Advances in the Application of eHealth Technology for Home Management of Heart Failure Patients: Postprint

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Abstract

Heart failure is a cardiovascular disease that poses a serious threat to global public health, characterized by a chronic and protracted disease trajectory. Effective home-centered management is crucial for symptom control and improving patient prognosis. Electronic health (e-health) technology represents a research hotspot in the field of home management for heart failure, offering the advantage of overcoming temporal and spatial barriers to enable continuous health status monitoring, intelligent assessment, and dynamic management for home-based patients. This article provides a systematic review of e-health research related to home management of heart failure patients, examining its application value in medication management, exercise rehabilitation, symptom management, risk prediction, and other domains, while concurrently analyzing and prospecting limitations such as suboptimal digital inclusivity of e-health systems, incomplete operational frameworks, and data security risks, with the aim of providing reference for innovating home management models for heart failure patients.

Full Text

Application Progress of Electronic Health Technology in Home Management of Patients with Heart Failure

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Abstract

Heart failure is a cardiovascular disease that poses a serious health risk to the global population and is characterised by a chronic and prolonged disease course. Effective management centered on home care is essential for controlling symptoms and improving patient prognosis. Electronic health (e-health) technology is one of the hotspots in the research field of home management of heart failure, with the advantage of overcoming temporal and spatial barriers, and can achieve continuous monitoring, intelligent assessment, and dynamic management of the health status of patients at home. This paper systematically sorts out the related research on e-health in home management of patients with heart failure, and discusses its application value in drug management, exercise rehabilitation, symptom management, risk prediction, and other aspects of patients with heart failure. It also analyzes and prospects the limitations of the e-health system such as poor digital inclusion, imperfect operation system, and risk of data security. The purpose of this study is to provide reference for the innovation of home management model for patients with heart failure.

Key words: Heart failure; Electronic health; Home management; Mobile health; Review

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Heart failure (hereinafter referred to as HF) is a complex clinical syndrome in the middle-to-late stages of all cardiovascular diseases, resulting from abnormal changes in cardiac structure and/or function due to various causes. Statistics show that approximately 64.3 million people suffer from HF globally, with about 8.9 million in China. The hospitalization burden, readmission rates, and mortality rates remain high, posing a tremendous challenge to global public health systems. While novel pharmacological and device therapies have improved outcomes for HF patients, discharged patients still face a 50% risk of readmission, indicating that the home management aspect of HF remains relatively weak. The "explosive" development of Internet Plus Healthcare and the COVID-19 pandemic have accelerated the transition of HF management from a hospital-centered to a home-centered model, making patients recognize the necessity of integrating electronic health (e-health) technology into home management planning. E-health technology breaks through temporal and spatial barriers and serves as an important means to achieve continuous monitoring, intelligent assessment, and dynamic management of patients' health status at home, which can effectively improve the effectiveness of home management for HF patients and reduce hospitalizations. This article systematically reviews research progress in the field of e-health for home management of HF patients, primarily from the perspectives of e-health technology overview, home management applications for HF patients, existing limitations and countermeasures, aiming to provide references for further development of e-health management services for HF patients in China.

1. Overview of e-health Technology

The origin of e-health technology can be traced back to the late 20th century, when it was considered an innovative approach that utilized the convergence of wireless communications, computer-telephone interactive voice response, and the internet to provide medical services to users. In recent years, with the widespread popularization of smart electronic devices and mobile terminals, the connotation of e-health technology has continuously expanded. In 2016, the WHO defined e-health technology as information and communication technology applied in the healthcare field, a general term for a series of tools that support and promote health care, prevention, diagnosis, treatment, monitoring, and management. Its application forms have gradually evolved from early single modalities such as short message services and structured telephone support to new integrated digital collaboration forms embedded with mobile applications (APPs), wearable devices, the internet, social platforms, telemedicine systems, and electronic health records (EHR). These can provide structured disease management processes for home-based patients and enable patients to actively participate in self-management through empowerment. E-health utilizes home monitoring systems and patient self-reporting mobile terminals to collect and monitor data, provide diagnosis and alerts, and simultaneously provide healthcare teams with patients' historical blood pressure, body weight, symptoms, medication lists, and latest laboratory reports to adjust medication, enabling timely detection of disease deterioration and prevention of rehospitalization. Additionally, healthcare teams can provide tailored health behavior guidance and decision support based on e-health cloud data, reducing time investment for medical staff and creating time for managing more patients. The interactive integration of e-health technology with the medical field has gradually become a hotspot in disease management.

2. Applications of e-health Technology in Home Management of HF Patients

2.1 Home Medication Management

Medication therapy and adherence are important factors in home medication management. Guideline-directed medical therapy (GDMT) is the primary method for reducing HF mortality and hospitalization rates. Medication management systems based on implantable cardiac devices, wearable devices, and mobile APPs have been widely applied in the field of GDMT for HF. Implantable cardiac devices have the advantage of directly measuring cardiac function, ensuring monitoring accuracy and sensitivity. The CardioMEMS™ system is an implantable pulmonary artery pressure (PAP) sensor approved by the U.S. Food and Drug Administration (FDA) that monitors patients' hemodynamics by measuring PAP. COSTANZO et al. analyzed the medication adjustment effects of this system and found that the intervention group had significantly more medication adjustment episodes and greater total diuretic

dose increases than the control group. Subsequent studies also found that the system generated approximately 2.5 times more total medication adjustments than the control group, and GDMT in the intervention group was significantly higher than in the control group. Wearable device-based medication titration systems, which typically consist of wearable devices, sphygmomanometers, and supporting APPs, can track patients' physiological data in real-time or periodically. The Daily Ambulatory Remote Monitoring System for HF transfers data on heart rate, blood pressure, and oxygen saturation measured by wearable devices via Bluetooth to a mobile APP and synchronizes it to cloud storage, allowing healthcare staff to access data through a main dashboard to assess patient status and gradually adjust medication dosage to maximum tolerated dose (MTD). Results showed that the proportion of patients receiving $ $50% of GDMT target dose and the percentage of patients receiving GDMT at MTD were significantly increased. The Medly system pairs the Medly program with a Bluetooth-enabled scale and blood pressure monitor, automatically sending alerts to the healthcare team when patient parameters exceed thresholds. Studies found that this system shortened the time to reach GDMT target dose. Currently, the system has embedded voice control technology and voice user interface design to better meet patient needs and increase e-health technology accessibility.

Furthermore, ensuring medication adherence is also an important issue in HF home management. In recent years, e-health technology-assisted medication adherence interventions have primarily focused on remote health systems, mobile APPs, and social media platforms, providing extensive support for medication reminders, dose tracking, and medication information storage. The MedSentry medication monitoring system consists of an electronic pillbox and an integrated monitoring center that can remind patients when they need to take medication and send reports to the monitoring center when medication is not taken or not taken according to dose, allowing the healthcare team to urge correct medication intake. DIETRICH et al. developed the AMoPac medication adherence detection package that combines N-terminal pro-B-type natriuretic peptide (NT-proBNP) with medication data to generate a multi-layered image of patient medication behavior, used to guide healthcare teams in adjusting interventions according to medication adherence levels. Chinese scholars have used mobile APPs and social media platforms to explore the potential value of remote HF management for patients' home medication use, finding that e-health technology-assisted HF management helps improve patient medication adherence and cardiac function. Currently, domestic medication management based on e-health technology is still in the exploratory development stage, with applications mainly in the form of mobile APPs and online platforms, but mature medication management systems and platforms are rare. Future efforts can draw on foreign mature experiences, fully considering China' s social and medical development status to achieve design and model innovation in e-health technology for better HF medication management.

2.2 Home Exercise Rehabilitation

Cardiovascular guidelines indicate that exercise rehabilitation is an important component of HF management, but resource, time, and transportation issues prevent the popularization of HF exercise rehabilitation. Currently, home exercise programs utilizing wearable devices, mobile APPs, virtual reality (VR) technology, and other remote platforms are gradually being applied in the field of HF exercise rehabilitation. NAGATOMI et al. used Fitbit devices to monitor patients' pulse during exercise for individualized adjustment of exercise frequency and intensity, finding that patients' 6-minute walking distance (6MWD) improved. However, wearable devices focus on single content and have not yet considered the comprehensiveness of home exercise rehabilitation. FAN Xiaoqing et al. developed a smart bracelet-based exercise rehabilitation APP covering exercise data monitoring, exercise prescription adjustment, remote exercise guidance, and health education functions, finding that the APP could improve patients' cardiac function, 6MWD, and exercise adherence. KIKUCHI et al. developed a remote rehabilitation platform (RH-01) including IoT-equipped fitness equipment, tablet computers, and wireless ECG monitoring devices, where healthcare teams set exercise intensity based on patient condition and anaerobic threshold, conducted real-time video conference monitoring of patients' aerobic exercise, and continuously monitored heart rate and ECG synchronized to the healthcare port to support exercise intensity adjustment. Preliminary results are promising, and the platform is currently undergoing multicenter clinical trials in Japan to further evaluate its safety and effectiveness for home exercise in HF. VR-intervened gamified exercise appears to be a potential means to improve exercise adherence. Exergame (Nintendo Wii) is an exercise game where patients use Wii remotes to complete bowling, tennis, baseball, and boxing games in Wii Sports, with healthcare teams regularly contacting patients and providing assistance. Results showed that patients' muscle function improved, but there was no significant effect on 6MWD, exercise adherence, or exercise self-efficacy. Considering that this study did not provide patients with a comprehensive exercise plan, this suggests that developing individualized exercise plans for patients is the future direction for exercise games. Compared with traditional exercise rehabilitation, home-based remote exercise rehabilitation meets patients' continuous rehabilitation needs in terms of time and space, eliminating barriers caused by socioeconomic, geographical, and personal factors. However, e-health-assisted home exercise rehabilitation is still in its infancy, with small scale and has not yet been popularized among most HF patients. Therefore, how to ensure the effectiveness and accessibility of remote home rehabilitation will be the focus of future research.

2.3 Home Symptom Management

Clinical Stage C HF patients exhibit congestion-related signs and symptoms (including dyspnea, fatigue, peripheral edema, etc.) that signal hemodynamic decompensation. Good symptom management plays a positive role in reducing

patient readmission rates. Symptom tracking systems using social platforms, mobile applications, and user website systems enable patients to observe trends in monitoring data and provide opportunities for self-care and early identification of symptom deterioration. GONG Chen et al. used the WeChat platform to construct an Internet Plus HF health education model, providing patients with graphic, voice, and video information support, increasing patients' opportunities to access health information. The ManageHF4Life mobile APP has functions such as self-symptom monitoring and health status indication. Patients use the APP to independently complete an 8-question symptom survey, and the APP provides patients with visualized health status risk stratification to help them quickly identify signs of HF deterioration. Healthcare teams develop symptom management plans based on patient health status categories and display the plans in corresponding colors on the patient side to enhance patients' symptom perception ability and self-efficacy. SONG Yujie et al. developed an HF management cloud platform covering four functional modules: patient health records, health diary, HF management knowledge push, and healthcare-patient communication. Patients learn symptom management knowledge through the HF management knowledge module while uploading daily HF symptoms, signs, and physiological parameters such as blood pressure and body weight through the health diary module. Healthcare staff provide disease-specific guidance to patients through the platform or telephone based on uploaded health data, effectively improving patients' symptom monitoring and recognition skills. This demonstrates that healthcare staff should not only improve patients' disease knowledge but also enhance their symptom monitoring and recognition skills to provide comprehensive support for HF patients' home self-management.

2.4 Predicting HF Decompensation Risk

E-health systems constructed based on algorithmic models can timely predict HF decompensation risk, providing opportunities for timely medical intervention. Major e-health systems include HeartLogic and Triage-HF Plus. The HeartLogic system, embedded with the HeartLogic algorithm and approved by the FDA in 2017, uses multiple sensors from implantable cardiac electronic devices (CIEDs) to obtain data, measuring first and third heart sounds (S1 and S3) and S3/S1 ratio, respiratory rate, intrathoracic impedance, nocturnal heart rate, and physical activity in real-time. The HeartLogic algorithm (with 70% sensitivity and 87.5% specificity) generates a HeartLogic HF index based on a logistic regression model using measured data. When the index exceeds a set threshold, the system sends alert notifications to clinical healthcare teams through the LATITUDETM NXT remote management system. Subsequent studies found that HF decompensation risk was 25 times higher during alert status than outside alert status, and medical intervention after remote alerts reduced HF events by nearly 3 times. Currently, the system is undergoing more clinical studies in the United States, Europe, Japan, and other countries to further verify its effectiveness and safety. Triage-HF Plus integrates the HF risk score (HFRS) algorithm, an online data management platform, and telephone

assessment tools. Based on multiple parameters measured by CIEDs including OptiVolTM (a technology for measuring lung fluid volume), patient activity, atrial fibrillation/flutter incidence and duration, ventricular pacing percentage, nocturnal ventricular rate, and heart rate variability, the HFRS algorithm classifies patients'HF decompensation risk as low, medium, or high. The high-risk and medium-risk groups had 10-fold and 2.1-fold increased risks of HF decompensation events, respectively, compared with the low-risk group. Further studies showed that the system had 98.6% sensitivity and 63.4% specificity in identifying HF decompensation. Notably, remote risk assessment still has the possibility of errors and bias and cannot replace comprehensive clinical examination. Patients at risk of HF decompensation require re-evaluation by healthcare staff to further determine their health status and provide basis for treatment and management plan adjustments. Moreover, the above algorithm systems use data from European and American populations and may not be applicable to domestic HF patients. Therefore, it is necessary to develop HF decompensation prediction systems with high sensitivity and specificity tailored to the characteristics of domestic home-based HF populations.

2.5 Other Application Areas

In addition to emphasizing medication management, exercise rehabilitation, and symptom management, HF patients should also receive attention regarding negative emotions and nutritional status due to disease recurrence and long disease course. The prevalence of anxiety and depression in HF patients is 4-5 times that of the general population, and negative emotions increase patient readmission and mortality rates, creating a vicious cycle. Studies have found that e-health technology can effectively alleviate patients' negative emotions by establishing new bonds between doctors and patients and between nurses and patients, enhancing social support. ANGERMANN et al. applied the CardioMEMS HF system in 234 HF patients with New York Heart Association (NYHA) Class III functional status, providing psychological adjustment and health guidance through telephone calls. Results showed that patients' health questionnaire depression modules significantly improved after 6 months and continued to improve after 12 months. SHAN Liping et al. used social platforms such as WeChat and QQ to communicate with patients, accept consultations, and provide rehabilitation intervention suggestions, finding that patients' anxiety and depression significantly improved. Additionally, HF patients often suffer from malnutrition due to gastrointestinal absorption disorders, chronic inflammation, and decreased appetite. ASSAAD et al. found that follow-up management based on the CardioMEMS system improved diet in 70% of patients. Domestic scholars used the WeChat platform to regularly push video, text, and image nutrition knowledge to HF patients and urged patients or caregivers to upload diet diaries through WeChat groups, with nutritionists adjusting nutrition management content based on daily dietary conditions. Results showed that patients' nutritional indicators such as serum albumin and hemoglobin significantly improved, and self-nutrition management ability also increased. This

demonstrates that e-health technology also shows potential value in improving negative emotions and nutritional management for HF patients.

3. Current Limitations of e-health Technology in Home Management of HF Patients

3.1 Poor Digital Inclusivity of e-health Technology

Digital inclusivity is defined as a strategy to ensure that all people have equal opportunities and appropriate skills to benefit from a wide range of digital technologies and systems. However, China still faces challenges in achieving digital inclusivity, including insufficient device usability and high costs, low digital literacy among vulnerable groups, and uneven geographical distribution of digital resources. YANG Qiaoyun et al. explored digital inclusivity practice pathways in developed countries and, combined with China' s local context, proposed countermeasures and suggestions to promote digital inclusivity in China from three perspectives: government "concept" and "policy" aspects, enterprise "product" and "strategy" aspects, and social "education" and "assistance" aspects, to improve the digital inclusivity collaborative mechanism with government guidance, enterprise leadership, and social participation. Therefore, future efforts should leverage government leadership, comprehensively consider local economic and social levels, formulate hardware infrastructure construction policies to support local network construction and upgrades, and improve e-health service pricing and medical insurance payment policy systems. Establishing e-health supporting product pricing and subsidy mechanisms, gradually incorporating e-health technology into medical insurance coverage, and forming a fair, unified, and sustainable e-health service system are essential. Second, focusing on digitally vulnerable groups dominated by the elderly, it is necessary to create an elderly-friendly ecological environment from the aspects of meeting population needs and matching population acceptance capabilities, and continuously cultivate digital skills of vulnerable groups through digital skill education and training methods such as "digital feedback" and "social collaboration" to enhance e-health technology adaptability. Finally, utilizing innovative technologies to continuously develop low-cost, high-performance hardware systems and develop age-friendly and specialized supporting mobile APPs, and developing e-health technology solutions with characteristics of low bandwidth, low energy consumption, and offline environments for remote areas will help promote the comprehensive application and popularization of e-health technology.

3.2 Incomplete Multi-party Operation System of e-health

The "Hospital-Community-Family"integrated whole-process management model emphasizes the coordination and continuity of in-hospital and home disease management, effectively improving home management effects by vertically integrating high-quality medical resources and bridging the "disconnection" phenomenon in home disease management contexts. E-health technology has estab-

lished a more convenient and comprehensive service and communication bridge for the multi-level integrated home management service system of "Hospital-Community-Family." However, the functional positioning of China' s "Hospital-Community-Family" triad in remote home management has not yet been clearly defined, leading to insufficient integrated management. Future research should clarify the responsibilities and obligations of hospitals, communities, and families in e-health home management, construct a localized home management model that deeply integrates e-health technology with "Hospital-Community-Family,"rationally utilize hospital resources, use communities as extension points to assist family care, provide home management services according to patients' conditions and needs, promote information sharing, real-time communication, and collaborative decision-making among hospitals, communities, and families, and explore deeper blocking factors in the full-chain management of HF home care covered by e-health technology to break operational barriers in the e-health management system and establish a high-quality, efficient, and applicable HF remote home management operation and supervision system in China, achieving more coordinated, comprehensive, and effective remote home management for patients.

3.3 Data Security Risks in e-health

Personal information security is the cornerstone of e-health interventions and receives comprehensive attention from healthcare management, healthcare providers, and patients. Although most e-health technologies have relevant privacy protection policies and access permissions, gaps still exist in real-world practice, with issues such as data leakage, data tampering, and data abuse emerging endlessly. China successively implemented the Data Security Law of the People' s Republic of China and the Personal Information Protection Law of the People' s Republic of China in 2021, but such laws still have problems such as insufficient coordination, unclear implementation processes and standards, and imperfect supervision and review mechanisms during implementation, making it difficult to effectively avoid cybersecurity and privacy security issues in e-health data. This suggests that future research should attach importance to information security construction for e-health data, improve privacy protection mechanisms such as e-health data desensitization and encryption, and lay the foundation for secure sharing and interoperability of e-health data. Blockchain technology has characteristics of distributed storage, efficient confidential sharing, and low operating costs, supporting complex permission management with multiple signatures, which is beneficial for solving e-health data security and privacy protection challenges. In addition to technological innovation, it is necessary to actively establish a tripartite linkage mechanism led by government departments, coordinated among industries, and participated in by social personnel, continuously improve and implement monitoring and review mechanisms to ensure the legalization and standardization of e-health data sharing, and facilitate the secure and efficient application of health data.

Conclusion

E-health technology has promoted the digital transformation of home management for HF patients and plays an important role in assisting HF home medication management, guiding home exercise rehabilitation, empowering home symptom management, predicting HF decompensation risk, and other aspects. However, current e-health technology applications still have problems such as poor digital inclusivity, incomplete operation systems, and data security risks. Therefore, in future applications, efforts should focus on improving e-health product design, enhancing device and technology accessibility, strengthening population digital skills, and balancing digital resources to promote digital inclusivity in e-health technology. Simultaneously, effective interaction among healthcare staff, community teams, caregivers, and patients should be strengthened to promote information sharing, real-time communication, and collaborative decision-making among the three parties. Additionally, through policy support, application of emerging confidentiality technologies, and industry supervision, e-health data security and sharing should be guaranteed to help achieve a new model of comprehensive and full-coverage HF home management, thereby improving the quality of life for HF patients.

References

[1] Chinese Society of Cardiology Heart Failure Group, Chinese Medical Doctor Association Heart Failure Professional Committee, Editorial Board of Chinese Journal of Cardiology. Chinese guidelines for the diagnosis and treatment of heart failure 2018[J]. Chinese Journal of Cardiology, 2018, 46(10): 760-789. DOI:10.3760/cma.j.issn.0253-3758.2018.10.004.

[2] GBD Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017[J]. Lancet, 2018, 392(10159): 1789-1858. DOI:10.1016/S0140-6736(18)32279-7.

[3] 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.

[4] STEVENSON L W, ROSS H J, RATHMAN L D, et al. Remote monitoring for HeartFailure management at home[J]. J Am Coll Cardiol, 2023, 81(23): 2272-2291. DOI:10.1016/j.jacc.2023.04.010.

[5] MOHEBALI D, KITTLESON M M. Remote monitoring in heart failure: current and emerging technologies in the context of the pandemic[J]. Heart, 2021, 107(5): 366-372. DOI:10.1136/heartjnl-2020-318062.

[6] SUBEDI N, RAWSTORN J C, GAO L, et al. Implementation of tel-

erehabilitation interventions for the self-management of cardiovascular disease: systematic review[J]. JMIR Mhealth Uhealth, 2020, 8(11): e17957. DOI:10.2196/17957.

[7] DELUCA J M, ENMARK R. E-health: the changing model of healthcare[J]. Front Health Serv Manage, 2000, 17(1): 3-15.

[8] World Health Organization. mHealth: use of mobile wireless technologies for public health[EB/OL]. (2017-11-27)[2023-11-02]. https://apps.who.int/gb/ebwha/pdf_{files}/EB142/B142_{
en.pdf?ua=1.

[9] CHEN Dandan, YE Zhihong, TANG Leiwei, et al. Application progress of e-health technology in self-management of chronic disease patients[J]. Chinese Nursing Management, 2020, 20(7): 1028-1033. DOI:10.3969/j.issn.1672-1756.2020.07.015.

[10] KOMAJDA M, ANKER S D, COWIE M R, et al. Physicians' adherence to guideline-recommended medications in heart failure with reduced ejection fraction: data from the QUALIFY global survey[J]. Eur J Heart Fail, 2016, 18(5): 514-522. DOI:10.1002/ejhf.510.

[11] COSTANZO M R, STEVENSON L W, ADAMSON P B, et al. Interventions linked to decreased HeartFailure hospitalizations during ambulatory pulmonary artery PressureMonitoring[J]. JACC Heart Fail, 2016, 4(5): 333-344. DOI:10.1016/j.jchf.2015.11.011.

[12] VARMA N, BOURGE R C, STEVENSON L W, et al. Remote hemodynamic-guided therapy of patients with recurrent heart failure following cardiac resynchronization therapy[J]. J Am Heart Assoc, 2021, 10(5): e017619. DOI:10.1161/JAHA.120.017619.

[13] WONG C K, UN K C, ZHOU M, et al. Daily ambulatory remote monitoring system for drug escalation in chronic heart failure with reduced ejection fraction: pilot phase of DAVID-HF study[J]. Eur Heart J Digit Health, 2022, 3(2): 284-295. DOI:10.1093/ehjdh/ztac024.

[14] BRAHMBHATT D H, ROSS H J, O SULLIVAN M, et al. Use of a remote telemonitoring platform significantly improves medication optimisation in heart failure patients[J]. Eur Heart J, 2022, 43(Supplement_2): ehac544.1094. DOI:10.1093/eurheartj/ehac544.1094.

[15] BARBARIC A, MUNTEANU C, ROSS H, et al. A voice app design for heart failure self-management: proof-of-concept implementation study[J]. JMIR Form Res, 2022, 6(12): e40021. DOI:10.2196/40021.

[16] HALE T M, JETHWANI K, KANDOLA M S, et al. A remote medication monitoring system for chronic heart failure patients to reduce readmissions: a two-arm randomized pilot study[J]. J Med Internet Res, 2016, 18(5): e91. DOI:10.2196/jmir.5256.

[17] DIETRICH F, ZELLER A, ALLEMANN S, et al. Development and acceptance of a new adherence monitoring package to identify non-adherent patients with polypharmacy in primary care: a feasibility study[J]. BMJ Open Qual, 2023, 12(1): e002155. DOI:10.1136/bmjoq-2022-002155.

[18] SUN Huixue. Feasibility and efficacy study of telemedicine applied in follow-up management of heart failure patients with preserved ejection fraction[D]. Dalian: Dalian Medical University, 2020.

[19] ZHANG Chunxiao, LI Jing, MA Shanshan. Application of extended nursing under WeChat group management mode in patients with chronic heart failure[J]. Journal of Qilu Nursing, 2022, 28(11): 19-22. DOI:10.3969/j.issn.1006-7256.2022.11.006.

[20] STEFANAKIS M, BATALIK L, ANTONIOU V, et al. Safety of home-based cardiac rehabilitation: a systematic review[J]. Heart Lung, 2022, 55: 117-126. DOI:10.1016/j.hrtlng.2022.04.016.

[21] NAGATOMI Y, IDE T, HIGUCHI T, et al. Home-based cardiac rehabilitation using information and communication technology for heart failure patients with frailty[J]. ESC Heart Fail, 2022, 9(4): 2407-2418. DOI:10.1002/ehf2.13934.

[22] FAN Xiaoqing, XUE Shenglong, JIN Liqing, et al. Observation on the application effect of family cardiac rehabilitation guided by mobile medical technology in patients with chronic heart failure[J]. Nursing and Rehabilitation Journal, 2020, 19(10): 54-57. DOI:10.3969/j.issn.1671-9875.2020.10.017.

[23] KIKUCHI A, TANIGUCHI T, NAKAMOTO K, et al. Feasibility of home-based cardiac rehabilitation using an integrated telerehabilitation platform in elderly patients with heart failure: a pilot study[J]. J Cardiol, 2021, 78(1): 66-71. DOI:10.1016/j.jjcc.2021.01.010.

[24] JAARSMA T, KLOMPSTRA L, BEN GAL T, et al. Effects of exergaming on exercise capacity inpatients with heart failure: results of an international multicentre randomized controlled trial[J]. Eur J Heart Fail, 2021, 23(1): 114-124. DOI:10.1002/ejhf.1754.

[25] JERING K, CLAGGETT B, REDFIELD M M, et al. Burden of HeartFailure signs and symptoms, prognosis, and ResponsetoTherapy: the PARAGON-HF trial[J]. JACC Heart Fail, 2021, 9(5): 386-397. DOI:10.1016/j.jchf.2021.01.011.

[26] GONG Chen, ZHANG Xian, LIN Ying, et al. Application evaluation of "Internet Plus" health education in patients with chronic heart failure[J]. Shanghai Nursing, 2022, 22(2): 1-5. DOI:10.3969/j.issn.1009-8399.2022.02.001.

[27] DORSCH M P, FARRIS K B, ROWELL B E, et al. The effects of the ManageHF4Life mobile app on patients with chronic heart failure: randomized controlled trial[J]. JMIR Mhealth Uhealth, 2021, 9(12): e26185. DOI:10.2196/26185.

[28] SONG Yujie, SUN Xinglan, TU Hui, et al. Application of "Internet Plus" hospital-family integration model in volume management of patients with chronic heart failure[J]. Nursing Practice and Research, 2022, 19(15): 2221-2225.

[29] BOEHMER J P, HARIHARAN R, DEVECCHI F G, et al. A multisensor algorithm predicts HeartFailure events in patients with implanted devices: results from the MultiSENSE study[J]. JACC Heart Fail, 2017, 5(3): 216-225. DOI:10.1016/j.jchf.2016.12.011.

[30] CALÒ L, BIANCHI V, FERRAIOLI D, et al. Multiparametric implantable cardioverter-defibrillator algorithm for heart failure risk stratification and management: an analysis in clinical practice[J]. Circ Heart Fail, 2021, 14(10): e008134. DOI:10.1161/CIRCHEARTFAILURE.120.008134.

[31] AHMED F Z, TAYLOR J K, GREEN C, et al. Triage-HF Plus: a novel device-based remote monitoring pathway to identify worsening heart failure[J]. ESC Heart Fail, 2020, 7(1): 107-116. DOI:10.1002/ehf2.12529.

[32] PIEPENBURG S M, FALLER H, STÖRK S, et al. Symptom patterns and clinical outcomes in women versus men with systolic heart failure and depression[J]. Clin Res Cardiol, 2019, 108(3): 244-253. DOI:10.1007/s00392-018-1348-6.

[33] WEN Xuemei, LU Renquan, GUO Lin. Meta-analysis of incidence and intervention effect of depression and anxiety in Chinese heart failure patients[J]. Chinese Journal of Clinicians: Electronic Edition, 2014, 8(4): 702-709.

[34] ANGERMANN C E, ASSMUS B, ANKER S D, et al. Pulmonary artery pressure-guided therapy in ambulatory patients with symptomatic heart failure: the CardioMEMS European Monitoring Study for Heart Failure (MEMS-HF)[J]. Eur J Heart Fail, 2020, 22(10): 1891-1901. DOI:10.1002/ejhf.1943.

[35] SHAN Liping, YAN Jincui, XU Yuexia. Application of Internet Plus in elderly chronic heart failure patients with patient-centered construction[J]. Journal of Cardiovascular Rehabilitation Medicine, 2023, 32(4): 341-346. DOI:10.3969/j.issn.1008-0074.2023.04.05.

[36] MATSUMURA K, TERANAKA W, TANIICHI M, et al. Differential effect of malnutrition between patients hospitalized with new-onset heart failure and worsening of chronic heart failure[J]. ESC Heart Fail, 2021, 8(3): 1819-1826. DOI:10.1002/ehf2.13279.

[37] ASSAAD M, SINGH R, SARSAM S, et al. Impact of CardioMEMS device placement on lifestyle modifications: a "pseudo-placebo" effect beyond the expected?[J]. J Int Med Res, 2018, 46(8): 3195-3199. DOI:10.1177/0300060518774123.

[38] YANG Fang, BIAN Fengli, LU Jingjing, et al. Application of family empowerment program in nutritional management of elderly patients

with chronic heart failure[J]. Modern Clinical Nursing, 2022, 21(8): 23-30. DOI:10.3969/j.issn.1671-8283.2022.08.004.

[39] YANG Qiaoyun, LIANG Shilu, YANG Dan. Digital inclusion: practice exploration and experience reference from developed countries[J]. Information Studies: Theory & Application, 2022, 45(3): 194-201. DOI:10.16353/j.cnki.1000-7490.2022.03.027.

[40] LI Yali, WANG Na. Application value of hospital-community-family integrated management model in chronic heart failure patients[J]. Shanxi Medical Journal, 2022, 51(9): 1066-1068. DOI:10.3969/j.issn.0253-9926.2022.09.032.

[41] GUAN Qiang, WU Yanling, HAN Huiqiang, et al. Discussion on privacy protection of electronic health records[J]. Chinese Medical Ethics, 2022, 35(6): 613-618. DOI:10.12026/j.issn.1001-8565.2022.06.05.

[42] National People's Congress of China. Data Security Law of the People's Republic of China[EB/OL]. (2021-06-10)[2023-11-02]. http://www.npc.gov.cn/npc/c30834/2021/06/7c9af12f5133

[43] National People' s Congress of China. Personal Information Protection Law of the People' s Republic of China[EB/OL]. (2021-08-20)[2023-11-02]. http://www.npc.gov.cn/npc/c30834/202108/a8c4e3672c74491a80b53a172bb753fe.shtml.

[44] TIAN Shenghu, CHEN Yu, XIE Chunxiang. Application prospect and challenges of blockchain technology in electronic health records[J]. Chinese Journal of Hospital Administration, 2022, 38(5): 343-346. DOI:10.3760/cma.j.cn111325-20220209-00095.

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