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CHAPTER

5

Digital Technology in Heart Failure Management: Hope, Hype, or just Hep?

Prayaag Kini, Reeta Varyani

ABSTRACT

Heart failure (HF) patient cohort is an ever-growing population owing to higher longevity in current times. HF management has grown by leaps and bounds with the advent of the "Fantastic Four" concept of pharmacological management; yet there is a growing need of managing HF remotely after patient discharge to facilitate "continuity of care". The use of drugs such as angiotensin receptor-neprilysin inhibitor (ARNI) and sodium-glucose cotransporter-2 inhibitors (SGLT-2Is) combined with electronic devices for HF management has thrown up new vistas; however, there is need of continuous innovation to facilitate patient-end management and remotely monitor data from physician perspective. Also COVID epidemic brought in an urgent need to remotely manage disease in various dimensions and in a unique way facilitated the advent and use of more Artificial Intelligence (AI)-based healthcare management in general. AI has in last few years to a decade demonstrated significant capability to radically change nearly all areas of HF including diagnosis, device-guided accurate "measurement" and monitoring, eventually leading to better management. AI possesses the capability to perform tasks using similar-to-human capability by receiving input data, learning semantics from observing patterns in it, predicting results based on variates appearing repeatedly and thus formulating an analysis using various algorithms and cognitive computing eventually culminating in creation of an algorithm. In the cardiac sphere, AI can analyse raw image data from cardiac imaging techniques like electrocardiography, echocardiography, computed tomography, cardiac MRI amongst others to generate input data. AI and machine learning (ML)-based HF diagnosis using AI-Clinical Decision Support System (AI-CDSS), and deep learning with convolutional neural networks for image analysis are other exciting topics of ongoing research. The use of decision trees by rough Sets (RS), and logistic regression (LR) methods utilized to construct decision-making model to diagnose congestive HF, and role of AI in early detection of future mortality and destabilization episodes has played a vital role in optimizing cardiovascular disease outcomes. Wearables for HF and rhythm monitoring such as Apple Watch, the wearable Zio patch and the wear-on µCor patch should be accurate for clinical use, and considered more than just fancy gadgetry. Remote monitoring with devices such as remote dielectric sensing (ReDS) and intrathoracic impedance monitoring devices for HF are already on the horizon for clinical use. Eventual patient management should remain in clinical domain with digital technology playing a supportive role for the same.

Keywords: Digital health, heart failure, remote monitoring, wearables, sustainability.

INTRODUCTION

Clinical medicine, especially cardiovascular medicine, has made tremendous strides in both diagnostic and therapeutic armamentaria, leading to higher longevity and more patients surviving to older ages in the last two decades. The fallout is a unique challenge of managing a new and ever-increasing cohort of heart failure (HF) patients that has worldwide led to higher morbidity and financial implications. It is estimated that by 2030, 9.8 million people ≥18 years of age will be living with HF, representing ~50% increase in prevalence compared to 2012,[1,2] with almost half of the patients dying within 5 years of initial diagnosis.[2,3] Despite the availability of newer, effective, evidence-based treatment options such as angiotensin receptor-neprilysin inhibitor (ARNI) and the gliflozins, the prognosis remains uncertain for this subset of patients. This has ushered in the need of digital health and remote monitoring (RM) at home post-discharge, including but not limited to implantation of electronic devices which primarily use artificial intelligence (AI) for their functioning.

Where is the trade-off between expensive "fancy" digital healthcare (DH) gadgetry and effective management of HF, as of circa 2023?

RISE OF DIGITAL HEALTHCARE DESPITE THE OBITUARY OF IBM WATSON

Just over a decade ago, AI made one of its showier forays into the public's consciousness when IBM's Watson computer appeared on the American quiz show Jeopardy! that subsequently led its foray into making a bigger splash in oncological disease and management.[4] Although the machine triumphed comfortably, the next decade exemplified the numerous shortcomings of applying AI to healthcare. The brouhaha finally ended in 2022 when it was realized that data entry could be time-consuming and labor-intensive for a relatively small payoff, leading to MD Anderson finally backing out of its partnership with Watson. The two key failures of the Watson cited were interoperability and data collection and management. Watson XAI (using eXplainable AI) has resurfaced in the last 2 years—this "simpler" version of Watson based on machine learning (ML), holding more real-life applicability as per IBM.[5]

ADVENT OF DIGITAL TECHNOLOGY AND ARTIFICIAL INTELLIGENCE FOR HEART FAILURE MANAGEMENT

Digital health entails the use of various forms of information and communications technology to monitor patient health with the aim of improving outcomes of care for HF at the patient end, even after he or she is physically distanced from the treating primary physician. Mobile healthcare or "mHealth," a subset of digital health, involves the use of mobile wireless technologies to the same end[6,7] and has been applied to even diagnosis of HF using ML techniques.[7] There is ample evidence today that supports the potential role of digital health across the entire spectrum of HF, including primary prevention, early detection, and treatment options for HF, eventually reducing associated morbidity and mortality.

The diagnosis of HF can be difficult, even for HF specialists. Artificial Intelligence-Clinical Decision Support System (AI-CDSS) was designed with the potential to assist physicians in HF diagnosis using a hybrid (expert-driven and ML-driven) approach of knowledge acquisition to evolve the knowledge base with HF diagnosis. A retrospective cohort of 1,198 patients with and without HF was used for the development of AI-CDSS (training dataset, $n = 600$) and to test the performance (test dataset, $n = 598$). A prospective clinical pilot study of 97 patients with dyspnea was used to assess the diagnostic accuracy of AI-CDSS compared with that of non-HF specialists. In retrospective cohort, the concordance rate was 98.3% in the test dataset. The concordance rate for patients with HF with reduced ejection fraction (EF), HF with mid-range EF, HF with preserved EF, and no HF was 100%, 100%, 99.6%, and 91.7%, respectively. In a prospective pilot study of 97 patients presenting with dyspnea to the outpatient clinic, the concordance rate between AI-CDSS and HF specialists was a whopping 98%, whereas that between non-HF specialists and HF specialists was 76%. Thus, AI-CDSS showed a high diagnostic accuracy for HF and may be useful especially when HF specialists are not immediately available.

DID CORONAVIRUS DISEASE 2019 OPEN UP THE CASCADE OF DIGITAL HEALTHCARE AVENUES?

As more of the medical world becomes digitally empowered and "cloud connected," technology can reach the patient's bedside remotely for better HF management. OptiVol[8] and CardioMEMS[9] were two evidence-based devices already in use for RM for fluid management in HF patients. The coronavirus disease 2019 (COVID-19) pandemic forced healthcare systems to reevaluate the widespread adoption of DH approaches to HF diagnosis and care.[10] Self-monitoring of blood glucose (SMBG) or management of sugars in diabetic patients using sensors had already opened new avenues to active patient participation with limited physician contact.[11] This was closely followed by self-management of blood pressure to reduce the risk of HF rehospitalization and mortality due to HF. Reimbursement mechanisms were also forced to keep pace parallelly to enhance the usage of these DH technologies.[12]

APPLICATION OF ARTIFICIAL INTELLIGENCE-BASED DIGITAL TOOLS FOR MANAGEMENT OF HEART FAILURE

Digital technology that incorporates clinical data recording, combined with clinician feedback and structured follow-up, appears to be more efficacious and has been proven to reduce hospital readmissions.[12] Multiple forms of noninvasive mobile digital technology are now available to assist in the optimal management of HF patients, such as teleconsultations, SMS systems, smartphone applications, wearables, and RM systems **(Figs. 1 and 2)**.

Teleconsultation

Teleconsultation employs the facilities of enhanced communications technology to enable the physician to consult with patients at a distance and has been a possible solution to overburdened outpatient HF clinics. The ESC has even set guidelines on the management of HF via RM much before its enhanced popularity with the advent of the COVID-19 pandemic.[13,14]

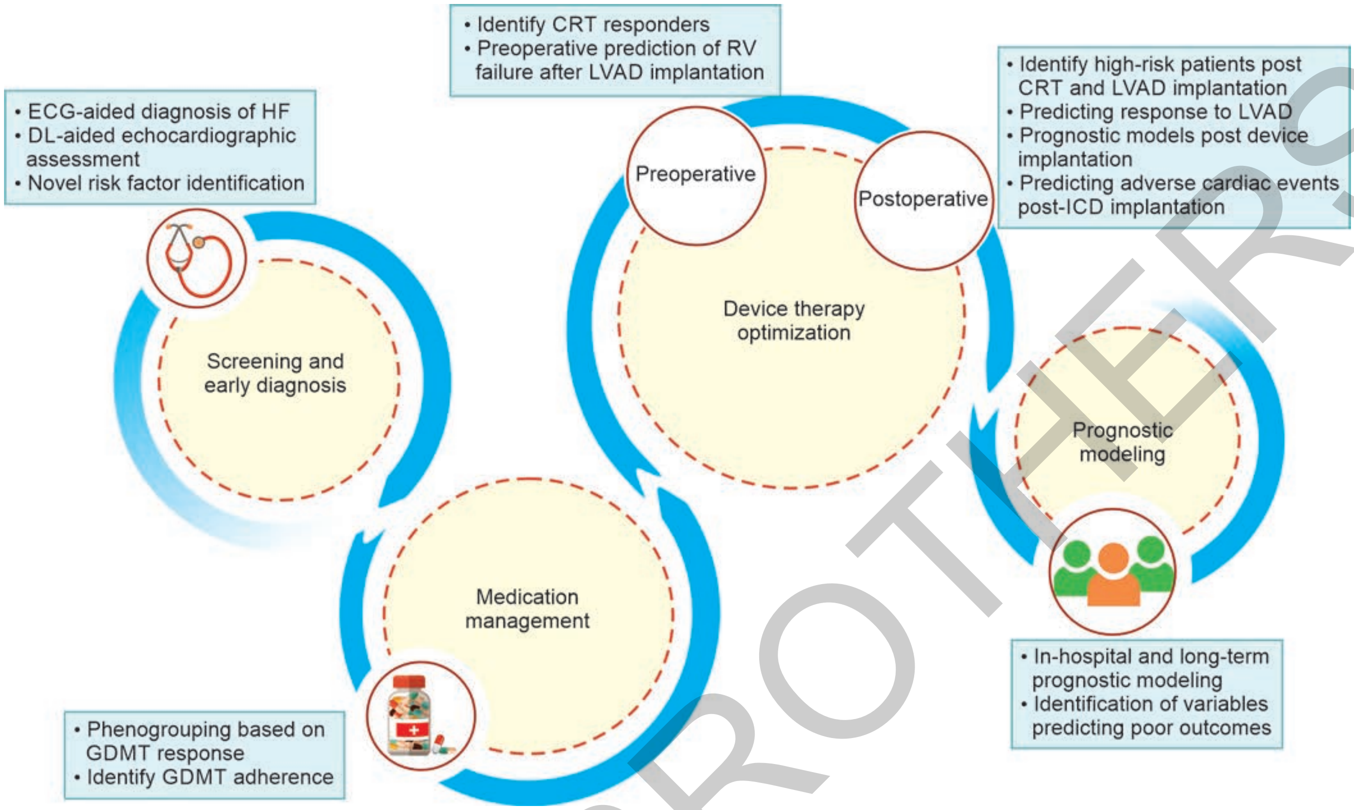

FIG. 1: Spectrum of applications of AI in HF management.

(AI: artificial intelligence; CRT: cardiac resynchronization therapy; DL: deep learning; ECG: electrocardiogram; GDMT: guideline-directed medical therapy; HF: heart failure; ICD: implantable cardioverter defibrillator; LVAD: left ventricular assist device; RV: right ventricular)

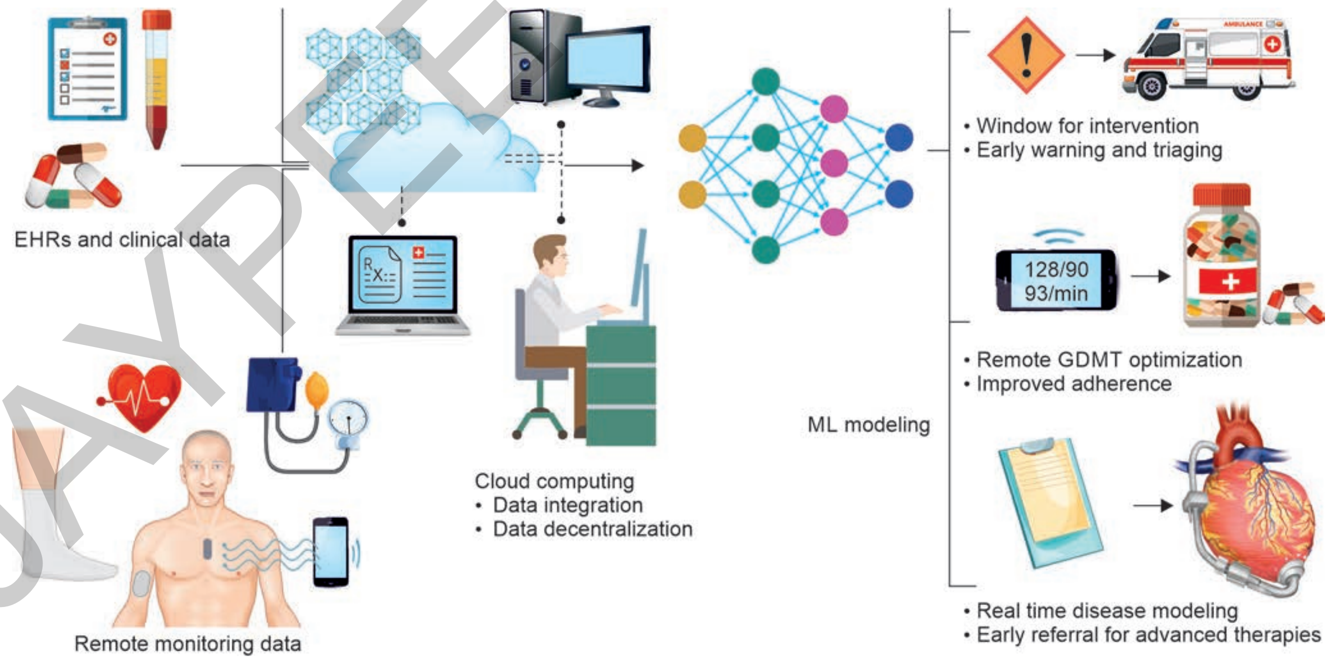

FIG. 2: Managing data accrued from remote monitoring facilities.

(EHRs: electronic health records; GDMT: guideline-directed medical therapy; ML: machine learning)

Device-based Monitoring for Decompensation of Heart Failure

Patients with symptomatic HF with severely reduced left ventricular ejection fraction (LVEF) are advised cardiac implantable electronic devices such as an implantable cardioverter defibrillator (ICD) or cardiac resynchronization therapy (CRT). These devices are periodically "interrogated" to monitor device alerts for arrhythmias, therapies provided by the machine, and device longevity and elective replacement indicators such as battery voltage. Most modern devices can wirelessly be monitored from a central healthcare specialist facility or heart station by enabling Bluetooth facilities using smartphone applications.

Intrathoracic impedance monitoring (IIM) correlates well with pulmonary fluid content, multiparametric monitoring incorporating detection of heart sounds and concomitantly studying intrathoracic impedance, patient heart rate, and heart rate variability with physical activity carries more promise scientifically **(Fig. 3)**.

The LIMIT-CHF (Lung Impedance Monitoring in Treatment of Chronic Heart Failure) trial[15] randomized to either the active group (IIM alarm turned on and diuretic dose increased by 50% for 1 week in the event of alarm sounding) or the control group (IIM alarm turned off) found no unplanned HF visits in the active group versus 0.1 ± 0.3 per patient in the control group. In another study, patients were studied with an implantable device at nine English hospitals over an average of 2.8 years to adjust therapies based on temporal results. Though it failed to show a clear mortality benefit, refined iterations of this model in time to come may prove beneficial with larger data volume. Ongoing studies may expand the choice of location of IIM, allowing a more personalized approach. Implant sites currently under investigation in first-in-human safety trials include the inferior vena cava (FUTURE-HF trial) and the left atrium [VECTOR-HF (V-LAP™ Left Atrium Monitoring systEm for Patients With Chronic sysTOlic and Diastolic Congestive heaRt Failure) trial]. Placed in the interatrial septum, preliminary results from the left atrial pressure sensor show it is likely to be safe—the readings showing a strong correlation with invasive pulmonary artery pressure (PAP) measurements and improvement in New York Heart Association (NYHA) class based on device-guided therapy.[16]

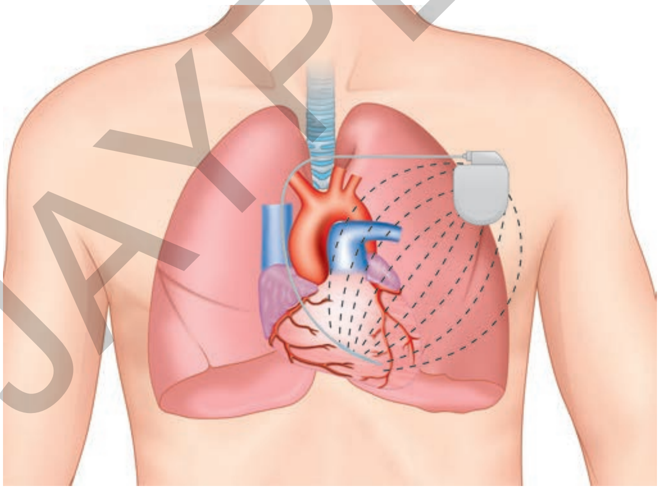

FIG. 3: Intrathoracic impedance monitoring (IIM).

The HeartLogic algorithm (Boston Scientific) was able to identify HF decompensation with a sensitivity of 70% and an unexplained alert rate of only 1.47 per patient-year, with a median lead time of 34 days before the HF event.[17] Implantable hemodynamic monitors have shown promise at preventing HF hospitalization with early detection of rise in PAP in response to increasing intracardiac left ventricular (LV) end-diastolic pressures typically preceding symptoms by up to 2–3 weeks.

Remote Dielectric Sensing (ReDS™) (Sensible Medical, USA) is an easy-to-use, noninvasive system for the monitoring and management of lung fluid in patients with HF and other chronic diseases requiring lung fluid level monitoring. ReDS technology originated in the defense technology that allows the military to see through walls and find survivors in the rubble of collapsed buildings. This was adapted for medical use by creating a system to see through the "walls" of the chest and inside the lungs of HF patients. It takes less than a minute to get a ReDS measurement at the hospital, clinic, or even in the comfort of a patient's home **(Fig. 4)**.

The use of the ReDS noninvasive lung fluid monitoring system to assess readiness for discharge in patients hospitalized with acute HF was evaluated in a pilot study by Bensimhon et al. who performed[18] ReDS measurement for all patients once they were deemed ready for discharge. Patients in the treatment arm with residual lung congestion defined by ReDS ≥ 39% had HF consultation and further diuresis. Of 108 HF patients [50% male, age 73.6 ± 12.6 years, body mass index (BMI) 29.3 ± 4.3 kg/m^2, EF 38.5 ± 15.1%, B-type natriuretic peptide (BNP) 1138 ± 987 pg/mL], 32% demonstrated residual lung congestion at the time of proposed hospital discharge. ReDS guided therapy triggered additional diuresis in 30% of the patients in the treatment arm (average weight loss 5.6 pounds, $p = 0.02$). Patients discharged as planned with residual lung congestion with ReDS ≥ 39% had higher 30-day readmission rate compared to patients who were adequately decongested at discharge with ReDS < 39% (11.8% vs. 1.4%, $p = 0.03$). They concluded that ReDS testing demonstrated that 32% of HF patients deemed ready for discharge have clinically significant residual lung congestion which was associated with a higher risk of readmission. ReDS-guided management was associated with significant decongestion but not a reduction in HF readmissions in this sample.

A further meta-analysis on the efficacy of ReDS in the prevention of HF rehospitalizations was presented by Sattar et al. among 985 patients across seven studies.[19] Patients with HF monitored with ReDS had significantly lower odds

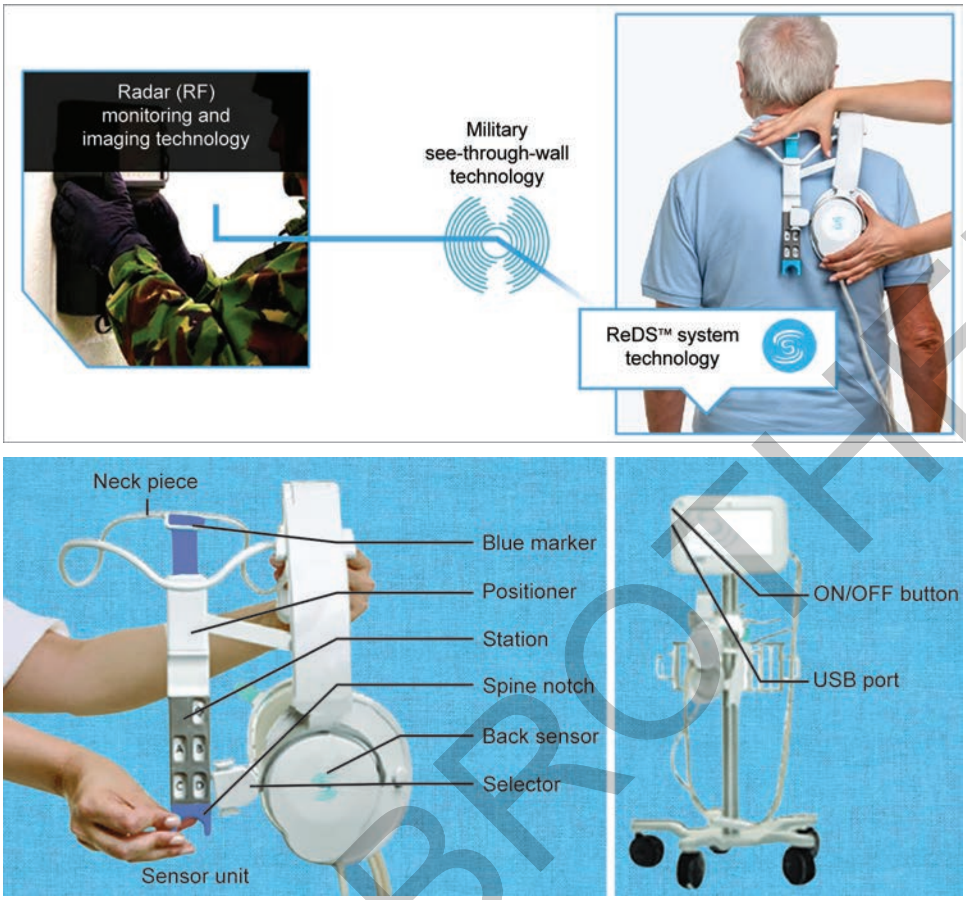

FIG. 4: Remote Dielectric Sensing (ReDS) for heart failure (HF).

of hospital readmission compared with non-ReDS patients. Subgroup analysis based on the duration of follow-up showed lower odds of readmission within 30 days as well as between 1 and 3 months. ReDS effect of lower readmissions of HF was observed irrespective of the duration of follow-up (<1 month vs. 1–3 months). ReDS monitoring significantly lowered the odds of HF readmission within 3 months compared to participants not using ReDS.

As mentioned earlier, remote daily PAP monitoring in CardioMEMS device-implanted patients had already been facilitating titration of medications, mitigating the need to be subsequently hospitalized by up to 30% and ushering in the era of AI-based fluid management.[9] The MultiSense study, MANAGE-HF (Multiple Cardiac Sensors for Management of Heart Failure) trial, and GUIDE-HF (Hemodynamic-GUIDEd Management of Heart Failure) randomized trial are more such instances in the pipeline and will impact clinical practice in the coming years.[17,20]

The European registry database shows a recent decompensation of HF portended to a 24% increased risk of death within 1 year—identification of the event before patients deteriorate therefore carries obvious implications. Simple avenues of self-monitoring by patients for their symptoms, pedal edema, weight, and blood pressure do not require complex training and can be managed even by an educated family member, and hence have been a mainstay of HF management for over two decades now and can subvert a "too little, too late" situation with patients having lost crucial time in instituting therapies in a timely manner.[21,22]

Home monitoring has proven safe and effective with even routine device checks collecting valuable physiological and rhythm data that may correlate with HF status; the main criticism however has been that device-based impedance alerts resulted in a 79% increase in HF hospitalization in one randomized trial due to both low specificity of alerts and the lack of immediate trained on-site healthcare personnel to respond to these alerts not to mention the obvious anxiety for the patient and family triggered by an audible alert at unearthly hours.[21]

In a very recent development in 2023,[22] published in Lancet Digital Health, Dr Banerjee et al. detected five ML-informed subtypes of HF, which might inform etiological research, clinical risk prediction, and the design of HF trials. They classified them as (1) early onset, (2) late onset, (3) atrial fibrillation (AF) related, (4) metabolic, and

(5) cardiometabolic. In the external validity analysis, *late onset* and *cardiometabolic subtypes* of HF were the most similar and strongly associated for hypertension, myocardial infarction, and obesity. They have developed a prototype app for routine clinical use and enable its effectiveness—large-scale use of this is eagerly awaited.

Remote Monitoring

Remote Monitoring is the use of telecommunication technologies to monitor patient status at a distance **(Fig. 5)**. In structured telephone support (STS), patients are called by a member of the HF team to discuss symptoms, drug therapy, and compliance with lifestyle measures.[23,24] STS is relatively labor intensive and costly due to gadgetry and logistic requirements, and a 2015 meta-analysis reported only a marginal mortality benefit [risk ratio (RR) 0.87 for all-cause mortality; 95% confidence interval (CI) 0.77–0.98] and reduction in HF hospitalizations (RR 0.85; 95% CI 0.77–0.93) with no effect on all-cause hospitalizations.

One randomized trial of telemonitoring in 1,571 HF patients with NYHA Class II–III symptoms and HF hospitalization in the preceding 12 months compared a wireless system, transmitting daily readings of weight, blood pressure, oxygen saturations, heart rate, and a health status questionnaire, with usual care. The composite outcome of all-cause mortality and percentage days hospitalized was reduced (RR 0.8; 95% CI 0.65–1.00). A meta-analysis of smaller randomized telemonitoring trials showed a small mortality benefit also. (RR 0.80 for all-cause mortality; 95% CI 0.68–0.94).[25]

Apps and Wearables

The last decade has seen a rapid proliferation of health apps. In 2017, it was estimated that 325,000 health apps were available on smartphones.[26] Despite this, very few of them have been designed specifically for HF patients; a 2019 review identified 10 apps focused on HF self-care available on the Apple App Store and Google Play Store. Four of these were developed by scientific societies [including the American Heart Association (AHA)] and predominantly aimed at patient education, symptom tracking, and prompting users to seek early self-care in HF.[27] While RM systems are generally "prescribed" by clinicians and often reimbursed by healthcare systems or insurance companies, apps and wearables are largely marketed directly to consumers as tools for health and lifestyle maintenance. Consumer wearables are devices that record and transmit physiological signals that can be worn, such as activity trackers and smartwatches, and these are becoming increasingly popular. Some products such as the Fitbit[28] are user-friendly and also offer irregular pulse detection, single-lead ECG, blood pressure, and oxygen saturation monitoring, and carry potential in HF self-care. The fact though remains that these wearables and HF apps have not been actually evaluated in randomized clinical trials (RCTs), and without quality evidence and clear app standards, there is need for regulation in this field.

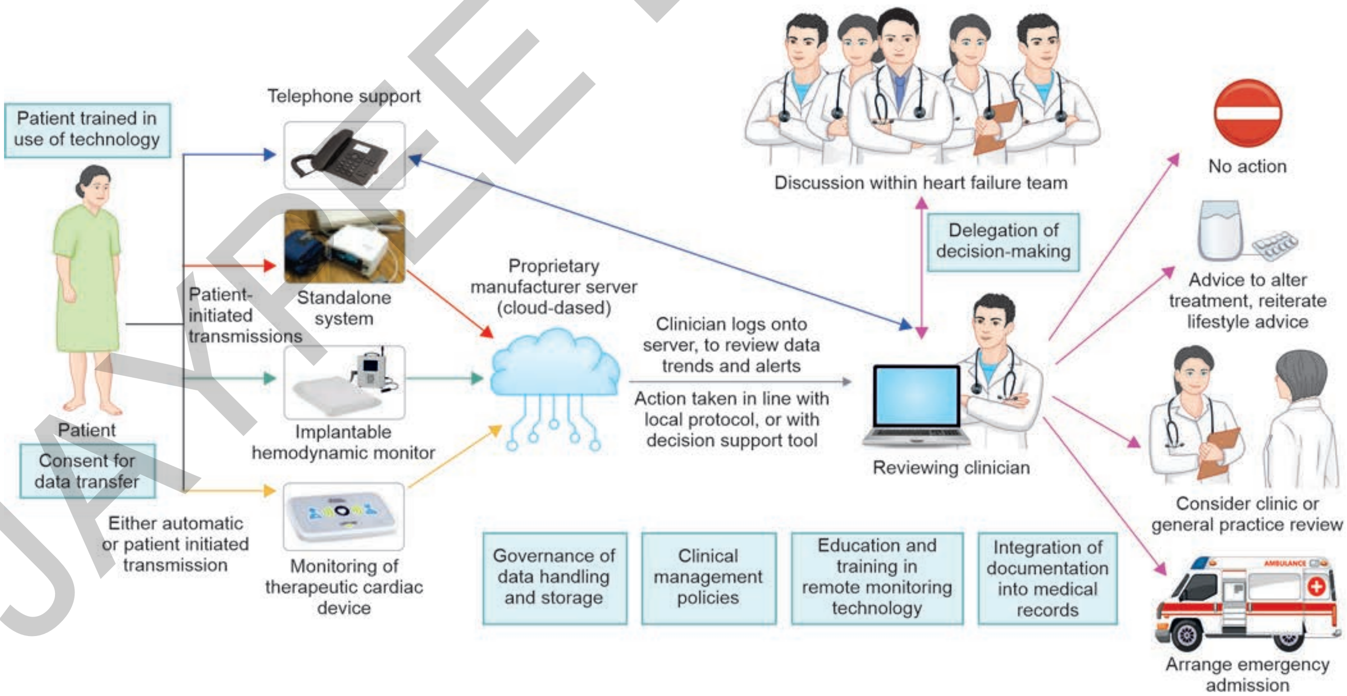

FIG. 5: Remote monitoring system's workflow for heart failure (HF) monitoring.

USING DATA FROM WEARABLES IN HEART FAILURE PATIENTS

Physical activity is an important prognostic parameter in HF and a measure of functional limitation. 6-minute walk test performance is a strong predictor of subsequent cardiac death in HF patients but is rarely used outside of research as it is cumbersome to measure. A retrospective study of 189 patients with self-reported HF showed a significant negative association between physical activity and mortality, and a prospective Japanese study of 170 HF patients showed a step count of <4,889 steps/day was a stronger predictor of mortality than VO_2 max (peak oxygen consumption, an important marker of cardiopulmonary fitness) on exercise testing.[29] However, prospective evidence of using activity monitors to guide therapy and adherence to exercise therapy in HF is lacking and not endorsed widely by authoritative bodies.[29,30] Patient acceptability of wearables, including a watch or other wrist-worn devices, is also likely to be variable.[28-30]

INCORPORATING DIGITAL TECHNOLOGY INTO ELECTRONIC HEALTH RECORDS: THE WAY AHEAD

Activity monitors in the form of a wristband/watch that use accelerometry are the most common form of wearable devices and have found easy acceptance with lay population, despite the fact that these devices have less accurate performance at low ambulation speeds.[30] Wearable heart rate monitors use photoplethysmography that relies on illumination of a capillary bed and measurement of pulsatile changes in light absorption as does an oxygen saturation probe in most critical care units. Analysis of photoplethysmogram (PPG) waveforms can help detect irregularities in pulse and therefore potentially be used for AF screening and critical decisions regarding rate or rhythm control, and potential need for lifelong anticoagulation—this especially if PPG is combined with ECG patch recording for confirmation.[31-33] Performance of PPG-based devices is best for resting heart rate and has been shown to significantly degrade with exertion, and a study of HF patients using Fitbit and Apple Watch showed poor accuracy in measuring dynamic heart rate changes. PPG alone cannot differentiate between AF and other causes of irregular pulse, but it can be combined with ECG patch recording for confirmation in patients with an irregular pulse.[32-34]

In the large-scale AF screening, Apple Heart Study using a PPG-based smartwatch algorithm with ECG patch analysis done, up to one-third of patients had confirmed AF during the subsequent 2-week recording period and 77% of irregular pulse notifications with simultaneous recording were confirmed to be AF, with atrial ectopy making up the majority of the remainder. The HEARTLINE study, recruiting 150,000 patients aged over 65 years, is investigating whether the irregular pulse detection algorithm and ECG feature lead to a reduction in stroke and death in a real-world setting.[35]

In addition to PPG and ECG features, miniature wrist oscillometric sphygmomanometers can now be incorporated into a smartwatch for blood pressure monitoring; the first such device to be licensed showed high accuracy when compared with manual blood pressure measurement at rest.[36]

MACHINE LEARNING AND DIGITAL HEALTH FOR PATIENT CARE IN HEART FAILURE

Most implanted devices can only provide short daily samples of data, but noninvasive monitors linked with smartphones can transmit continuously and allow for larger, richer datasets for analysis. ML is the proverbial "new kid on the block" in medicine, though it has been existing for decades in other fields of digital technology. ML bases itself on computers training themselves on large sample datasets to build predictive mathematical models. As the systems are able to incorporate these data with electronic health records, the resulting datasets offer the potential of studying unknown disease patterns and predictors and potentially leading to "customized" solutions (precision medicine). Algorithms using convoluted neural networks and deep learning are gaining big time on ECG and ECHO image analysis for creating stencils for more accurate, faster, and earlier diagnosis based on big data input and are exciting tools to look forward to in the future.

The LINK-HF study, for instance, investigated the use of a multisensor patch continuously measuring ECG signals, thoracic impedance, body temperature, and accelerometry in 100 HF patients with real-time continuous data uploaded to the cloud via a smartphone to create a personalized ("customized") monitoring and response system for individual patients.[37] The ML algorithm succeeded in predicting impending decompensation with a sensitivity of 88% and a specificity of 86%, a median of 6.5 days before the HF event.

Machine learning algorithms may pick up subtle ECG changes not detectable by human observers. They have shown promise in predicting future episodes of AF from sinus rhythm ECGs and even at identifying left ventricular systolic dysfunction (LVSD) from ECGs. A study from the Mayo Clinic in the United States retrospectively analyzed the ECGs of 1,606 patients without known LVSD who had a subsequent echocardiogram within 30 days.[38] The ML algorithm was able to predict LVSD (defined as an EF < 35%) with a sensitivity and specificity of 74% and 87%, respectively. The area under the receiver operating characteristic curve (AUROC) was 0.89, outperforming N-terminal pro-BNP (AUROC: 0.80) at predicting LVSD. Such algorithms are not yet in clinical practice and would need to be certified as a medical device before they would be able to be used, but they may form part of decision and diagnostic aids in the near future.

The µCor patch (Zoll) **(Fig. 6)** and Zio patch **(Fig. 7)**, equipped with an ECG monitor and radiofrequency

FIG. 6: μCor wear-on patch (Zoll) patch for detection of abnormal heart rhythms.

FIG. 7: Wearable Zio patch for atrial fibrillation (AF) detection.

transmitter measuring pulmonary fluid content, are under investigation for its ability to predict HF event, and a smart-textile vest with multiple electrodes measuring similar parameters to HeartLogic (heart rate, heart rate variability, respiratory rate, and thoracic impedance) is also under study.[39,40] Big data analysis will be required to determine whether such algorithms can be used to trigger an appropriate intervention to prevent the need for HF hospitalizations.

PSYCHOSOCIAL SUPPORT USING TELEMEDICINE-BASED COUNSELING IN HEART FAILURE

Artificial intelligence-enabled psychological support plays a large role in RM of HF patient cohort. Interactive voice response (IVR) allows patients to communicate with clinicians asynchronously using a mobile or landline telephone. Based on their responses, the patients can receive tailored feedback during the same call from the physician and also facilitate peer-to-peer support among older adults with HF by contacting them once a week using a toll-free IVR phone system.[41] Studies have noted positive effects and an improvement in depressive symptoms. In a study of HF patients using IVR by Zan et al., it was found that HF-related quality of life (QOL) scores improved from baseline in almost all participants, with the latter feeling more connected to their healthcare provider team. Studies by Clark et al. demonstrated a high acceptability rate of 78% for IVR system-(IVRS)-based technologies, especially in elderly patients due to increased engagement and support that may alleviate loneliness and social isolation.

There is ample evidence today for the benefit in HF patients accruing from tele-based psychological support and counseling. The BEAT-HF (Better Effectiveness After Transition–Heart Failure) study by Ong et al. in 2016 offered detailed HF patient education and counseling on medicines prior to hospital discharge to the patient and family, regularly scheduled telephone coaching, and home telemonitoring of symptoms and concluded that telephone support improved the QOL for patients 180 days after hospital discharge.[42] Kolasa et al. in 2020 have shown that telephone contact to a trained nurse with access to a family physician can prevent hospitalization in a quarter of HF patients. In a multisite RCT of the CASA (Collaborative Care to Alleviate Symptoms and Adjust to Illness) intervention by Bekelman et al. in 2018, it was found that secondary outcomes of depression and fatigue, both difficult symptoms to treat in HF, did improve by telecounseling.[43] In yet another RCT by Pekmezaris in 2018 that compared telemedicine versus a comprehensive outpatient management program, there was a demonstrated reduction in both anxiety and depression over the study period of 90 days.[44] Koehler et al., in the TIM-HF2 (Telemedical Interventional Management in Patients with Heart Failure) study in 2018, studied the efficacy of a structured remote patient management intervention in HF patients—there was significant improvement in the QOL and reduction in the rate of lost days due to unplanned hospital admissions for cardiovascular causes and mortality from any cause.[45] Studies by Mao-Huan et al. and Kuan et al. found that HF patients who received diet, medication, and lifestyle teaching via real-time IVRS with nurses improved their mental health status, QOL scores, and decreased rehospitalization over a 1-year period.[46,47]

BARRIERS TO "BLANKET APPLICATION" OF DIGITAL TECHNOLOGY FOR HEART FAILURE PATIENTS

Healthcare is human science and technology ought to reflect the clinical nature of it. Technology firms marketing health apps and wearable devices "sell" their products online as "health and wellness" products rather than tools for disease management. Currently, there is no clinical regulatory authority checking their claims and accuracy and few RCTs have validated their use in large-scale populations—for the common man, they are more appealing and fancier than the need to be truly reflective of devices used for improving healthcare status.[48] "Black-box decisions" made by programs such as IBM Watson could not explain clinical real-life events, leading to their questionability. Artifacts during recording or transmission add to fear and confusion, impeding their wider applicability, especially for AF detection. Privacy policies and legalities involved due to data protection regulations of many medical apps and wearables may not meet standards set for data storage, control, and processing by the Food and Drug Administration (FDA).[13,49] Incorporating wearable data into electronic health records needs a dedicated and savvy workforce since it requires manual input.

Second Big Barrier in the Sustainability of this Healthcare System[49,13]

Digitalization and use of technology comes with a cost—the "COST"!! Teleconsultation following the detection of an abnormal rhythm or alert is associated with a significant start-up cost for equipment and requires personnel training and software licenses. Following the COVID-19 pandemic, there has been a big push on this front, but still RM systems need to prove themselves on both counts, clinical and cost-effectiveness, in different healthcare settings, both in nations where third-party payment for healthcare facilities is the norm and in countries such as India where it is not and patients pay out of their pocket for the same.

KEY POINTS

- HF cohort is an ever-increasing population with continuing research happening into its myriad etiologies, early diagnosis, treatment, and avenues for home monitoring after discharge.
- AI- and ML-based HF diagnoses using AI-CDSS and DL with convolutional neural networks for image analysis are other exciting topics of ongoing research.
- The use of drugs such as ARNI and sodium-glucose cotransporter-2 inhibitors (SGLT-2Is) and electronic devices for HF management have thrown up new vistas; wearables for HF monitoring should be accurate and used more than just fancy gadgetry.
- RM with devices such as ReDS and IIM are on the horizon for clinical use.
- Eventual patient management should remain in clinical domain with digital technology playing a supportive role for the same.

CONCLUSION

Digital health technologies have emerged as potentially useful tools to complement HF care in both research and clinical realms. As they continue to play an increasing role in transforming healthcare delivery at the patient bedside by allowing RM facilities and bringing healthcare at the patient bedside after discharge, they are also creating their own framework for effective use. Regulatory practices will certainly be essential to ensure that digital health applications maintain accuracy and patient privacy along with consistently improving outcomes and enhancing care for HF patients. They should not encroach upon clinical sensibilities of the treating physicians by always keeping in mind that medicine is eventually a science on humans and not tech gadgetry.

ONLINE REFERENCES

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In recent years, the field of cardiology has witnessed remarkable advancements that have revolutionized the management of cardiovascular diseases. The development of wearable devices, smartphone applications, and telemedicine platforms has made remote monitoring and management of cardiovascular conditions a reality. Minimally invasive procedures such as transcatheter aortic valve replacement (TAVR), transcatheter mitral valve replacement (TMVR), MitraClip, and imaging-guided coronary intervention have revolutionized the treatment outcomes.

This book aims to provide a comprehensive overview of these recent advances in cardiology. Our esteemed contributors, who are renowned experts in their respective areas, have meticulously examined the latest evidence and shared their invaluable insights in the book. It is our sincere hope that this book will benefit all of us.

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