia, severe HRV reduction, or severe OSAHS), 15 (2.02%) met two criteria, and 0 met all three criteria. Among medium-risk patients, 1,148 (70.00%) met one criterion (positive arrhythmia, moderate HRV reduction, or moderate OSAHS), 466 (28.41%) met two criteria, and 26 (1.59%) met three criteria.

2.4 Management Rates for Patients with Low, Medium, and High Comprehensive Cardiovascular Risk A total of 3,000 patients were managed, achieving a 100% management rate. Protocol-based management rates for high-, medium-, and low-risk patients were 94.49% (703 cases), 88.10% (1,445 cases), and 100.00% (616 cases), respectively. Among the 236 (9.90%) high- and medium-risk patients who did not follow the protocol-based management pathway, all were managed according to the low-risk patient follow-up process. See Table 1 .

Discussion

Single-lead wearable ECG devices, due to their simple application, lightweight design, and comfortable wear, meet patients' needs for long-term out-of-hospital monitoring, facilitating early diagnosis and long-term monitoring of arrhythmias. Consequently, they have been applied for arrhythmia screening, diagnosis, and long-term follow-up outside the hospital. However, the limited lead configuration and the monofunctional nature of most associated mobile APPs and cloud platforms prevent comprehensive cardiovascular risk assessment of

chronic disease patients from multiple dimensions and hinder implementation of a closed-loop management model encompassing screening, diagnosis, treatment, and follow-up, thereby limiting their application in primary care institutions.

This study first explored overcoming the limitation that single-lead wearable devices have value only in effective arrhythmia diagnosis due to their single-lead configuration. By simultaneously performing arrhythmia, HRV, and OSAHS analyses and risk stratification on the collected 72-hour data, and combining the stratification results from these three methods for comprehensive cardiovascular disease risk assessment and stratification, the study expanded the devices' utility. Second, the study addressed the bottleneck that existing cloud platforms for single-lead wearable ECG devices only have analytical and diagnostic functions, enabling disease screening and diagnosis but not subsequent referral and tracking management. The cloud platform functionality was expanded to comprise three systems: analysis and diagnosis, patient management, and triage and referral, integrating 83 physicians from 28 medical institutions within the region (including one tertiary A-level hospital, two tertiary B-level hospitals, one secondary A-level hospital, eight township health centers, four community health service centers, and ten community health service stations) registered on the platform. Leveraging the characteristic of mobile smart healthcare that enables high-speed connectivity between people and objects and between objects themselves, the system automatically matched different follow-up management processes designed by the research team for different risk stratifications based on identifiers selected by ECG physicians in the analysis and diagnosis system, and sent text message notifications, thereby enabling patients to receive timely, convenient, and equitable medical services at primary care institutions.

The risk stratification results based on arrhythmia, HRV, and OSAHS analyses revealed substantial differences in the number of patients detected across different risk categories by the three methods, likely attributable to their distinct assessment mechanisms. Arrhythmia assessment evaluates whether cardiac rhythm changes cause hemodynamic changes that endanger vital signs and consciousness. HRV assessment evaluates whether autonomic nervous function is balanced and whether the degree of imbalance causes hemodynamic disturbances and increased myocardial oxygen consumption. AHI assesses patient risk from multiple factors including hemodynamics, autonomic nervous function, inflammatory response, oxidative stress, and metabolic disorders. These results also demonstrate that combined application of the three methods not only overcomes the long-standing bottleneck that single-lead wearable ECG devices can only be used for early arrhythmia screening and diagnosis but also enables comprehensive cardiovascular risk assessment and stratification of chronic disease patients from multiple dimensions, thereby reducing cardiovascular events and facilitating primary care cardiovascular disease prevention and control. This was confirmed by the HRV and OSAHS assessment results among the 1,526 patients classified as normal based solely on arrhythmia diagnosis: severely reduced HRV and severe OSAHS were found in 6 (0.39%) and 325 (21.30%) patients, respectively.

Previous studies have shown that the incidence of OSA in elderly individuals reaches as high as 60%, with more than half having comorbid cardiovascular disease. However, atypical clinical symptoms and low awareness of OSAHS in the elderly often lead to diagnosis only after target organ damage such as hypertension, coronary heart disease, arrhythmia, and pulmonary heart disease have occurred. In this study, patients could undergo OSAHS screening at home using single-lead wearable ECG devices in primary care institutions, with different interventions and management measures implemented according to risk stratification, potentially reducing cardiovascular events caused by OSAHS.

Comprehensive cardiovascular disease risk statistics showed that the numbers of patients identified as medium and high risk were 1,640 (54.67%) and 744 (24.80%), respectively, both higher than the numbers identified as equivalent risk by any single method. This suggests that applying the three methods in combination using single-lead wearable devices for cardiovascular risk screening in elderly chronic disease patients at the primary care level can identify more patients with potential cardiovascular disease risk. During follow-up in this study, one male patient with hypertension and diabetes had severely reduced HRV but only occasional ventricular premature contractions in 72-hour ECG data; the patient refused further referral and died of acute myocardial infarction three months later.

Patient management rate statistics showed that 2,148 (90.10%) high- and medium-risk patients were managed according to protocol. Although 236 (9.90%) patients did not follow the protocol-based management pathway, they were still managed according to the low-risk patient follow-up process. The management rate for high-risk patients was higher than for medium-risk patients (94.49% vs. 88.10%), and among high- and medium-risk patients, the management rate increased with the number of criteria met (87.63%, 89.05%, 100.00%; 94.47%, 100.00%). The management rates in this study were higher than those reported in previous studies, contrary to previous findings that more severe disease increases referral management difficulty.

Several factors may explain these results. First, this study adopted a patient-centered approach, focusing on potential outcomes associated with disease risk and communicating from a prevention-oriented perspective, which facilitated patient understanding and awareness of benefits from active cooperation. Second, from the moment ECG physicians selected risk identifiers in the cloud platform to the selection of specialist physicians, appointment times, and locations, and to primary care physicians' access to specialists' treatment plans, all processes were completed online. This not only shortened communication time between primary care physicians and patients but also eliminated the inconvenience and psychological burden of patients carrying materials and explaining their condition and treatment plans to physicians. The online process also prevented information asymmetry between higher-level and primary care physicians while enabling both specialists and primary care physicians to understand patient conditions and treatment plans in advance, enhancing patient experience and trust

and thereby improving compliance.

In summary, this study utilized mobile smart healthcare technology to combine multiple analytical methods for cardiovascular disease risk assessment and pathway-based management of elderly chronic disease patients in primary care. This approach not only achieved effective integration of disease risk screening, assessment, referral, diagnosis, and management but also established a unified, efficient, real-time, and interconnected hierarchical prevention and control system for cardiovascular disease in elderly chronic disease patients at the primary care level. The system improved patient enthusiasm and compliance for referral and regular follow-up, creating an efficient management mechanism with collaboration among "patients—medical institutions at different levels—medical teams of different specialties."

References

[1] WANG Zhuoqun, ZHAO Wenhua. Review and prospect of chronic disease prevention and control in China [J]. Chinese Journal of Disease Control & Prevention, 2019, 23(9): 1025-1028, 1036. DOI: 10.16462/j.cnki.zhjbkz.2019.09.001.

[2] Writing Group of China Cardiovascular Health and Disease Report 2021. Summary of China Cardiovascular Health and Disease Report 2021 [J]. Chinese Circulation Journal, 2022, 37(6): 553-578. DOI: 10.3969/j.issn.1000-3614.2022.06.001.

[3] HU Shilian, WANG Jing, FANG Xiang, et al. Trends in population mortality from major fatal chronic diseases among Chinese residents and coping strategies [J]. Chinese Journal of Clinical Healthcare, 2022, 25(3): 297-302. DOI: 10.3969/J.issn.1672-6790.2022.03.002.

[4] DAI Xiaohui, BIAN Lin. Bioethical research on chronic disease prevention and control issues based on Healthy China 2030 goals [C]. // Proceedings of the 19th Academic Annual Meeting and International Forum on Medical Ethics of the Chinese Medical Association Medical Ethics Branch. 2017: 587-590.

[5] MAJUMDER S, CHEN L, MARINOV O, et al. Noncontact wearable wireless ECG systems for long-term monitoring [J]. IEEE Rev Biomed Eng, 2018, 11: 306-321. DOI: 10.1109/RBME.2018.2840336.

[6] GUAN J Q, WANG A L, SONG W J, et al. Screening for arrhythmia with the new portable single-lead electrocardiographic device (SnapECG): an application study in community-based elderly population in Nanjing, China [J]. Aging Clin Exp Res, 2021, 33(1): 133-140. DOI: 10.1007/s40520-020-01512-4.

[7] YU Xinyan, ZHAO Ruiqin, PENG Jun, et al. Study on pre-hospital application of scatterplot for preliminary screening of wearable single-lead remote ECG monitoring of arrhythmias [J]. Chinese General Practice, 2022, 25(2): 159-165. DOI: 10.12114/j.issn.1007-9572.2021.01.405.

[8] YU Xinyan, ZHAO Xudong, ZHAO Xiaoye, et al. Real-world study of community-based mobile healthcare screening program for arrhythmias [J]. Chinese General Practice, 2023, 26(2): 192-200, 209. DOI: 10.12114/j.issn.1007-9572.2022.0511.

[9] YU Xinyan, ZHAO Xiaoye, YANG Jianyun, et al. Analysis of wearable single-lead remote ECG monitoring device combined with scatterplot in out-of-hospital application [J]. Chinese Circulation Journal, 2021, 36(11): 1096-1100. DOI: 10.3969/j.issn.1000-3614.2021.11.006.

[10] YU Xinyan, WANG Zhixin, LANG Liguo, et al. Exploration of application mode of single-lead wearable remote ECG monitoring device in patients with symptomatic arrhythmias [J]. Journal of Practical Electrocardiology, 2021, 30(1): 46-49. DOI: 10.13308/j.issn.2095-9354.2021.01.010.

[11] ZHENG Bo, DU Xiao, WANG Jian, et al. Research on architecture design of smart healthcare based on 5G network technology in the field of mobile stroke emergency system [J]. Chinese Journal of Stroke, 2021, 16(1): 7-14. DOI: 10.3969/j.issn.1673-5765.2021.01.002.

[12] FASSBENDER K, GROTTA J C, WALTER S, et al. Mobile stroke units for prehospital thrombolysis, triage, and beyond: benefits and challenges [J]. Lancet Neurol, 2017, 16(3): 227-237. DOI: 10.1016/s1474-4422(17)30008-x.

[13] Shanxi Provincial Medical Association Electrocardiography Information Committee, Shanxi Provincial Physicians Association Electrocardiography Branch. Shanxi Province dynamic electrocardiogram major positive value prompt recommendations [J]. Journal of Practical Electrocardiology, 2018, 27(6): 442-443.

[14] Heart Rate Variability Task Force of the Editorial Board of Chinese Journal of Cardiology, SUN Ruilong, WU Ning, et al. Recommendations for clinical application of heart rate variability testing [J]. Chinese Journal of Cardiology, 1998, 26(4): 252-255.

[15] QASEEM A, DALLAS P, OWENS D K, et al. Diagnosis of obstructive sleep apnea in adults: a clinical practice guideline from the American college of physicians [J]. Ann Intern Med, 2014, 161(3): 210. DOI: 10.7326/m12-3187.

[16] PADDY M, BARRETT, MB B, et al. Comparison of 24-hour holter monitoring with 14-day novel adhesive patch electrocardiographic monitoring [J]. Am J Med, 2014, 127(1): 95.e11-95.e17. DOI: 10.1016/j.amjmed.2013.10.003.

[17] REED M J, GRUBB N J, LANG C C, et al. P422Diagnostic yield of an ambulatory patch monitor in patients with unexplained syncope after initial evaluation in the Emergency Department: the PATCH-ED study [J]. Europace, 2018, 20(suppl_1): i79. DOI: 10.1093/europace/euy015.233.

[18] CHEN Xiuling, LIU Ming, YANG Jing. Clinical application value of single-lead long-term dynamic electrocardiogram [J]. Journal of Practical Electrocardiology, 2018, 27(4): 269-272, 278. DOI: 10.13308/j.issn.2095-9354.2018.04.011.

[19] SENATORE G, STABILE G, BERTAGLIA E. Role of transtelephonic electrocardiographic monitoring in detecting short-term arrhythmia recurrences after radiofrequency ablation in patients with atrial fibrillation [J]. ACC Curr J Rev, 2005, 14(7): 31. DOI: 10.1016/j.accreview.2005.06.057.

[20] WANG Zhichen, FENG Jingyi. Smart healthcare system based on IoT technology in China and its development and application [J]. China Medical Devices, 2022, 37(1): 174-179. DOI: 10.3969/j.issn.1674-1633.2022.01.044.

[21] ZHANG Yingqian. Research progress on mechanisms of ischemic arrhythmia [J]. Medical Recapitulate, 2011, 17(21): 3210-3213. DOI: 10.3969/j.issn.1006-2084.2011.21.004.

[23] JIE X, GUREV V, TRAYANOVA N. Mechanisms of mechanically induced spontaneous arrhythmias in acute regional ischemia [J]. Circ Res, 2010, 106(1): 185-192. DOI: 10.1161/circresaha.109.210864.

[24] KLEIGER R E, MILLER J P, BIGGER J T Jr, et al. Decreased heart rate variability and its association with increased mortality after acute myocardial infarction [J]. Am J Cardiol, 1987, 59(4): 256-262. DOI: 10.1016/0002-9149(87)90795-8.

[25] CASOLO G C, STRODER P, SIGNORINI C, et al. Heart rate variability during the acute phase of myocardial infarction [J]. Circulation, 1992, 85(6): 2073-2079. DOI: 10.1161/01.cir.85.6.2073.

[26] NISHIHATA Y, TAKATA Y, USUI Y, et al. Continuous positive airway pressure treatment improves cardiovascular outcomes in elderly patients with cardiovascular disease and obstructive sleep apnea [J]. Heart Vessels, 2015, 30(1): 61-69. DOI: 10.1007/s00380-013-0451-x.

[27] SHI J, PIAO J Y, LIU B, et al. Obstructive sleep apnea increases systolic and diastolic blood pressure variability in hypertensive patients [J]. Blood Press Monit, 2017, 22(4): 208-212. DOI: 10.1097/MBP.0000000000000259.

[28] LIANG J X, ZHANG X M, LUO Y X, et al. The impact of respiratory events on the autonomic nervous system during sleep [J]. Int Heart J, 2018, 59(2): 378-386. DOI: 10.1536/ihj.16-429. [PubMed]

[29] LI Qianqing, LIU Yuqiong, HUANG Haiming. Effects of sleep disorders on ventricular repolarization and cardiac electrical activation conduction [J]. Journal of Practical Electrocardiology, 2022, 31(1): 49-54. DOI: 10.13308/j.issn.2095-9354.2022.01.010.

[30] BENJAFIELD A V, AYAS N T, EASTWOOD P R, et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis [J]. Lancet Respir Med, 2019, 7(8): 687-698. DOI: 10.1016/S2213-2600(19)30198-5.

[31] Sleep Medicine Branch of Chinese Geriatrics Society. Expert consensus on diagnosis and evaluation of sleep apnea syndrome in the elderly [J]. Chi-

nese General Practice, 2022, 25(11): 1283-1293. DOI: 10.12114/j.issn.1007-9572.2022.0014.

[32] NIE Shaoping, HAO Wen. Obstructive sleep apnea-hypopnea syndrome: a new direction for risk factor control and prevention of cardiovascular disease [J]. Chinese Journal of Cardiovascular Research, 2020, 18(12): 1057-1060. DOI: 10.3969/j.issn.1672-5301.2020.12.001.

[33] HUA Yingying, GAO Lina. Analysis of patients' two-way referral decision-making behavior based on prospect theory [J]. Medicine and Society, 2022, 35(10): 52-56. DOI: 10.13723/j.yxysh.2022.10.010.

[34] JIANG Chengbang, CHEN Shui, GU Xiang. Current status and countermeasures of two-way referral between district/county hospitals and community health service institutions [J]. Jiangsu Medical Journal, 2016, 42(3): 356-357. DOI: 10.3969/j.issn.1672-4232.2013.03.003.

[35] ZHONG Yanshan. Study on influencing factors of two-way referral between hospitals and community health service institutions under the background of new medical reform [J]. Accounting Learning, 2020(20): 148-149. DOI: 10.3969/j.issn.1673-4734.2020.20.074.

[36] PAN Shulan. Analysis of problems in two-way referral of inpatients between tertiary hospitals and community health centers [J]. Clinical Research and Practice, 2016, 1(17): 190-190, 193. DOI: 10.3969/j.issn.1671-8631.2013.01.036.

[37] UKWAJA K N, ALOBU I, NWEKE C O, et al. Healthcare-seeking behavior, treatment delays and its determinants among pulmonary tuberculosis patients in rural Nigeria: a cross-sectional study [J]. BMC Health Serv Res, 2013, 13(1): 1-9. DOI: 10.1186/1472-6963-13-25.

[38] FU Hua, FU Dongbo, GAO Junling, et al. Innovating community health service processes to address challenges of chronic diseases brought by aging and other factors [J]. Chinese Preventive Medicine, 2010, 11(11): 1138-1140. DOI: 10.3321/j.issn:0254-6450.2008.09.005.

(Received: February 20, 2023; Revised: May 20, 2023)

Figure 1 Management pathway process for high-, medium-, and low-risk patients [Figure 1: see original paper]

Table 1 Statistics on the management rate of patients with medium and high comprehensive risk

Note: Figure translations are in progress. See original paper for figures.