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VIEWPOINT

Transforming Cardiovascular Care With Digital Health

The Past, Progress, and Promise

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Cardiovascular diseases (CVDs) remain the leading cause of morbidity and mortality, affecting 621 million people worldwide and causing approximately 20.5 million deaths annually, 80% of which occur in low- and middle-income countries (LMICs).[1] Although there has been an improvement in the age-standardized CVD-related death rates over the past 3 decades, this progress is uneven, with faster improvements in high-income countries than in LMICs. In fact, the overall trend in progress has begun to plateau and is at risk of reversing without focused collective action. The issue is further compounded by persistent inequalities in access to and distribution of preventive and curative services in lower socioeconomic groups. This has become clearly apparent during the coronavirus disease-19 pandemic, highlighting an urgent need for implementing scalable and cost-effective tools.

Digital health technologies (DHTs) offer a promising solution to bridge the existing gaps in health care delivery and provide strategies for improving health care. The concept of "digital health," however, is not new. Between the early 1970s and 2000s, terms like "telematics," "telemedicine," "telehealth," and "eHealth" were introduced over time to enhance patients' participation in their care and improve access and quality of care by delivering health services over a distance using information and communication technologies.[2] As mobile devices became more common, the World Health Organization (WHO) highlighted the importance of "mHealth" as a subset of "eHealth" and defined it as medical and public health practices supported by mobile devices, including but not limited to data collection, care delivery, patient communication, real-time medication monitoring, and adherence support.[2] In 2019, the WHO released the first evidence-based guidelines on digital health, which encompass eHealth, mHealth, interoperability and telemedicine, health information systems, the Internet of Things, blockchain, and emerging areas like big data, genomics, and artificial intelligence (AI), offering guidance to stakeholders and policymakers on implementing and scaling digital health interventions.[2]

With exponential growth in handheld and consumer wearable devices (CWDs) (eg, smartwatches, wristbands, rings, smart clothing) and software applications (apps), as well as a growing belief that "health" can take place outside of a health care setting, CVD care presents an incredible opportunity for implementing these DHTs. Healthy preventive behaviors related to diet, physical activity, nicotine exposure, sleep health, body mass index, blood lipids, blood glucose, and blood pressure can now be readily measured and tracked over time using user-friendly mobile apps or CWDs. Daily step count has become an accepted measure of exercise prescription and has been linked to improved outcomes. A meta-analysis of 15 international cohorts found that 6,000 to 8,000 steps/day in adults aged ≥60 years and 8,000 to 10,000 steps/day in those aged <60 years is associated with a lower risk of mortality.[3] However, it is worth noting that changing to a healthy behavior is more complex than just purchasing a CWD or app; therefore, incorporating behavioral science

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approaches into digital health interventions is as important.[2]

Traditionally, screening and diagnosis of CVDs have relied on clinician-led interpretation of history, examination findings, imaging, and blood test. However, advancements in CWDs and AI comprising machine learning algorithms, neural networks, and large language models have transformed CVD screening, enabling early detection and timely management. Based on photoplethysmographic signals with or without electrocardiographic (ECG) data, radial artery tonometry, and bioimpedance, smartphone connected or CWDs can measure blood pressure and track heart rate and rhythm to screen for hypertension and subclinical rhythm disorders. The Apple Heart Study, involving over 419,000 participants, showed that among those with an initial notification about irregular pulse, more than one-third had atrial fibrillation identified on a subsequently worn ECG patch monitor. Among those notified who returned an ECG patch, positive notifications were concordant with atrial fibrillation 84% of the time.[4] AI-enhanced ECGs may pick up hidden signals from electrical remodeling that naturally precedes actual structural changes in heart symptoms and detect subclinical coronary atherosclerosis, valvular disease, systolic dysfunction, and various cardiomyopathies before they manifest or become evident on standard testing.[5] These AI models, when extended to single-lead ECG acquisitions through AI-assisted stethoscopes and CWDs, can allow for an easy and scalable point-of-care platform for diagnosing both chronic (eg, cardiomyopathy) and acute conditions (eg, myocardial infarction).[5]

Another useful avenue for DHTs is to assist with chronic CVD management. Telemedicine paired with a clinical decision support system and a “task-shifting” strategy to enhance patient engagement, close communication gaps, and help provide personalized care outside of a health care setting, especially for the vulnerable sections of society (elderly, women, rural, and low socioeconomic groups) has been extensively evaluated and scaled up in India.[6] The same group, in collaboration with Chinese investigators, conducted a cluster-randomized, controlled trial and tested a simplified CVD care delivery model (community health workers plus smartphone-based electronic clinical decision support system) across 47 villages in China and India and found an improvement in medication compliance and blood pressure.[7] Similarly, smartphone-based ECG has been used to guide anticoagulation management in patients with paroxysmal atrial fibrillation and guide post myocardial infarction care involving structured exercise prescription, education, risk factor modification, and medication optimization to improve clinical outcomes and healthcare costs.[5] In patients with heart failure, DHTs can help improve symptoms, physical function, and quality of life by promoting self-care and allowing for continuous and remote monitoring. CardioMEMS, an implantable wireless remote pulmonary artery pressure monitoring device, can help recognize early warning signs of worsening heart failure, provide actionable insights for management, and prevent rehospitalizations and emergency visits.[8] In order for DHTs to be effective, it is important to consider the implementation aspect and ensure that patients have the support they need to integrate these tools into their daily lives.

During actual clinical encounters, AI can accelerate routine clinical tasks, generate detailed recommendations, and maximize direct patient care. Additionally, it can analyze large data sets to identify digital biomarkers and risk profiles and provide actionable insights into disease trajectory and management. AI tools can enable untrained individuals to perform scalable community-based screenings with portable devices, including automated ECG interpretations and handheld ultrasound for various rhythm, valvular, and myocardial disorders, facilitating risk-informed care and narrowing the gap in access to high-quality diagnostic care in remote health centers.[5] By adapting to new data, AI can maintain performance across diverse populations, improve risk prediction, and provide prognostic information in patients with cardiopulmonary disorders. In fact, the risk-predictive performance of some deep learning algorithms based on perioperative ECGs in patients undergoing cardiac or noncardiac surgeries may exceed the established risk scores.[5] Similar to their impact on clinical CVD care, DHTs hold the potential to revolutionize the field of CVD research. Mobile apps and social media can aid in patient recruitment, fundraising, and ensure long-term follow-up. Studies can include digital clinical end points like daily activity levels, which might provide superior prognostic information versus traditional measures of functional status during a clinical encounter (eg, a 6-minute walk). Innovative tools for consent based on mobile apps or video platforms have also shown promise but could pose a challenge when it comes to verifying identity and understanding of the study.

Despite the enormous potential to augment and improve CVD care, effective incorporation of DHTs into the health care system is not easy. This is particularly important in LMICs where several patient-level (low digital literacy, poor technology reliability, privacy concerns, lack of technical

TABLE 1 Key Objectives Outlined by the 2017 American College of Cardiology Task Force in the Era of Digital Health

Objective	Description
Innovation collaborative	Engaging diverse stakeholders to align new technologies with patient care needs.
Patients as partners	Promoting patient-centric innovation by enhancing patients' access to health information, consumer empowerment, and clinician activation.
Research in health care innovations	Supporting research endeavors in health care innovations with a focus on improving care for rural and underserved populations.
Compact for human-centered design	Focus on priority problems, facilitate meaningful information exchange, user (patients, caregivers, and physicians) activation, ensure dedicated infrastructure/resources, and promote cultural empowerment and best practice models to evaluate the impact of innovations on access, equity, health outcomes, and costs.
Innovation platforms	Using innovation platforms for technology development based on factors important to patients, clinicians, and health care institutions.
Milestones for innovation success	Establish milestones for innovation success and create innovation groups to guide activities across all member types, including fellows-in-training.

support, language barriers), provider-level (inadequate clinical history, demographic and lab data, time constraints, poor technology integration), and system-level (untrained staff, difficult access to digital services, health care information protection) barriers limit the widespread use of DHTs.[2] Increasingly popular CWDs and AI algorithms have outpaced the rigorous scientific scrutiny needed to ensure efficacy and safety, raising questions on their validity for large-scale use. Additionally, concerns regarding data privacy and security, high startup costs, limited reimbursement, lack of external validation, interoperability across health systems, and unclear regulatory controls only add to the existing barriers.[5] Furthermore, there is marked variability in device accuracy and measurement methods. For example, photoplethysmography-based CWDs can be inaccurate in people with dark skin, obesity, tattoos, low skin perfusion, cold temperatures, poor skin contact, ambient light, and motion. It is crucial to consider that minority and vulnerable patient groups may lack access to technology and the Internet. This digital divide may exacerbate the existing health care disparities in chronic CVD care.

Innovative-assisted telemedicine models using trained health workers to facilitate patient-doctor interactions and an interoperable, disease-agnostic platform (such as the project DigiSahayam by the Center for Chronic Disease Control, India) with connected devices can bridge this digital health divide, provide easy access to specialist consultations in remote areas, and resultant health care savings from large-scale implementation can offset the initial costs (Dr Dorairaj Prabhakaran, personal communication, July 2024). During the implementation of digital health platforms, it is critical to make provisions for internet hotspots, social incentives, gamification, and financial rewards to enhance patient engagement. Errors in photoplethysmography-based CWD measurements can be reduced to some extent using high-pass filters, improved calibration, and optical shielding. International societies and regulatory authorities must address accountability, liability, and data protection. In 2017, the Food and Drug Administration proposed an action plan for digital health regulation and certification process based on five "Excellence Principles," including patient safety, product quality, cybersecurity, clinical responsibility, and proactive culture.[2]

DHTs, including CWDs, portable technologies, and AI, have the potential to revolutionize CVD care by leveraging multiomics (genomics, proteomics, metabolomics) data to personalize medicine, guide biomarker discovery, identify new drug targets, and optimize existing therapies. Successful digital health transformation in CVD care necessitates systematic implementation studies and pragmatic trials to ensure real-world effectiveness and long-term sustainability. The 2017 American College of Cardiology Task Force outlined a few key objectives in the era of digital health (Table 1).[9] Similarly, the WHO's Global Strategy for Digital Health 2020 to 2025 and World Heart Federation's Digital Health Roadmap underscore the importance of global collaboration between governments and private stakeholders to invest in digital health, assessment of health care needs and barriers, fostering inclusive and user-friendly technology design, national digital health implementation and reimbursement strategies, enhanced digital health governance and regulatory standards, and promotion of people-centered health systems through digital health.[2,10] Future efforts should focus on longitudinal disease surveillance, building digital registries, assessing improvement in financial metrics, and ethical and equitable integration of digital health tools into clinical care.

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REFERENCES

1. Lindstrom M, DeCleene N, Dorsey H, et al. Global Burden of cardiovascular diseases and risks collaboration, 1990-2021. *J Am Coll Cardiol*. 2022;80:2372–2425.

2. Labrique A, Agarwal S, Tamrat T, Mehl G. WHO Digital Health Guidelines: a milestone for global health. *NPJ Digit Med*. 2020;3:120.

3. Paluch AE, Bajpai S, Bassett DR, et al. Daily steps and all-cause mortality: a meta-analysis of 15 international cohorts. *Lancet Public Health*. 2022;7:e219–e228.

4. Perez MV, Mahaffey KW, Hedlin H, et al. Large-scale assessment of a Smartwatch to identify atrial fibrillation. *N Engl J Med*. 2019;381:1909–1917.

5. Khera R, Oikonomou EK, Nadkarni GN, et al. Transforming cardiovascular care with artificial intelligence: from discovery to practice. *J Am Coll Cardiol*. 2024;84:97–114.

6. Jindal D, Sharma H, Gupta Y, et al. Improving care for hypertension and diabetes in India by addition of clinical decision support system and task shifting in the national NCD program: I-TREC model of care. *BMC Health Serv Res*. 2022;22:688.

7. Tian M, Ajay VS, Dunzhu D, et al. A cluster-randomized, controlled trial of a simplified Multifaceted management program for individuals at high cardiovascular risk (SimCard trial) in rural Tibet, China, and Haryana, India. *Circulation*. 2015;132:815–824.

8. Givertz MM, Stevenson LW, Costanzo MR, et al. Pulmonary artery pressure-Guided management of patients with heart failure and reduced Ejection Fraction. *J Am Coll Cardiol*. 2017;70:1875–1886.

9. Bhavnani SP, Parakh K, Atreja A, et al. 2017 Roadmap for Innovation-ACC health policy Statement on healthcare transformation in the era of digital health, big data, and Precision health: a Report of the American College of Cardiology task Force on health policy Statements and systems of care. *J Am Coll Cardiol*. 2017;70:2696–2718.

10. Tromp J, Jindal D, Redfern J, et al. World heart Federation Roadmap for digital health in Cardiology. *Glob Heart*. 2022;17:61.

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