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Digital health interventions for cardiovascular disease: A review of recent developments

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Abstract

Digital healthcare is revolutionizing cardiovascular care by enhancing diagnostic accuracy, treatment precision, and patient management. This review highlights key advancements, including the integration of smartphones and tablets with echocardiogram transducers for remote diagnosis, particularly in underserved regions. Emerging technologies such as 3-D printing are expected to make cardiac valve replacements more affordable, while artificial intelligence (AI) is transforming diagnostic practices by improving image analysis and risk prediction. Wearable devices, equipped with sensors for monitoring heart rate, rhythm, and other vital signs, offer real-time data that aids in early detection and personalized treatment. Mobile health applications facilitate immediate cardiac care and long-term management by leveraging the portability of smartphones. The Internet of Things (IOT) further enhances cardiovascular care by enabling comprehensive, remote monitoring and efficient data management. Collectively, these innovations are not only advancing the accuracy and accessibility of cardiovascular diagnostics but also empowering patients through more personalized and proactive healthcare approaches. This review explores the impact of these technologies on improving cardiovascular health outcomes and highlights future directions for further advancements.

Keywords: Wearable Devices; Artificial Intelligence; Mobile Health; Cardiac Diagnostics; Telemedicine

1. Introduction

Digital healthcare has emerged as a game-changer in cardiovascular care, transforming the diagnosis, treatment, and management of heart diseases. Traditional methods are being enhanced and, in some cases, revolutionized by cutting-edge technologies, making healthcare more accessible and personalized. From smartphones equipped with echocardiogram transducers to the advent of AI-driven diagnostic algorithms, digital tools are bridging gaps in cardiovascular care, especially in resource-limited settings. Wearable devices now offer real-time monitoring of vital signs, such as heart rate and rhythm, providing patients and doctors with continuous data that can be crucial for the early detection and management of cardiovascular conditions. These devices, ranging from smart watches to advanced patches, are empowering patients by allowing them to track their health metrics effortlessly. Furthermore, AI is not just a buzzword but a powerful ally in predicting and managing cardiovascular risks by analyzing vast amounts of data to identify patterns that may elude human detection. Mobile health applications are also playing a critical role, making it easier for patients to manage their cardiac health on-the-go and ensuring timely interventions through improved connectivity and real-time data sharing. The Internet of Things (IOT) further enhances this landscape by integrating devices to monitor and manage cardiovascular health remotely, thus improving patient outcomes and streamlining healthcare delivery. This review focuses on these technological advancements, their impact, current applications, and future potential in cardiovascular care.

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2. Role of digital health care in cardiovascular care

Digital healthcare plays a crucial role in improving the accuracy of cardiovascular diagnosis, symptom monitoring, treatment, and lifestyle management. In settings where traditional echocardiogram machines are unavailable, using smartphones or tablets connected to echocardiogram transducers can be advantageous for diagnosing valvular heart disease, especially in resource-limited areas[1]. Looking forward, 3-D printing technology holds promise for producing affordable cardiac valves, potentially lowering costs associated with valve replacement procedures. Artificial intelligence (AI) is poised to assist radiologists by enhancing image acquisition and reconstruction tasks. Initiatives like the machine learning-based program by GE Healthcare and Canon Medical Systems aim to reduce radiation exposure during CT scans while maintaining high image quality. Advancements in cardiovascular monitoring technologies, such as utilizing everyday mobile devices and developing portable sensors with seamless wireless connectivity and AI algorithms, offer potential for delivering personalized healthcare[2]. These innovations could enable specialist-level diagnoses nearly in real-time, thereby improving healthcare quality tailored to individual patient needs. Digital health interventions have also been instrumental in assessing the impact of healthcare technologies on enhancing patient self-management and outcomes in cardiovascular care. For example, research has shown that patients recovering from acute myocardial infarctions demonstrate higher levels of patient activation in self-managing their health. In summary, digital healthcare innovations are transforming cardiovascular care by enhancing diagnostic accuracy, enabling remote monitoring, supporting personalized treatment approaches, and empowering patients to manage their health more effectively[3].

3. Emerging technologies in cardio vascular diagnostics

Artificial neural networks (ANNs) are computational models inspired by the human brain's neural structure, allowing them to learn from data and make predictions. Their integration into cardiac diagnostics represents a significant shift in how heart-related conditions are identified and predicted [4]. AI-driven diagnostic algorithms are crucial for the early detection and risk assessment of cardiovascular diseases (CVDs). By analyzing diverse datasets such as electrocardiograms (ECGs), cardiac imaging studies, and electronic health records, these algorithms enhance the accuracy and efficiency of diagnosis and risk stratification. Convolutional neural networks (CNNs), a type of deep learning model, are specifically designed for rapid data interpretation. Operating through multiple layers, CNNs process input and output data to efficiently generate outputs [5]. Unlike traditional methods that focus on specific findings like ST elevation or T-wave changes, AI technology can uncover a broader spectrum of deviations, thereby improving diagnostic accuracy and potentially enabling earlier intervention[6].

4. Wearable devices for real time cardiovascular monitoring

Wearable devices have become essential tools in digital healthcare, leveraging mobile sensors to monitor physiological and behavioural functions such as physical activity, heart rate, and sleep patterns[7]. The market for these devices, including smart watches, bands, patches, rings, medical ear buds, and smart clothing, has grown significantly [8]. These devices use a variety of sensors to track parameters like step count, activity level, heart rate variability, and blood pressure. Blood technology possesses the capability to identify signals and patterns in ECGs that may evade human interpretation. These intricate patterns and subtle signs, often unnoticed by the human eye, are detected by deep learning algorithms through extensive analysis of ECG data, including pressure, oxygen saturation, and body temperature.

For real-time cardiovascular monitoring, several sensor types are commonly used:

- Photoplethysmogram (PPG): Measures blood volume changes in microvascular tissue by emitting and detecting light on the skin. It is used to monitor heart rate, rhythm, pulse oximetry, blood pressure, and vascular aging [9,10].
- Electrocardiogram (ECG): Records electrical activity of the heart using skin electrodes, useful for monitoring heart rate, detecting arrhythmias, and diagnosing myocardial infarction. ECG patches are often used for outpatient arrhythmia detection[11,12].
- Seismocardiogram (SCG): Captures local vibrations of the chest wall during cardiac cycles using accelerometers or gyroscopes. It helps estimate cardiac timing, assess hemodynamics, and differentiate between heart failure states[13,14].
- Ballistocardiogram (BCG): Measures forces generated by the body's blood flow, often using modified scales or beds. It estimates heart rate and assesses heart failure status[13].

These wearable devices and their sensors provide non-invasive, continuous monitoring, enhancing early detection, management, and treatment of cardiovascular conditions and overall health[14].

5. Artificial intelligence in cardiovascular risk prediction

Artificial intelligence (AI) in medicine focuses on utilizing machine learning techniques to establish complex relationships among various types of data, such as behavioural patterns, system rules, and classification schemes [15]. It integrates diverse data sources, including clinical measurements, biological omics, experimental results, environmental data, and wearable device outputs, into models that describe and predict human diseases [16]. AI techniques typically fall into two categories: supervised and unsupervised learning, which are used to discover relationships and patterns in data. In the realm of cardiovascular disease prevention, AI offers significant opportunities to advance medical practice globally. For instance, in managing hypertension, AI has been employed to predict future incidences of hypertension in population-based studies. It also plays a crucial role in risk stratification and predicting the development of cardiovascular diseases like atrial fibrillation and coronary artery disease [17, 18]. Early detection of atrial fibrillation is critical for timely treatment and preventing related complications, such as strokes. Advances in heart rhythm monitoring technologies, such as single-lead ECGs from smartwatches, ECG patch monitors, and photoplethysmography, have enhanced ambulatory monitoring capabilities, improving the chances of detecting atrial fibrillation early. In coronary artery disease, AI models utilize clinical and demographic data to estimate the pretest probability of CAD, aiding in early detection and guiding personalized medical therapies. Machine learning algorithms, particularly those based on stress imaging like single photon emission computed tomography (SPECT), contribute to predicting CAD outcomes [19]. Furthermore, AI is pivotal in managing heart failure by predicting exacerbations through invasive and non-invasive devices. For example, algorithms integrated into cardiac resynchronization therapy defibrillators analyze multiple parameters such as heart sounds, intrathoracic impedance, respiration rate, and activity levels to predict heart failure exacerbations with high sensitivity. These devices utilize machine learning techniques to tailor predictions specific to each patient's condition. In summary, AI-guided medicine represents a transformative approach to combating chronic diseases like cardiovascular conditions. By leveraging advanced data analytics and predictive modeling, AI holds promise for enhancing early diagnosis, risk assessment, and personalized treatment strategies, thereby improving patient outcomes and reducing healthcare burdens [20].

6. Mobile application for cardiovascular health management

Mobile health (mHealth) utilizes smartphones and tablets to enhance medical and public health practices. Unlike traditional telehealth, mHealth benefits from the accessibility, portability, cost-effectiveness broadening access to healthcare[21,22]. In cardiac health, mHealth plays a crucial role:

- Cardiac Arrest: Mobile phones aid in improving survival rates from out-of-hospital cardiac arrest (OHCA) by supporting timely CPR and defibrillation, integral to the chain of survival(23).
- Arrhythmias: Continuous external and implantable monitors for arrhythmias can be costly and complex. Mobile apps and ECG devices connected to smartphones offer an affordable and effective means for real-time detection and management, particularly for conditions like atrial fibrillation (AF)(24).
- Myocardial Infarction (MI): Mobile health advances facilitate early intervention and improve pre-hospital care for ST-elevation MI (STEMI), enhancing ECG transmission, reducing door-to-balloon time, and lowering healthcare costs. Additionally, mobile-based secondary prevention and cardiac rehabilitation programs aid in reducing cardiovascular risk and improving outcomes for MI survivors (25,26,27).

7. Internet of things in cardiovascular care

The Internet of Things (IOT) connects physical objects equipped with sensors and software embedded in them, enabling data transmission and collection with relatively little human involvement. This technology enables remote control and access, merging the physical and digital realms to enhance efficiency, accuracy, and economic benefits [28]. These "things" can vary from tiny nanochips to large buildings, all equipped with sensors, actuators, and software for data exchange. IoT's rapid expansion is demonstrated by the anticipated increase in connected devices, expected to exceed the global population by 2020, highlighting its growing significance in daily life and its potential for substantial technological investment over the next five years. In the healthcare sector, IoT has introduced advanced applications that benefit patients, doctors, and caregivers. It improves existing systems by providing real-time patient monitoring, information management, and emergency response. Patients can use mobile apps and wearable devices to track their health data, while hospitals employ IoT for real-time healthcare delivery and personnel management. Applications include monitoring blood pressure, glucose levels, heart function, and physical fitness. IoT offers precise tracking of people, equipment, and supplies, facilitating rapid diagnosis and better resource utilization. Despite its potential to enhance patient experience, workflow, and cost savings, scalable systems are still under development [29]. Key challenges such as technological issues, safety, security, privacy, and trust need to be addressed. Although IoT is still a novel concept for many healthcare professionals, its integration into healthcare is inevitable. This paper reviews recent IoT-based healthcare technologies, exploring their architecture and functionality addressing the major challenges, including technological and security issues, and provides insights and future research directions to advance IoT in healthcare [30].

8. Challenges in digital cardiovascular health care

Securing patient data requires strong encryption and regular updates. Integrating new technologies with systems requires standardized and interoperable solutions. Ensuring equitable access through affordable devices and expanded telehealth services is crucial.Patient engagement can be enhanced through intuitive designs and effective educational resources [31]. Accurate data collection demands rigorous testing and high standards. Building trust among healthcare professionals relies on solid clinical evidence, making thorough research essential. Training providers to use new technologies effectively and addressing regulatory and cost concerns by demonstrating value and advocating for supportive policies are also critical.

9. Conclusion

Digital advancements are revolutionizing cardiovascular care, but challenges remain. The primary goal is to ensure these technologies are secure, accessible, and effective. Recommendations include implementing robust data encryption, integrating new tools with existing systems through standardized protocols, and expanding access to underserved populations. To engage patient's focus on intuitive designs and comprehensive education. Ensuring data accuracy through continuous testing and building trust with solid evidence are crucial. Additionally, investing in provider training and navigating regulatory complexities will support smoother technology adoption. Addressing cost and reimbursement issues by demonstrating the value of these innovations is essential for their broader implementation.

Compliance with ethical standards

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References

[1] Zwack CC, Haghani M, Hollings M, Zhang L, Gauci S, Gallagher R, et al. The evolution of digital health technologies in cardiovascular disease research. npj Digital Medicine [Internet]. 2023 Jan 3;6(1):1–11.

[2] Krittanawong C, Rogers AJ, Johnson KW, Wang Z, Turakhia MP, Halperin JL, et al. Integration of novel monitoring devices with machine learning technology for scalable cardiovascular management. Nature Reviews Cardiology. 2020 Oct 9;18(2):75–91.

[3] Maddula R, MacLeod J, McLeish T, Painter S, Steward A, Berman G, et al. The role of digital health in the cardiovascular learning healthcare system. Frontiers in Cardiovascular Medicine [Internet]. 2022 Nov 3;9:1008575.

[4] Sinha T, Swathi Godugu, Syed. Navigating the Future of Cardiac Diagnostics: Insights From Artificial Neural Networks. Cureus [Internet]. 2024 Feb 11 [cited 2024 Mar 22]

[5] Karatzia L, Aung N, Aksentijevic D. Artificial intelligence in cardiology: Hope for the future and power for the present. Frontiers in Cardiovascular Medicine. 2022 Oct 13;9.

[6] Muhammad Ali Muzammil, Javid S, Azra Khan Afridi, Rupini Siddineni, Shahabi M, Muhammad Haseeb, et al. Artificial intelligence-enhanced electrocardiography for accurate diagnosis and management of cardiovascular diseases. Journal of Electrocardiology. 2024 Jan 1.

[7] Goldsack JC, Coravos A, Bakker JP, Bent B, Dowling AV, Fitzer-Attas C, et al. Verification, analytical validation, and clinical validation (V3): the foundation of determining fit-for-purpose for Biometric Monitoring Technologies (BioMeTs). npj Digital Medicine. 2020 Apr 14;3(1).

[8] Ferguson T, Olds T, Curtis R, Blake H, Crozier AJ, Dankiw K, et al. Effectiveness of wearable activity trackers to increase physical activity and improve health: a systematic review of systematic reviews and meta-analyses. The Lancet Digital Health. 2022 Aug;4(8):e615–26.

[9] Varol Burak Aydemir, Supriya Nagesh, Hasan M, Fan J, Klein L, Etemadi M, et al. Classification of Decompensated Heart Failure From Clinical and Home Ballistocardiography. IEEE Transactions on Biomedical Engineering. 2020 May 1;67(5):1303–13.

[10] 10.Castaneda D, Esparza A, Ghamari M, Soltanpur C, Nazeran H. A Review on Wearable Photoplethysmography Sensors and Their Potential Future Applications in Health Care. International Journal of Biosensors & Bioelectronics [Internet]. 2018;4(4).

[11] Becker DE. Fundamentals of Electrocardiography Interpretation. Anesthesia Progress [Internet]. 2006 Jun;53(2):53–64.

[12] Steinhubl SR, Waalen J, Edwards AM, Ariniello LM, Mehta RR, Ebner GS, et al. Effect of a Home-Based Wearable Continuous ECG Monitoring Patch on Detection of Undiagnosed Atrial Fibrillation. JAMA. 2018 Jul 10;320(2):146.

[13] Inan OT, Migeotte PF, Park KS, Etemadi M, Tavakolian K, Casanella R, et al. Ballistocardiography and seismocardiography: a review of recent advances. IEEE journal of biomedical and health informatics [Internet]. 2015 Jul 1;19(4):1414–27.

[14] Inan OT, Baran Pouyan M, Javaid AQ, Dowling S, Etemadi M, Dorier A, et al. Novel Wearable Seismocardiography and Machine Learning Algorithms Can Assess Clinical Status of Heart Failure Patients. Circulation: Heart Failure. 2018 Jan;11(1).

[15] Visco V, Ferruzzi GJ, Nicastro F, Virtuoso N, Carrizzo A, Galasso G, et al. Artificial Intelligence as a Business Partner in Cardiovascular Precision Medicine: An Emerging Approach for Disease Detection and Treatment Optimization. Current Medicinal Chemistry. 2021 Oct 15;28(32):6569–90.

[16] Johnson KW, Torres Soto J, Glicksberg BS, Shameer K, Miotto R, Ali M, et al. Artificial Intelligence in Cardiology. Journal of the American College of Cardiology [Internet]. 2018 Jun;71(23):2668–79.

[17] Barabási AL, Gulbahce N, Loscalzo J. Network medicine: a network-based approach to human disease. Nature Reviews Genetics [Internet]. 2011 Jan 1;12(1):56–68.

[18] Liu Y, Chen PHC, Krause J, Peng L. How to Read Articles That Use Machine Learning: Users' Guides to the Medical Literature. JAMA [Internet]. 2019 Nov 12;322(18):1806–16.

[19] Betancur J, Mathieu Rubeaux, Fuchs TA, Yuka Otaki, Arnson Y, Slipczuk L, et al. Automatic Valve Plane Localization in Myocardial Perfusion SPECT/CT by Machine Learning: Anatomic and Clinical Validation. The Journal of Nuclear Medicine. 2016 Nov 3;58(6):961–7.

[20] Attia ZI, Noseworthy PA, Lopez-Jimenez F, Asirvatham SJ, Deshmukh AJ, Gersh BJ, et al. An artificial intelligence-enabled ECG algorithm for the identification of patients with atrial fibrillation during sinus rhythm: a retrospective analysis of outcome prediction. The Lancet [Internet]. 2019 Sep;394(10201):861–7.

[21] Ryu S. Book Review: mHealth: New Horizons for Health through Mobile Technologies: Based on the Findings of the Second Global Survey on eHealth (Global Observatory for eHealth Series, Volume 3). Healthcare Informatics Research [Internet]. 2012;18(3):231.

[22] Martínez-Pérez B, de la Torre-Díez I, López-Coronado M. Mobile Health Applications for the Most Prevalent Conditions by the World Health Organization: Review and Analysis. Journal of Medical Internet Research [Internet]. 2013 Jun 14;15(6):e120.

[23] Public-Access Defibrillation and Survival after Out-of-Hospital Cardiac Arrest. New England Journal of Medicine. 2004 Aug 12;351(7):637–46.

[24] Gussak I, Vukajlovic D, Vukcevic V, George S, Bojovic B, Hadzievski L, et al. Wireless remote monitoring of reconstructed 12-lead ECGs after ablation for atrial fibrillation using a hand-held device. Journal of Electrocardiology. 2012 Mar;45(2):129–35.

[25] Qureshi AI, Suri MFK, Guterman LR, Hopkins LN. Ineffective Secondary Prevention in Survivors of Cardiovascular Events in the US Population. Archives of Internal Medicine. 2001 Jul 9;161(13):1621.

[26] Bates ER, Jacobs AK. Time to Treatment in Patients with STEMI. New England Journal of Medicine. 2013 Sep 5;369(10):889–92.

[27] Brunetti ND, Gennaro LD, Amodio G, Dellegrottaglie G, Pellegrino PL, Biase MD, et al. Telecardiology improves quality of diagnosis and reduces delay to treatment in elderly patients with acute myocardial infarction and atypical presentation. European Journal of Cardiovascular Prevention & Rehabilitation. 2010 Dec;17(6):615–20.

[28] Zanella A, Bui N, Castellani A, Vangelista L, Zorzi M. Internet of Things for Smart Cities. IEEE Internet of Things Journal [Internet]. 2018 Feb;1(1):22–32.

[29] Laplante PA, Laplante N. The Internet of Things in Healthcare: Potential Applications and Challenges. IT Professional. 2016 May;18(3):2–4.

[30] Ma Y, Wang Y, Yang J, Miao Y, Li W. Big Health Application System based on Health Internet of Things and Big Data. IEEE Access. 2017;5:7885–97.

[31] Health care system and Health care delivery in India - Opportunities and Challenges [Internet]. Google Books. 2018 [cited 2024 Aug 5]. Available from:https://books.google.co.in/books?id=te1qEAAAQBAJ&lpg=PA60&ots=X2l0hrIQx0&dq=bhooma%20devi&lr&pg=PA60#v=onepage&q=bhooma%20devi&f=false.