Heart & Lung - The Journal of Acute and Critical Care xxx (xxxx) xxx

Contents lists available at ScienceDirect

Heart & Lung

journal homepage: www.heartandlung.com

Integrated Health Technologies in Heart Failure: A Scientific Statement From the Heart Failure Society of America and the American Association of Heart Failure Nurses☆

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ARTICLE INFO

Keywords:
Heart failure
digital therapeutics
medical therapy
quality improvement
implementation science

ABSTRACT

Integrated health technologies (IHTs) have emerged as promising tools for improving heart failure (HF) management by facilitating care coordination and enabling timely clinical intervention. This joint scientific statement from the Heart Failure Society of America and the American Association of Heart Failure Nurses summarizes current evidence about the use of IHTs in HF management, including traditional telemonitoring, mobile health-based remote monitoring, and implantable devices. IHT interventions have demonstrated benefits, such as improved quality of life and reduced hospitalization rates, but their effectiveness varies, depending on patients' adherence, clinical integration, and feedback mechanisms. Challenges to widespread implementation of IHTs include suboptimal patient engagement, disparities in digital literacy and access, lack of interoperability between systems, concerns about data privacy and security, disruptions to clinician workflow, and substantial start-up and maintenance costs. This statement outlines strategies to overcome these challenges, including enhancing patients' engagement through personalized, actionable feedback; improving digital literacy and access; advancing interoperability; ensuring data security; engaging clinicians during implementation to facilitate seamless integration; and expanding reimbursement. Finally, the statement proposes key priorities for future research, including the use of automation and machine learning to reduce clinician burden, the integration of emerging technologies that reduce patient burden, and the evaluation of cost-effectiveness to support broader implementation.

Introduction

Heart failure (HF) remains an important public health issue, with rising prevalence driven by an aging population and improved survival rates following initial diagnoses due to advances in life-saving treatments.[1] Despite advances in pharmacological and device-based

☆ This paper was jointly developed by Journal of Cardiac Failure, Heart and Lung and jointly published by Elsevier Inc. The articles are identical except for minor stylistic and spelling differences in keeping with each journal's style. Either citation can be used when citing this article.

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https://doi.org/10.1016/j.hrtlng.2025.11.020

therapies, HF management remains suboptimal. Many patients with HF are not initiated on or titrated to guideline-directed medical therapy (GDMT), often due to gaps in treatment intensification, limited access to specialty care, or poor care coordination.[2–4] Delays in post-discharge follow-up, inadequate self-management support, and fragmented communication among providers contribute to avoidable readmissions and worsening clinical outcomes.[5,6] These challenges are particularly pronounced among patients receiving care across multiple health care settings or residing in underserved areas with limited access to HF-trained clinicians.[7–9] Given these persistent challenges, integrating health technologies—such as remote monitoring, telehealth, mobile health devices and applications, and electronic health record (EHR)--based decision support—offers a promising solution to enhance continuity of care, improve therapy optimization, and support timely clinical interventions across the HF-management continuum.

This scientific statement builds on prior efforts by offering a unified framework for implementing integrated health technologies (IHTs) into HF management. Unlike previous statements[10–12] that focused on individual technologies in isolation, this statement emphasizes the combined use of these tools and their integration into clinical workflows. We examine the current evidence concerning the effectiveness of IHTs, explore key implementation barriers, and identify potential strategies to enhance scalability and interoperability, and support clinical decision making. By bridging siloed technologies and aligning them with the needs of patients and clinicians, IHTs have the potential to close critical gaps in HF management and improve outcomes across diverse health care settings.

Defining Integrated Health Technologies and Related Terms

In this statement, IHT is defined as the combined use of multiple technologies to improve the delivery and coordination of care across clinicians and care settings. These technologies include electronic health records, telehealth, mHealth applications, wearable devices, and implantable devices (Fig. 1). Definitions of IHTs are provided in Table 1.

Overview of IHT Interventions for Heart Failure Management

This section summarizes evidence from key randomized controlled trials (RCTs) that examined the impact of IHT interventions on patients' outcomes, including hospitalizations, mortality rates, and quality of life.

A rapid literature search was conducted across 5 databases (PubMed, Embase, Scopus, PsycINFO, and CINAHL) by using search terms related to HF and IHT, such as HF management, EHRs, telemedicine, telehealth, telemonitoring, remote monitoring, mobile health, mHealth, eHealth, digital health, wearable devices, intracardiac pressures, multiparametric signals, cardiac implantable electrical devices, and cardiopulmonary physiology. The search was limited to English-language articles.

To align with the focus of this statement, interventions were excluded if they involved only a single technology (eg, a stand-alone mHealth app) or if they did not actively engage patients in managing their own conditions (ie, no actionable clinician feedback based on patient-generated data). Additionally, studies that did not include patient-facing technologies (eg, clinical decision-support tools, predictive analysis interventions) were also excluded.

Table 2 summarizes the key characteristics and outcomes of the included RCTs. Fig. 2 illustrates the common components of IHT interventions.

Traditional Telemonitoring

Traditional telemonitoring interventions, which relied primarily on landline telephones and personal computers (ie, non-mobile devices), were designed to monitor physiological parameters, such as weight, blood pressure, and heart rate. These systems typically triggered alerts when values exceeded predetermined thresholds, prompting follow-up

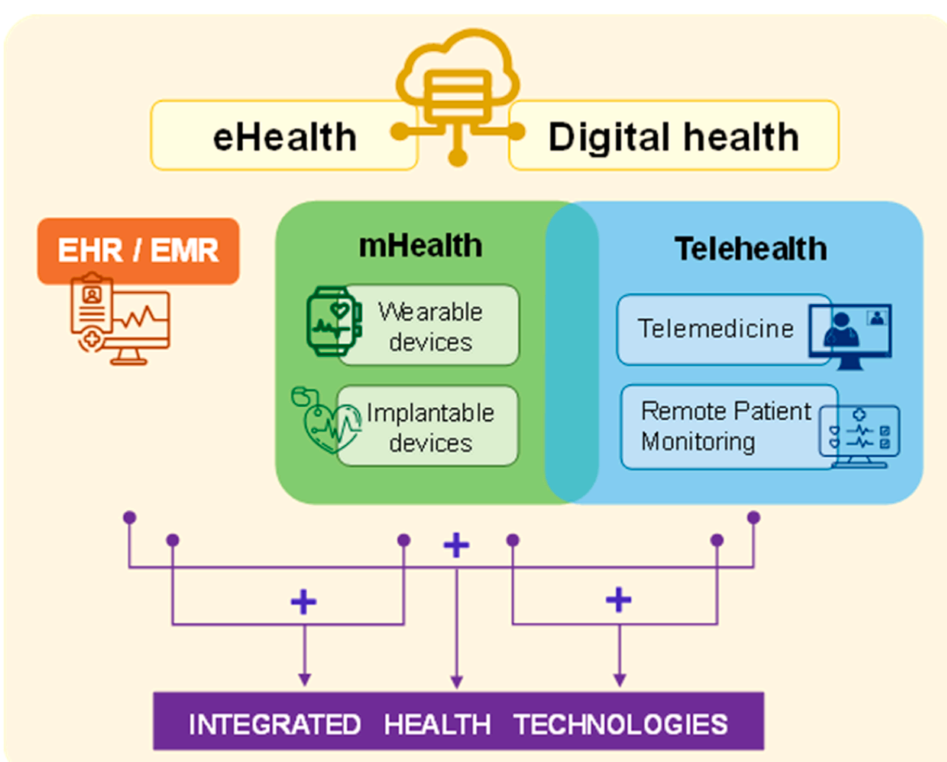

Fig. 1. Integrated health technologies and related concepts. There are many health technologies that may enhance heart failure care delivery; those selected are defined in Table 1 and are highlighted in this figure. These technologies are often considered as individual entities, but there is a major need for integration so as to enhance longitudinal care for patients with heart failure. EHR, electronic health records; EMR, electronic medical records; mHealth, mobile health.

Table 1
Definitions of related terms.

Term	Definition
Electronic Health (eHealth)	The use of the internet and related technologies to enhance the delivery of health services and information[56]
Digital Health	The use of information and communication technologies in health care to improve health care delivery and patient outcomes[57,58]
Electronic Health Records (Ehrs) or Electronic Medical Records (EMRs)	The electronic (digital) collection of a person's health data, including information such as diagnoses, tests, medications, and treatment plans[59]
Telehealth	The use of communication technologies to provide health care at a distance[60,61]; this includes a wider variety of health care services provided by nurses, pharmacists, or social workers, including patient education, medication adherence, and social support.[60]
Telemedicine	The use of telecommunication technologies to support the delivery of medical, diagnostic, and treatment-related services by healthcare providers[60]
Mobile Health (mHealth)	The use of mobile computing, medical sensors, and wireless communication technologies for health care[62]
Wearable Device	A device that can be worn on the body to monitor and transmit the individual's activity and/or physiological data[63]
Implantable Device	A medical device that is either partly or totally introduced surgically or medically into the body and is intended to remain there after the procedure[64]
Remote patient monitoring	The collection, transmission, and evaluation of patient health data through electronic devices, such as wearables, mobile devices, mobile applications, and internet-enabled computers[61]

calls to verify data and medication adjustments by clinicians or coordination with the patient's cardiologist.[13–21] Despite these structured protocols, most trials reported no significant differences between telemonitoring and usual care in terms of hospitalizations,[15–21] cardiovascular or all-cause mortality rates,[13,16–18,20] or health-related quality of life.[13–15,20,21] A key limitation of traditional telemonitoring systems is their lack of integration with EHRs, which hinders seamless clinical decision making.[22] Enhancing interoperability with pharmacy records and other health-data systems, along with streamlined mechanisms for clinical responses to patient-generated alerts, may improve the utility and impact of traditional telemonitoring.

Mobile Health-based Remote Monitoring

Mobile health (mHealth)-based remote monitoring uses mobile technologies, including smartphones, tablets, mobile apps, and wearable devices, that function as a modern extension of traditional telemonitoring. Some of the largest trials concerning mHealth interventions with remote patient monitoring (RPM) and clinical feedback include TIM-HF,[23] TIM-HF2,[24] OSICAT,[25] MESSAGE-HF,[26] and the Danish TeleCare North HF trial.[27] Similar to traditional telemonitoring, mHealth interventions used digital blood pressure monitors,[23,24,27] weighing scales,[23–25,27] and electrocardiograms[23,24] to assess the participants' physiological statuses.

Findings from these trials vary; taken collectively, the evidence suggests that mHealth interventions incorporating RPM and clinical feedback are not inferior to traditional ways of delivering care and may be used as adjuncts to usual care to help reduce the risk of all-cause mortality and HF-related hospitalizations.[28] These tools offer potential advantages in scalability and patient engagement, but their integration into health-care systems remains limited. Future research should focus on integrating workflows, enhancing data interoperability, and addressing barriers related to digital literacy and access, particularly among older or underserved populations.

Implantable Devices

Implantable technologies provide continuous physiological monitoring and are increasingly used to guide clinical management in HF. These include devices that directly measure intracardiac pressures, such as the CardioMEMS pulmonary artery pressure monitor (Abbott Laboratories, Abbott Park, IL), as well as cardiac implantable electronic devices (CIEDs) that collect multiparametric data. In a pivotal trial, the CardioMEMS device resulted in a 37% reduction in HF-related hospitalizations among patients with both preserved and reduced ejection fraction,[29] and subsequent studies confirmed its efficacy in patients in New York Heart Association (NYHA) classes II and III.[30,31] Similarly, the V-LAP (Vectorious Medical Technologies, Tel Aviv, Israel) laptop device, which measures left atrial pressure via a trans-septal sensor, demonstrated a 41% reduction in hospitalizations before early termination due to procedural complications.[32–34]

CIEDs—including implantable cardioverter defibrillators and cardiac resynchronization therapy devices—are also being adapted for HF monitoring. These devices can collect physiological signals, such as thoracic impedance, heart rate variability, and respiratory rate, which may predict impending decompensation.[35–37] However, a large trial that implemented weekly clinician reviews of CIED data did not find reductions in HF hospitalizations.[38]

Although some EHR platforms now integrate data from devices like CardioMEMS, broader interoperability with telehealth systems, pharmacy data, and wearable consumer devices are limited. Strengthening these linkages could enable a more holistic approach to HF management by combining physiological monitoring with behavioral and medication-adherence data.

Clinical Implications

The use of IHT in HF management offers practical strategies for improving patients' outcomes, particularly when integrated with timely clinician feedback. In clinical practice, these tools are most beneficial for patients at higher risk,[11] such as those with recent HF hospitalizations or in advanced NYHA classes, where early detection and intervention can prevent further deterioration. To realize their full potential, providers must ensure that patients understand the purpose of monitoring, are supported in daily device use, and receive clear, timely responses to concerning data.

Invasive monitoring technologies, such as implantable hemodynamic sensors, further enhance clinical decision making by detecting subclinical changes well before symptom onset.[34] These tools are particularly valuable for patients who experience recurrent hospitalizations or have poor responses to standard therapy.[11] However, due to their higher costs and procedural complexity, these devices should be reserved for carefully selected patients and implemented within structured care models that ensure regular data review and therapeutic adjustment.

Patient selection and adherence are critical for the successful implementation of both noninvasive and invasive technologies. Stable patients may not benefit as much, whereas those with frequent exacerbations or poor functional status stand to gain the most.[31] Providers should assess patients' motivation, cognitive and emotional readiness, and social support. Studies have shown improved adherence when patients with significant depressive symptoms were excluded,[24] highlighting the importance of behavioral readiness.

Newer RPM devices, such as the Withings Body Pro (Withings Health Solutions) and Bodyport cardiac scale, automatically transmit data via cellular networks, reducing patient burden and potentially improving adherence to daily monitoring. These technologies also offer enhanced capabilities; for example, the Bodyport scale measures peripheral

Table 2
Summary of existing IHT intervention studies.

Author, Year (Study acronym) Country	Study Design	Intervention Group	Control Group	Patient Characteristics	Study Outcomes	Main Findings*
Traditional Telemonitoring						
Antonicelli et al., 2008[13] Italy	RCT	Telephone, BP device, transtelephonic ECG recording device	UC	IG (n=28): 77±8 years, 43% female, EF 35%±6%, NYHA II (54%), III (43%), IV (4%) CG (n=29): 79±6 years, 35% female, EF 37±7%, NYHA II (62%), III (31%), IV (7%)	ACM, ACH, QOL (SF-36)	• **Significantly lower hospitalization rates in the IG vs CG (P < 0.05)** • No significant difference in QOL • No significant difference in ACM
Balk et al., 2008[14] The Netherlands	Multi-center RCT	MOTIVA system: TV channel, automated BP device, automated weighing scale, data transfer through telephone	UC	IG (n=101): 68 years, 36% female, EF 31%, NYHA I (6%), NYHA II (41%), NYHA III (48%), NYHA IV (2%) CG (n=113): 65 years, 25% female, EF 31%, NYHA I (7%), NYHA II (38%), NYHA III (48%), NYHA IV (3%)	ACM, ACH, QOL (SF-36, MLHFQ)	• No difference in days alive and out of the hospital • No difference in the number of days in the hospital • No difference in QOL
Blum et al., 2014[15] (MCCD) USA	Multi-center RCT	Philips Electronics E-care System	UC	IG (n=102): 73±8 years, 30% female, 82% with EF≤40%, NYHA II (13%), NYHA III (87%), NYHA IV (3%) CG (n=101): 72±10 years, 28% female, 76% with EF≤40%, NYHA II (18%), NYHA III (81%), NYHA IV (0%)	ACM, ACH, SF-36, MLHFQ	• No difference in the mortality rates or survival time • No difference in the number of hospitalizations or time to first hospitalization • No difference in QOL
Dar et al., 2009[17] UK	Multi-center RCT	Control box connected to phone line, electronic weighing scale, automated BP device, pulse oximeter	UC	IG (n=91): 70±13 years, 62% male, 39% with EF≥40% CG (n=91): 72±10 years, 59% male, 40% with EF≥40%	ACH, HFH, QOL (MLHFQ and Euroqol)	• **Significantly fewer emergency HF admissions in the IG (36%) vs CG (81%), P = 0.01** • No difference in days alive and out of the hospital • No difference in time to the first HFH • No difference in QOL
Lynga et al., 2012[16] Sweden	Multi-center RCT	Zenicor System, telephone, modem, electronic scale	Instructed to call the HF clinic in case of weight gain of >2 kg in 3 days	IG (n=166): 73.7±10 years, 24% female, NYHA III (96%), NYHA IV (4%) CG (n=153): 73.5±10 years, 26% female, NYHA III (97%), NYHA IV (3%)	CVH, ACH, ACM	• No difference in CVH • No difference in ACH • No difference in ACM
Mortara et al., 2009[21] (HHH) UK, Italy, Poland	Multicenter RCT	Automated interactive voice response system, Holter-style monitor, modem, digital BP device, electronic weighing scale	UC	IG (n=301): 60±12, 14% female, EF 28%, 43% with NYHA ≥ 3 CG (n=160): 60±12, 17% female, EF 30%, 34% with NYHA ≥ 3	CVM, ACH, HFH	• No difference in HFH • No difference in the composite outcome of CVM plus HFH • Heterogeneous effect of telemonitoring among the 3 countries - In Italy, significantly lower CVM & HFH in IG (P = 0.016) - The opposite was seen in Poland, but the difference was not significant.
Ong et al., 2016[18] (BEAT-HF) USA	Multi-center RCT	Telephone, wireless transmission pod, weight scale, BP device, heart rate monitor, device that could display text questions and send simple text responses	UC	IG (n=715): (median) 73 years, 47% female, EF 43%, NYHA II (23%), NYHA III (66%), NYHA IV (11%) CG (n=722): (median)	ACM, ACH, MLHFQ	• **Lower 30-day ACM in IG (P = 0.03)** • **Better QOL at 180 days for IG (P = 0.02)** • No difference in the 180-day ACH

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Table 2 (*continued*)

Author, Year (Study acronym) Country	Study Design	Intervention Group	Control Group	Patient Characteristics	Study Outcomes	Main Findings*
				74 years, 47% female, EF 43%, NYHA II (26%), NYHA III (64%), NYHA IV (10%)		• No difference in the 30-day ACH • No difference in the 180-day ACM
Pekmezaris et al., 2019[19] USA	RCT	American TeleCare LifeView + peripheral devices for measuring BP, oxygen saturation, weight, and heart rate	UC	IG (n=46): 58±15 years, 43% female, 58% with EF≤40%, NYHA II (28%), NYHA III (72%) CG (n=58): 61±15 years, 40% female, 63% with EF≤40%, NYHA II (31%), NYHA III (69%)	ACH, HFH, MLHFQ	• Lower 30-day ED utilization in the IG ($P = 0.07$) • No difference in 90-day ED use • No difference in the 90-day ACH and HFH • No difference in the length of stay • No difference in QOL
Weintraub et al., 2010[20] USA	Multi-center RCT	Philips Telemonitoring Services, Health Buddy appliance	Nurse-driven disease management program	IG (n=95): 69.5±14 years, 63% male, EF 32% ± 17% CG (n=93): 68.5±13 years, 69% male, EF 27% ± 16%	HFH, CVH, ACH, ACM	• **Fewer HFHs in the IG ($P = 0.05$)** • CVH was greater in the IG • No difference in ACH • No difference in ACM
mHealth						
Cichosz et al., 2020[27] Denmark	Multi-center RCT	Tablet, mobile app (HF questionnaire), BP device, weighing scale	UC	IG (n=145): 70 years, 83% male, mean NYHA score 2 CG (n=154): 69 years, 79% male, mean NYHA score 2	SF-36, KCCQ12	• **Better QOL scores (mental component) in IG** • No difference in QOL (physical component) and KCCQ12 scores
Galinier et al., 2020[25] (OSICAT) France	Multi-center RCT	Symptom questionnaire administered through a device, weighing scale	UC	IG (n=482): 70± 12 years, 73% male, EF 39%, NYHA I (6%), NYHA II (44%), NYHA III (38%), NYHA IV (11%) CG (n=455): 70± 12 years, 71% male, EF 38%, NYHA I (7%), NYHA II (43%), NYHA III (41%), NYHA IV (9%)	Composite ACM & ACH, CVH, HFH, SF-36	• **Longer median time to ACM or first HFH in IG (82 days) vs CG (67 days) in patients with NYHA III or IV HF ($P = 0.03$)** • **In socially isolated patients, the mean number of events was lower in IG ($P = 0.02$)** • **Lower mean number of events in patients who were >70% adherent to weight measurements ($P = 0.001$)** • No difference in composite ACM and ACH
Koehler et al., 2011[23] (TIM-HF) Germany	Multicenter RCT	Personal digital assistant, 3-lead ECG, BP device, weighing scale	UC	IG (n=354): 67± 11 years, 81% male, EF 27% NYHA II (50%), NYHA III (50%) CG (n=356): 67±11 years, 82% male, EF 27%, NYHA II (51%), NYHA III (49%)	ACM, CVM, HFH, SF-36	• No difference in ACM • No difference in CVM and HFH • Better QOL in IG at 12 months ($P < 0.05$) but not at 24 months.
Koehler et al., 2018[24] (TIM-HF2) Germany	Multicenter RCT	Mobile phone, ECG device, BP device, weighing scale, pulse oximeter	UC	IG (n=765): 70± 11 years, 30% female, 45% with EF≤40%, NYHA II (52%), NYHA III (47%), CG (n=773): 70±10 years, 31% female, 42% with EF≤40%, NYHA II (51%), NYHA III (47%)	ACM, CVM, CVH, HFH, MLHFQ	• **Lower ACM rate in IG (HR 0.70; $P = 0.03$)** • **Lower percentage of days lost to HFH in IG ($P = 0.007$)** • No significant difference in CVM • No difference in the percentage of days lost to CVH • No difference in QOL
Rohde et al., 2024[26] (MESSAGE-HF) Brazil	Multicenter RCT	Automated SMS messages, web-based monitoring system	UC	IG (n=352): 61± 15 years, 69% male, EF 27%, NYHA I (9%), NYHA II (53%), NYHA III (33%), NYHA IV (6%) CG (n=347): 61± 14 years, 63% male, EF 28%, NYHA I (9%), NYHA II (50%), NYHA	NT-proBNP, time to CVM, time to HFH, HF self-care	• **Better HF self-care in IG ($P = 0.004$)** • No significant difference in NT-proBNP • No significant difference in CVM and HFH

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Table 2 (*continued*)

Author, Year (Study acronym) Country	Study Design	Intervention Group	Control Group	Patient Characteristics	Study Outcomes	Main Findings*
				III (33%), NYHA IV (8%)		
Implantable Devices						
Abraham et al., 2011[29] (CHAMPION) USA	Multicenter RCT	CardioMEMS HF (PAP) sensor, electronic monitoring unit, internet-based database	UC (not influenced by hemodynamic data)	IG (n=270): 61 ± 13 years, 72% male, EF≥40% (23%), NYHA III (100%) CG (n=280): 62 ± 13 years, 73% male, EF≥40% (20%), NYHA III (100%)	HFH, change in pulmonary artery pressures, days alive outside hospital, MLHFQ	• **Lower rate of HFH in IG ($P = 0.0002$)** • **Lower risk of death or first HFH in IG ($P < 0.05$)** • **Greater reduction in pulmonary artery mean pressure in IG ($P = 0.008$)** • **More days alive outside the hospital in IG ($P = 0.02$)** • **Better QOL in IG ($P = 0.02$)**
Abraham et al., 2016[32] Maurer et al., 2015[33] (LAPTOP-HF) USA, New Zealand	Multi-center RCT	St. Jude Medical implantable LAP monitoring system, handheld patient unit, web-based database	UC	n=486 Groups well balanced at baseline Overall sample: 62 ± 12 years, 75% male, EF 30%, NYHA III (100%)	HFH	• **Lower rate of HFH in IG (0.40) vs CG (0.68) ($P = 0.005$)**
Bourge et al., 2008[46] (COMPASS-HF) USA	Multi-center RCT	Implantable continuous hemodynamic monitor (Chronicle), home monitor, web-based database	UC (no access to hemodynamic data)	IG (n=134): 58 ± 14 years, 34% female, NYHA III (84%) CG (n=140): 58 ± 13 years, 36% female, NYHA III (87%)	HF-related events (hospitalizations, ED and urgent care visits)	• **36% reduction in relative risk of HFH in IG ($P = 0.03$)** • No significant differences in HF-related events
Brugts et al., 2023[30] (MONITOR-HF) The Netherlands	Multicenter RCT	HF (PAP) sensor, electronic monitoring unit, Internet-based database	UC	IG (n=176): 69 (61-75) years, 78% male, EF <40% (73%), NYHA III (100%) CG (n=172): 69 (61-75) years, 78% male, EF <40% (73%), NYHA III (100%)	Health status (KCCQ), HFH, composite first HFH & ACM, composite first HFH & CVM, ACM, CVM	• **Better health status in IG at 12 months ($P = 0.013$)** • **Lower rate of HFH in IG ($P = 0.0053$)** • **Lower total HFH and ACM events in IG ($P = 0.011$)** • No significant differences in ACM ($P = 0.85$) and CVM ($P = 0.49$)
Lindenfeld et al., 2021[31] (GUIDE-HF) USA, Canada	Multicenter RCT	CardioMEMS HF (PAP) sensor, electronic monitoring unit, Internet-based database	UC (not influenced by hemodynamic data)	IG (n=497): 71 years, 62% male, EF 38%, NYHA II (29%), NYHA III (65%), NYHA IV (6%) CG (n=503): 70 years, 63% male, EF 40%, NYHA II (30%), NYHA III (65%), NYHA IV (5%)	Composite ACM & HF events (HFH & ED visit), health status (EQ-5D-5L & KCCQ12), functional status (6-minute walk test)	• **Pre-COVID-19 analysis showed a significant reduction in composite events ($P = 0.049$) and lower HFH ($P = 0.0072$) in IG** • **Greater treatment effect in NYHA II or III, Black, and female patients** • Overall analysis showed no significant differences in composite events, urgent HFH, or mortality • No significant differences in EQ-5D-5L and KCCQ12 scores • No significant difference in the 6-minute walk distance
Morgan et al., 2017[38] (REM-HF) England	Multicenter RCT	Cardiac implanted electronic device,	UC	IG (n=824): 70 ± 10 years, 86% male, EF 30%, NYHA II (71%), NYHA III (29%), NYHA IV (0.1%) CG (b=826): 70 ± 10 years, 86% male, EF 30%, NYHA II (68%), NYHA III (32%), NYHA IV (0.2%)	Composite ACM and CVH, ACM, CVM, non-CV hospitalization, CVH	• No significant difference in ACM or CVH • No significant differences in ACM, CVM, non-CV hospitalization, or CVH

* Favorable, significant findings are bolded.

ACH, all-cause hospitalization; ACM, all-cause mortality; BP, blood pressure; CG, control group; CVH, cardiovascular-related hospitalization; CVM, cardiovascular-related mortality; ECG, electrocardiogram; EF, ejection fraction; EHR, electronic health records; HFH, hospitalization for heart failure; IG, intervention group; KCCQ12, 12 item Kansas City Cardiomyopathy Questionnaire; LAP, left atrial pressure; MLHFQ, Minnesota Living with Heart Failure Questionnaire; NYHA, New York

Heart Association (functional class); PAP, pulmonary arterial pressure; QOL, quality of life; SF-36, 36-item short-form health survey; RCT, randomized controlled trial; UC, usual care.

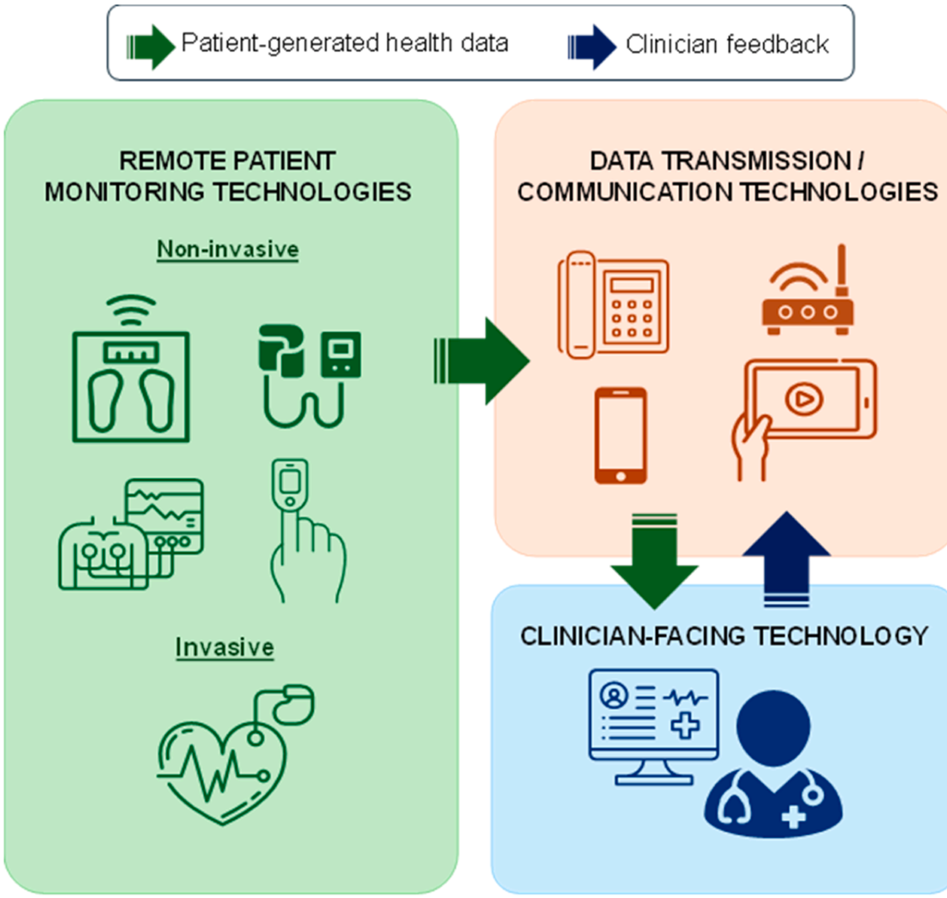


Fig. 2. Common components of integrated health technology interventions. This figure highlights many common components of integrated health technologies (IHTs) and underscores the importance of seamless data flow from patients and caregivers (eg, blood pressure monitoring) to/from clinicians and decision-support tools with the aid of communication technologies such as smartphones.

impedance and pulse rate to generate a congestion index, which may predict HF events more accurately than weight alone.[39] Clinicians should consider incorporating these devices into care pathways and should collaborate with patients and caregivers to reinforce consistent use and responsive action based on the monitoring data.

IHTs offer promising tools to enhance HF management, but their effectiveness depends on thoughtful implementation, patient-centered support, and tailored use for high-risk individuals. To facilitate sustained impact, health care systems should monitor key implementation and quality metrics, including patient-adherence rates, clinician-response times to alerts, the reliability of data transmission, and patient-reported outcomes related to usability. Regularly tracking these indicators can help to identify gaps, guide improvements, and ensure that IHT-based HF management programs remain responsive to both clinical needs and patients' experiences.

Challenges With Integrated Health Technologies in Heart Failure

This section examines the challenges associated with the implementation and wide adoption of IHTs. These barriers include patient-, technology-, clinician-, and cost-related challenges. Understanding these challenges is critical to optimizing the integration of IHT into clinical practice and ensuring equitable, effective, and sustainable care for individuals living with HF. Table 3 outlines potential solutions aligned with each challenge.

Patient-related Challenges

Adherence and engagement are critical for the success of IHT interventions, because their effectiveness depends heavily on consistent patient and caregiver involvement. For instance, the BEAT-HF (Barostim Therapy for Heart Failure) trial highlighted that suboptimal adherence to the telemonitoring and telephone-coaching intervention significantly contributed to its null findings.[18] Similarly, a subgroup analysis of the OSICAT (Optimization of the Ambulatory Monitoring for Patients With Heart Failure by Tele-cardiology) trial revealed a 42% reduction in all-cause mortality and unplanned hospitalizations among participants with adherence rates of 70% or higher, a benefit not observed in less-adherent participants.[25] To address these challenges, providing patients with actionable feedback has been suggested as a strategy to enhance engagement and adherence.[10] Trials incorporating clinician feedback, particularly guideline-recommended medication adjustments, demonstrated better adherence rates[24,29,30] compared with trials that merely instructed participants to contact their health care provider in response to abnormal physiological measurements.[18,25] These findings suggest that providing direct, actionable feedback (eg, medication dosage changes) is more effective than relying on patients to seek guidance independently (ie, indirect feedback). Access and digital literacy can also play a role in the effectiveness of IHT interventions. Patients with limited access or digital skills may struggle to engage with devices or apps, reducing adherence[40] and diminishing the

Table 3
Proposed solutions to key challenges in implementing IHT for HF management.

Challenges	Solutions
Patient-related	
Suboptimal patient engagement	Incorporate real-time, actionable feedback linked to guideline-based recommendations based on the patient's physiological data.
Limited digital literacy	▪ Develop user-friendly interfaces and offer low-tech options (eg, voice calls or text messaging-based monitoring) for individuals with limited digital literacy. ▪ Provide community-based digital literacy training. ▪ Offer technical support hotlines to assist users in navigating their devices.
Limited access to technologies (eg, mobile devices, internet)	Establish device-lending programs or subsidized technology access for patients in resource-limited settings.
Technology-related	
Lack of data standardization and interoperability across platforms and devices	▪ Advocate for industry-wide standards to improve interoperability between EHR systems and IHT, eg, Health Level Seven International-Fast Healthcare Interoperability Resources (HL7 FHIR). ▪ Encourage the use of middleware platforms that aggregate and standardize patient-generated health data.
Inconsistencies in the quality of patient-generated health data due to device malfunctions or improper device use	Employ automated data validation algorithms and quality assurance filters to flag outlying or inconsistent values.
Challenges in visualizing health data in clinically useful formats	Involve clinicians in designing data dashboards to ensure visualizations are meaningful and actionable.
Concerns about data privacy, security, and access	▪ Clearly inform patients how their data are collected, used, and protected. ▪ Require that all IHT partners comply with HIPAA and FDA cybersecurity guidelines, including the use of data encryption and regular vulnerability testing. ▪ Use blockchain (which maintains a record of activities or data entries that cannot be altered without consensus from the network) or zero-trust architectures (which require every access request to be authenticated, authorized, and encrypted) for secure data exchange.
Clinician-related	
Uncertainty around clinical accountability for data oversight	Develop protocols and workflows specifying who monitors, triages, and acts on IHT data.
Workflow disruptions	▪ Integrate IHT alerts and data summaries directly into the existing EHR interface to minimize toggling between systems. ▪ Use artificial intelligence-assisted triage systems to prioritize alerts and minimize clinician burden. ▪ Engage clinicians in the implementation process to achieve seamless workflow integration.
Cost-related	
Substantial initiation and maintenance costs	▪ Expand Medicare and Medicaid coverage to include broader IHT applications and streamline billing processes. ▪ Use cost-effectiveness models to demonstrate long-term savings to payers and policymakers. ▪ Position IHT as a scalable workforce extender, allowing clinicians to manage broader patient populations remotely.

intervention's impact. Additionally, disparities in access to necessary resources, such as smartphones, internet connectivity, or reliable devices, can exclude underserved populations, exacerbating health inequities. Addressing these barriers through user-friendly technologies, tailored training programs, and equitable-access initiatives is essential to ensuring that IHT interventions benefit all patients, regardless of their digital proficiency or socioeconomic status.

Technology-related Challenges

The integration of data from wearable and implanted devices, along with patient-reported measures, remains a challenge for clinical settings that already use EHR/electronic medical record (EMR) systems.[41] Although several EMR vendors (eg, Epic, Oracle Health) have been integrated with wearables, such as Fitbit, Apple Watch, and Withings, through Fast Healthcare Interoperability Resources (FHIR)-based application programming interfaces, partnerships with device manufacturers (eg, Apple HealthKit) or third-party digital health platforms (eg, Validic, iHealth), key issues remain.[42] These include data standardization, interoperability, validation, proper visualization, quality assurance, privacy, and security compliance.[42] Wearables generate large volumes of health data (eg, heart rate, activity levels, blood pressure, glucose levels) by using various algorithms, formats, and protocols to store and transmit these data.[43] Mapping and visualizing such data into structured and meaningful formats to inform clinicians are complex operations. Often, patient-generated health data may have inconsistencies due to sensor inaccuracies, patient misuse (eg, improper wear), or device malfunctions.[44] Clinicians need relevant and reliable data for decision making. Concerns about access, data security, and privacy further complicate the implementation of IHT into clinical practice. A systematic review and metasynthesis of mobile applications for cardiovascular disease self-management revealed that only 1 of 10 studies addressed compliance with national confidentiality laws.[45] Some IHT trials have addressed data-security concerns by using secure servers to store patient-generated health data.[18,25,29,33,46];Several employ encryption during data transmission to enhance security and confidentiality.[14,15,23,24]

Recognizing the importance of secure and effective integration of health technologies, the American College of Cardiology (ACC) Task Force on Health Policy Statements and Systems of Care developed a comprehensive roadmap to guide health care transformation in the era of digital health, big data, and precision health.[47] This roadmap emphasizes seamless integration of patient-generated data with clinical decision-support tools, prioritizing not only robust data security and privacy protections but also interoperability, stakeholder engagement, and care efficiency. The ACC calls for the creation of innovation platforms that support the development, evaluation, and implementation of emerging technologies. These platforms are grounded in key principles—evaluation, integration, engagement, and efficiency—and are designed to accelerate clinical translation, support personalized care, and enable real-time decision making.

Beyond data security, the interconnected nature of CIEDs, which leverages the internet for remote monitoring, also exposes their functionality to potential cyber threats. In 2016, a laboratory demonstration showed that excessive radio traffic could cause CIEDs manufactured by St. Jude Medical (now Abbott, Minneapolis, MN) to malfunction, rendering telemetry-based interrogation of the devices unworkable.[48,49] A second cybersecurity attack targeted the device's battery, effectively draining it and reducing its longevity.[48,49] No patients were harmed, and a software patch was released soon after to address the cybersecurity vulnerabilities,[50] but these events spurred the U.S. Food and Drug Administration to increase its efforts to prevent future cyberattacks with the release of the Postmarket Management of Cybersecurity in Medical Devices[51] guidance document that outlined recommendations for managing the post-market cybersecurity vulnerabilities of marketed and distributed medical devices.

Clinician-related Challenges

Clinicians play a pivotal role in the successful implementation of IHT for HF management. However, these technologies often introduce unique challenges that can affect their adoption and effectiveness. A key challenge is determining who should be responsible for monitoring and acting on data. Clearly defining roles and responsibilities within the interdisciplinary health-care team is essential to ensure that team members understand their specific duties, how to interpret incoming data accurately, and how to integrate patient-generated health data into individualized care plans.[11] Nurses can lead ongoing monitoring, provide patient education about device use, and triage alerts based on clinical relevance. Pharmacists can contribute by reviewing medication-related data, optimizing therapy based on guideline-directed recommendations, and ensuring adherence. Social workers can address social determinants of health that affect patients' engagement with technology, such as access to the internet, caregiver support, or digital literacy. Care coordinators and case managers can facilitate communication across team members and ensure that interventions are aligned with the overall care plan.

The additional time required to interpret and act on patient-generated health data is another obstacle. IHT interventions with frequent measurements and rapid feedback have been shown to be more effective,[52] but such approaches are often feasible only in research settings with dedicated clinicians, and they may not translate well to busy clinical environments. Therefore, evaluating the efficacy and safety of IHT interventions before widespread adoption is essential to determine their feasibility, clinical utility, and impact on the clinicians' workflow. Implementing pilot programs or quality-improvement projects can help to identify potential barriers and inform strategies so as to optimize their integration. To encourage adoption by clinicians, it is crucial to minimize workflow disruptions and ensure that the IHT intervention is integrated seamlessly into existing clinical practices.

Cost-related Challenges

Implementing IHT in HF management presents significant cost-related challenges that can impede its widespread adoption. The initial expenses for acquiring and deploying these technologies, such as remote monitoring devices, implantable devices, and supporting infrastructure, are substantial. Additionally, ongoing costs for device maintenance, data management, and training health care providers further strain financial resources. Economic analyses, such as those based on the TIM-HF2 (Telemedical Interventional Management in Heart Failure II) trial, indicate that noninvasive RPM with clinician feedback resulted in a cost saving of €1758 per patient year.[53] Meanwhile, a health-economic analysis of the CHAMPION (CardioMEMS Heart Sensor Allows Monitoring of Pressure to Improve Outcomes in NYHA Class III Heart Failure Patients) trial indicates that pulmonary artery pressure-guided HF management using CardioMEMS meets acceptable cost-effectiveness thresholds, with an incremental cost-effectiveness ratio of $12,262 per quality-adjusted life year for HF hospitalization outcomes and $29,593 per quality-adjusted life year for comprehensive management over 5 years.[54] However, it is important to note that although CardioMEMS is cost-effective, it is not cost-saving, because its total costs remain higher than those of standard care.[54] This underscores the need for health care systems to balance clinical benefits with financial feasibility carefully, and it highlights the importance of aligning reimbursement policies to support broader adoption. Although Medicare currently offers reimbursement for RPM services, including remote physiological and therapeutic monitoring, specific requirements must be met to qualify.[55] For instance, remote physiological monitoring necessitates an established patient relationship and mandates data collection for at least 16 days within a 30-day period. Moreover, only 1 practitioner can bill for RPM per patient in a 30-day cycle, and the services must be deemed medically reasonable and necessary. These stipulations can limit the financial viability of IHTs, especially for smaller practices and those serving underserved populations. To enhance the adoption of IHTs in HF management, it is crucial to address these cost-related barriers by developing sustainable funding models and advocating for more comprehensive reimbursement policies. It is also important to recognize that some IHT data may lead to additional testing, which might increase both cost and potential harm to patients.

Beyond direct cost savings resulting from reduced HF-related hospitalizations, IHT also presents alternative financial opportunities that warrant consideration. For example, IHT can facilitate remote care delivery to underserved populations, mitigating the need for additional clinical staff and costly infrastructure investments. By enabling proactive management of HF through remote monitoring, health care systems can expand access to specialized care while optimizing resource allocation and reducing financial strain on both providers and patients.

Opportunities for Future Research

Future research in IHT for HF management must prioritize the efficacy and safety of these strategies and should include more diverse study populations. Historically, trials have included predominantly male participants, with representation ranging from 53%[18] –85%,[38] potentially overlooking sex-specific responses to interventions. Notably, findings from the GUIDE-HF (Hemodynamic-GUIDEd management of Heart Failure) trial revealed a greater treatment effect among female participants compared to males,[31] underscoring the critical need for sex-balanced samples in future studies. Expanding diversity beyond sex to include racial, ethnic, and socioeconomic groups will ensure that findings are generalizable and inclusive, addressing disparities in HF care and outcomes.

Additionally, advancements in IHT offer exciting avenues for future research. Investigating the integration of newer technologies, such as those that upload data via cellular networks, could significantly improve patient adherence and reduce monitoring burdens. Combining traditional weight monitoring with hemodynamic biomarkers, like those used in the congestion index, has shown potential for improving the early detection of HF decompensation.[39]

Research should also prioritize the development and implementation of automation systems that can facilitate rapid responses to abnormal values detected through IHTs. Automation has the potential to significantly reduce the workload of clinicians by minimizing the need for manual data review and triage. For instance, systems that integrate machine-learning algorithms could analyze patients' data, prioritize alerts based on urgency, and even suggest preliminary actions. This approach not only conserves time but also reduces the risk of human error in managing large volumes of patient data. By enabling a more efficient and proactive response framework, automation can enhance the scalability of IHT in HF management, ensuring that high-quality care is maintained, even with increasing patient loads. Future research should explore the integration of these technologies into existing health care infrastructures, evaluate their cost-effectiveness, and assess their impact on patient satisfaction and clinical outcomes.

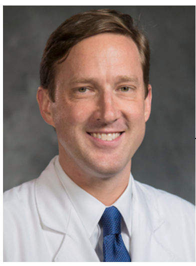
Addressing these critical areas will enable future research to refine the design and implementation of IHT, paving the way for HF management that is not only more effective and efficient but also more equitable and inclusive. These advancements have the potential to revolutionize patient care by improving outcomes, reducing disparities, and enhancing the overall quality of life for individuals living with HF.

Conclusion

Integrated health technologies hold considerable promise for enhancing HF management by facilitating care coordination, enabling early intervention, and empowering patients through remote-monitoring and self-management tools. Existing evidence supports their clinical utility, but widespread adoption is hindered by challenges related to patient engagement, technical obstacles, clinician workload, and cost. Addressing these barriers through equitable design, robust interoperability, clear clinical workflows, and supportive reimbursement policies is essential to realizing the full potential of IHT. Future efforts must prioritize inclusive implementation strategies and system-level readiness to ensure that IHT contributes meaningfully to improved outcomes in HF management.

Lay Summary

Integrated health technologies (IHTs) have emerged as promising tools for improving heart failure (HF) management by facilitating care coordination and enabling timely clinical intervention. This joint scientific statement from the Heart Failure Society of America and the American Association of Heart Failure Nurses summarizes current evidence about the use of IHT in HF management, including traditional telemonitoring, mobile health-based remote monitoring, and implantable devices.



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Declaration of competing interest

The authors declare no competing interests.

Funding

None.

Disclosures

A.D.V.. reports research funding through his institution from Biofourmis, Bodyport, Cytokinetics, American Regent, the NIH and NHLBI, Novartis, Story Health, and Ventricle Health and also provides consulting services for and/or receives honoraria from Bodyport, Cardionomic, LivaNova, Myovant, Natera, NovoNordisk, and Zoll.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.hrtlng.2025.11.020.

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