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An AI-Enabled, Patient-Centred Digital Platform for Integrated Chronic Heart Failure Management: Architecture, Validation and Clinical Insights

George Petridis[1] | Apostolia Karabatea[2] | Constantinos Bakogiannis[3] | Emmanouil S. Rigas[1] | Haridimos Kondylakis[4] | Alexander Berler[2] | Konstantinos Kangelidis[2] | Nikolaos Malamas[2] | Angelina Kouroubali[5] | Dimitrios Katehakis[6] | Vassilios Vassilikos[3] | Panagiotis D. Bamidis[1] | Antonios Billis[1]

[1]Lab of Medical Physics and Digital Innovation, School of Medicine, Aristotle University of Thessaloniki, Thessaloniki, Greece | [2]Gnomon Informatics SA, Thessaloniki, Greece | [3]Cardiovascular Prevention and Digital Cardiology Lab, Third Cardiology Department, Aristotle University of Thessaloniki, Thessaloniki, Greece | [4]FORTH-ICS and CSD-UOC, Heraklion, Crete, Greece | [5]Computational Biomedicine Laboratory, Centre for eHealth Applications and Services, FORTH-ICS, Heraklion, Crete, Greece | [6]Centre for eHealth Applications and Services, FORTH-ICS, Heraklion, Crete, Greece

Correspondence: Antonios Billis (ampillis@med.auth.gr)

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ABSTRACT

Healthcare systems across Europe and globally are increasingly challenged by the need to deliver high-quality, coordinated care for complex patient populations, such as those living with chronic heart failure (CHF). Many national healthcare policies consider the adoption and implementation of patient-centred and interoperable information communication technologies-enabled solutions offered in a single digital platform as a key facilitator towards the transition to integrated and coordinated care. Aiming to support CHF patients and to assist their management, in this paper, we present CareCardia, a modular digital solution designed to support the comprehensive management of CHF. CareCardia offers an interoperable ecosystem that connects healthcare professionals, informal caregivers and patients along a unified CHF care pathway spanning across diagnosis, acute care and jointly managed long-term care. Specifically, CareCardia integrates state-of-the-art, clinical evidence-based technologies such as a clinical decision support system and an exergaming platform that will follow patients through the CHF journey. This paper outlines the system architecture and core functionalities of CareCardia prototype. We also present early findings from the initial exploration of the tool, discussing its anticipated impact on CHF and its potential to foster patient empowerment across the continuum of care.

1 | Introduction

Cardiovascular diseases (CVD), cancer, diabetes, and other complex chronic diseases that involve multiple comorbidities will be the cause of death of over 50 million people in the European region by the end of the decade (2030), according to the World Health Organization [1]. Chronic diseases carry significant human costs (e.g., suffering, reduced productivity and social discrimination) while in Europe, over 85% of deaths are caused due to them [2]. This has as a consequence that 70% – 80% of

total healthcare costs are being spent on the treatment of chronic diseases, which translates into a total cost of over 700 billion euros for the EU.

Heart failure (HF) is defined as a pathophysiological state where the heart shows dysfunction, making it difficult to pump the needed amount of blood the body demands for its proper functioning [3]. A recent study showed an increase in heart failure hospitalisations and readmissions [4], whereas the prevailing strategies for addressing CVD have proven inadequate, underscoring the need for a paradigm shift to bridge the gap between evidence and practice [5, 6]. Disease management in CHF patients is considered unsatisfactory, as indicated by the insufficient uptake of evidence-based clinical practice guidelines [7, 8]. Medication non-adherence usually ranges from 40% to 60% and compliance with exercise in cardiac patients, in general, is below 50%, whereas due to physical symptoms, their participation rates in cardiac rehabilitation programs are disappointingly low at <20% [9]. However, there is one major barrier commonly identified among the healthcare stakeholders that limits the care delivery efficiency and effectiveness in terms of patient outcomes, which is the fragmentation of care provisioning and service delivery. Innovative, scalable, and culturally appropriate solutions are imperative to address the multifaceted risk factors of CVD [5].

Since CHF management is difficult and unsatisfactory in practice, it may benefit from using intelligent tools and systems aimed at supporting CHF patients in carrying out their complex treatment plans and providing them with personalised advice and recommendations [10]. In this context, several solutions related to chronic heart failure exist [11, 12], and a growing field of interest is related to the use of digital health to predict decompensation in stable HF patients.

Specifically, using digital health applications for monitoring parameters such as weight, voice, hemodynamics and patient-reported symptoms may allow the detection of anomalies and trigger early actions to optimise treatment. For example, the non-randomised, multicentre MultiSENSE (multisensor chronic evaluation in ambulatory heart failure patients) study has provided results that support the prognostic value of integrating device-detected data with heart sounds, respiration, thoracic impedance, heart rate and activity data [13]. Moreover, the remote dielectric sensing (ReDS) system [14], which consists of a wearable vest and two sensors, allows for non-invasive measurement of patient lung fluid content. The ReDS system was evaluated in a prospective single-arm study of 50 patients hospitalised for acute decompensated HF, which demonstrated a reduction of hospital readmission with ReDS-guided management by 87% compared to historical controls. Management of HF involves a complex medication regimen as well as ongoing self-driven dedication to behavioural modification and self-care. The E-tobacco (TEXT ME) trial demonstrated some improvement in cardiovascular risk factors (e.g., lipid control, blood pressure and body mass index) with the use of a lifestyle-focused text messaging service in patients with coronary heart disease. In a single-centre demonstration project that involved 60 HF patients with remote monitoring of blood pressure and weight with two interactive texting-based mobile apps in the 30-day high-risk period post-discharge, a promising 50% 30-day readmission rate reduction

was achieved, with 73% active patient engagement beyond the initial 30-day period [15]. In other studies, the WeChat platform-based health management [16] and advanced EHR-based tools for remote patient engagement, effective documentation, multifaceted analytics, and point-of-care education and decision support [17] showed an improvement in the self-care ability and compliance of patients with severe chronic heart failure and improved the cardiac function and related indices. Another research work focuses on the importance of readmissions and adverse events, such as deaths, in heart failure patients during readmissions. The authors propose a framework for reducing the burden of morbidity and mortality, exploiting digital technologies [18].

In a similar context, clinical decision support systems (CDSSs) have already given tangible results for the management of heart diseases, including risk predictions [19], diagnostic decision support [20], heart arrhythmia diagnosis [21], and coronary heart disease prediction models [21], amongst others. A systematic literature review of heart-disease diagnosis DSSs [22] showed that the rapid growth of CDSSs is playing a key role in gaining the continuity of care and a person-centric model, focusing on a knowledge-based approach integrating past and current data of each patient with statistical evidence. The trend of using CDSS in the management of CHF patients is also increasing the market of mHealth apps focusing on heart failure [23]. However, despite their potential, mobile health interventions still suffer from the lack of trial-based evidence [24–26].

The domain of chronic disease management in heart failure [27] includes various telemonitoring interventions, sensors, wearables, cardiac implantable electronic devices (CIEDs) and decision support systems. A recent review provides a comprehensive foundation for digital enhancement in CHF care, showing opportunities and challenges [27], and another review paper provides a comprehensive review of digital tools for heart failure, focusing on barriers, enablers, and real-world application strategies [27]. However, up to date, no other platform has been able to effectively integrate and deliver all these diverse functionalities into a single digital health intervention. The CareCardia application aims to build on the partial advances seen in integrated healthcare delivery and, for the first time, to integrate a range of features into a modular solution to effectively bring different care providers, informal caregivers and patients into a shared CHF care pathway spanning across diagnosis, acute care and jointly managed long-term care. To this end, CareCardia integrates state-of-the-art, clinical evidence-based technologies into a single digital platform that will follow CHF patients from the point of diagnosis, through treatment and care up to the receipt of early supportive care, having as key features patient-centeredness, the integrated and coordinated care, the shared and informed decision-making and the value-based care.

The remainder of this paper is structured as follows: Section 2 reports on the architecture and the components of the Care-Cardia solution, whereas in Section 3, we present the first prototype. Then, in Section 4, we present early findings from the first validation of the tool. Section 5 discusses the anticipated impact and, finally, Section 6 concludes this paper and presents directions for future work, including plans for its clinical validation.

2 | Solution Architecture and Components

The CareCardia solution builds upon the eHealthPass [28], which serves as the technological foundation for a comprehensive and patient-centred approach to CHF management. eHealth-Pass offers tailored interfaces for various users' roles including, patients, healthcare professionals, informal caregivers, and administrators. Key functionalities include access to electronic health records, secure information sharing among professionals, treatment planning and monitoring, emergency support services, with a focus on patient consent and privacy, and real time alerts for abnormal health events as defined by healthcare professionals. It is a mobile-enabled and web health solution that allows patients to collect personal medical history data, view lab results, share them with selected physicians and have access to medical information kept in connected healthcare systems. A key strength of eHealthPass lies in its interoperability framework, which serves as a foundation for effective coordination among multidisciplinary care teams. By leveraging standardised data exchange protocols, eHealthPass facilitates seamless communication and collaboration across diverse healthcare settings and professional roles. Applications communicate with the backend components through a secure API using OAuth 2.0 and a distributed event streaming platform. CareCardia extends the eHealthPass patient-centred suite with specific capabilities: user-friendly interfaces and applications covering both the patient and the healthcare professional teams' side, unobtrusive smart sensors and connected medical devices, smart analysis of heterogeneous data sources including ePROMs and digital biomarkers and a CDSS. In what follows, a brief description of the main components of the CareCardia solution is provided, while their interconnection is visualised in Figure 1.

2.1 | Patient Self-Management and Empowerment Platform (Patient Mobile Application)

This is the main point of interaction of CHF patients with the CareCardia platform. It includes the personal health record, personalised care plan and data dashboard, along with services for enabling digital communication, online peer support and, with the help of a virtual assistant, the e-coaching of patients.

2.2 | Remote Patient Monitoring (Patient-Generated Health Data [PGHD])

The integration of IoT and medical devices allows passive, unobtrusive collection of real-world data related to CHF patients' health and lifestyle. Through targeted ePROMs and ePREMs, patients actively contribute valuable information to the system.

2.3 | Health Care Professional Dashboard

It acts as a multidisciplinary team (MDT) coordination platform introducing the shared care plan, allowing for the digitalisation in a structured way of the patient transitions and pathways, including the discharge process or advance care planning. In addition, a common and unified data and information framework allows for the aggregation and representation of the patient's healthcare status (multidisciplinary 'situation reports'), offering multiple views for different Health Care Providers (HCPs') categories, according to their role in the care of the CHF patient.
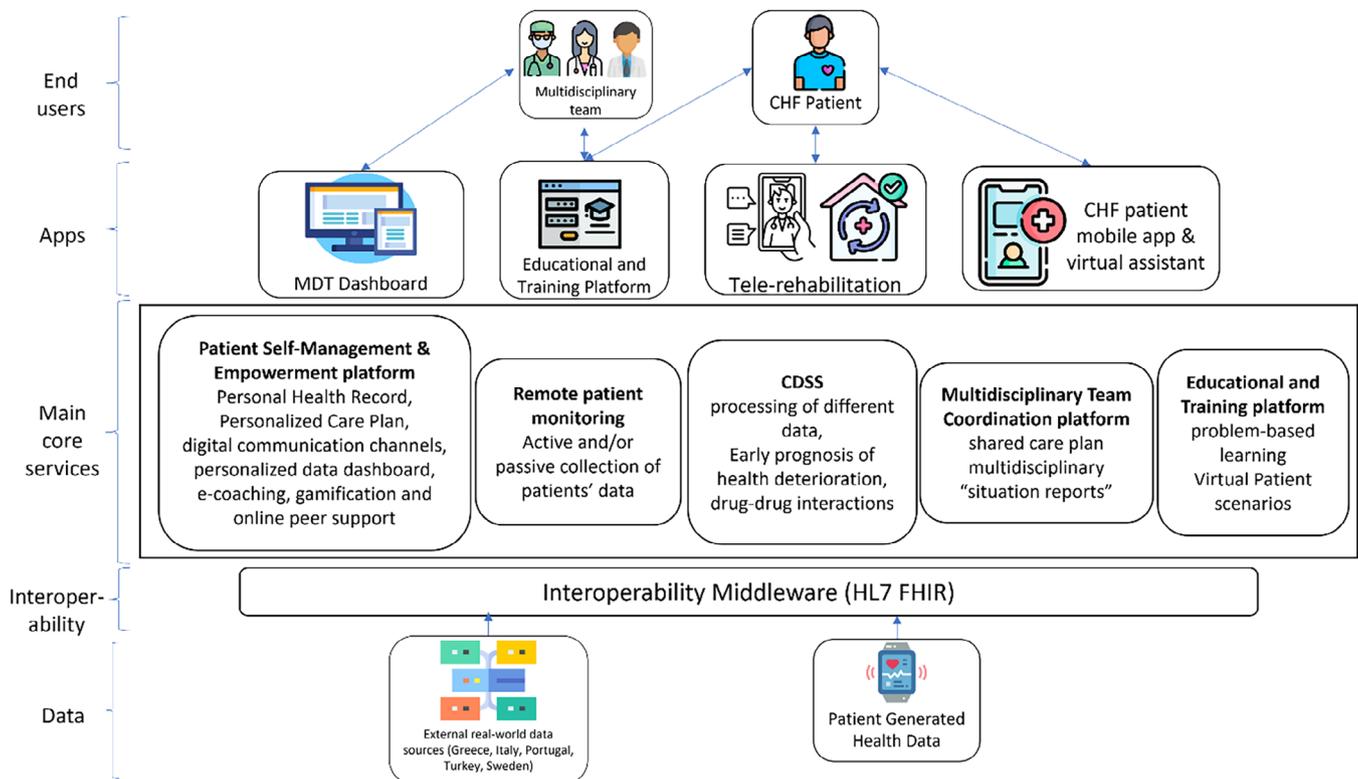

FIGURE 1 | CareCardia conceptual architecture.

TABLE 1 | CareCardia set of functionalities, in contrast to other digital health solutions targeting CHF.

	CareCardia	WeChat platform-based health management	RxUniverse	ReDS system	MultiSENSE	CDSS
Patient self-management and empowerment	√		√			
Remote patient monitoring	√			√	√	√
Care plans	√	√	√	√		
Clinical decision support system (CDSS)	√		√	√		√
Patient to HCP communication	√	√	√		√	
Patient education	√	√	√			
Tele-rehabilitation	√					
Interoperability	√					

2.4 | Clinical Decision Support System (CDSS)

This enables the coordination of the MDT's complex decision-making process by allowing the intelligent processing of different data collected either in the clinical environment (e.g., EHRs, laboratory results) or the home environment (patient-generated health data). The CDSS incorporates existing clinically validated rule-based models (i.e., Framingham Risk Score [29], MAGICC risk calculator [30]), allowing for the early diagnosis of CHF or decompensation episodes and exacerbation of symptoms. Early prognosis of serious health deterioration (transition from a fit condition to a frail one) leading to advanced care needs of the CHF patient is also a key feature of the CDSS, whereas the CDSS also helps the doctor follow the guidelines for the given disease stage. Finally, drug–drug interactions that might pose health risks are recognised, based on advanced analytical techniques (i.e., natural language processing).

2.5 | HealthCare Professional Mobile Application

A mobile application for the HCPs is also available to give them access to their calendar from anywhere, as well as letting them receive alerts about certain high-priority events (e.g., repeated loss of medication) if they choose so.

2.6 | Educational and Training Platform

This component is offered to both CHF patients and HCPs. Contemporary approaches, such as problem-based learning, are adopted. A series of virtual patient scenarios [31] enables CHF patients to practice key coping strategies through realistic case simulations that mirror daily life challenges. This experiential approach promotes active learning and disease self-management. A similar approach is adopted for HCPs who wish to acquire key competencies and soft skills relevant to empathy and palliative care, by providing the HCP training in empathic behaviour towards their patients using virtual reality.

2.7 | Tele-Rehabilitation (Exergaming) Platform

CHF patients have the option to perform cardiac rehabilitation in a personalised, safe, and engaging way, ensuring maximisation of physical exercise-derived health outcomes. webFitForAll [32, 33], developed as a serious game platform, was customised to account for the special needs of the patients suffering from CHF. The training programs are adjusted to patients' needs and preferences, varying from high-intensity interval training to supervised rehabilitation for the less autonomous patient. In general, the existing guidelines suggest 150 min of moderate aerobic exercise per week. The key parameters that should be considered are the patient's physical and clinical status (frailty), while the program is customised per the patient's heart rate zones and symptoms.

2.8 | Interoperability and Integration Middleware

Inheriting at a significant level the eHealthPass core interoperability framework which is based on the well-known healthcare interoperability standard of HL7 FHIR, one of the key strengths of the CareCardia solution is the fact that the current implementation allows seamless integration of the envisaged solution with any EHR information system which supports open interoperability standards.

To this end, a modular, scalable end-to-end system, which leverages a variable number of components targeted at self-management, care coordination, medical decision-making, training, and remote monitoring, is presented. In what follows, more details about the CareCardia solution components are presented (Tables 1 and 2).

3 | Early Prototype

CareCardia is an advanced healthcare platform designed to enhance the patient experience, streamline professional coordination and provide comprehensive data analysis. It combines a

TABLE 2 | CareCardia range of clinical applications within the CHF care continuum contrary to existing digital health solutions.

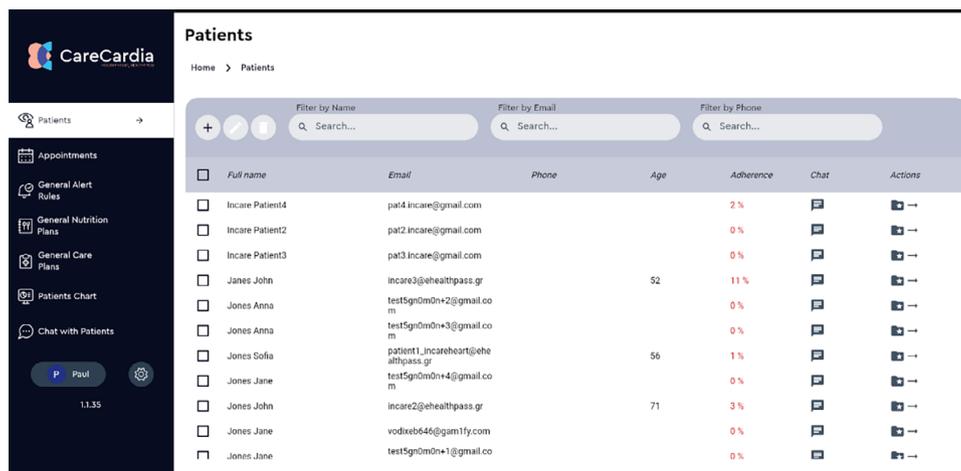|	CareCardia	WeChat platform-based health management	RxUniverse	ReDS system	MultiSENSE	CDSS
Prevention	√		√		√	√
Diagnosis/disease progression	√	√	√		√	√
Treatment/rehabilitation	√			√		
Self-management	√	√	√	√		
Supportive care	√					

FIGURE 2 | HCP dashboard—list of patients.

clinician's dashboard populated by self-assessment tools, integrated devices and EHRs with real-time information-sharing capabilities to identify and support at-risk patients. The platform introduces a role-based access control model, ensuring data is shared only after patient consent. It offers holistic empowerment tools for HF patients, like personalised educational content and telerehabilitation, while also assisting in treatment adherence through reminders and shared care plans. The system's AI capabilities facilitate early detection of exacerbations and drug–drug interaction prevention. Built on eHealthPass, it ensures data availability even during connection outages. The overarching goal is to provide tailored care, prompt end-of-life discussions, manage comorbidities, and guarantee interoperability and seamless integration with future systems, all aiming to enhance patient outcomes while reducing operational expenses. Two indicative screenshots of CareCardia's main platform are depicted in Figures 2 and 3 for test users, wherein in the first case the list of patients a doctor is monitoring is depicted and in the second case the care plans of a specific patient are listed.

Additionally, a mobile application is provided to both patients and health care professionals. It consists of user-friendly interfaces based on the eHealthPass platform. Key services include personal health record, advanced care digital directory, personalised care plan, health data sharing consent, digital communication channels, notifications, data dashboards and patient empowerment features like medication management, goal setting, self-tracking,

gamification, and online peer support. Figure 4 shows a view of CareCardia's home screen.

CHF patients can access their personal health information and share their overall medical history with their caregivers and their professional care team. The personalised goal-oriented care plan allows patients to track progress and manage their daily tasks. Customizable notifications, reminders, and follow-ups are also provided. The reasons for non-adherence are investigated. Patient empowerment services are based on Fogg's behaviour model [34], while a cognitive behavioural therapy concept is also implemented. CareCardia personalises patient and caregiver engagement through AI-driven prompts and behaviour-informed nudges, which are dynamically generated based on individual patient data, including lifestyle patterns, ePROMs, and adherence trends. The platform utilises the aforementioned behavioural model and principles to tailor motivational messaging, reminders, and coaching content to each user's psychological and clinical profile.

4 | Early Findings

4.1 | Results From the Initial Validation

During an early validation round, 55 patients and 20 healthcare professionals in five different countries (i.e., Greece, Turkey,
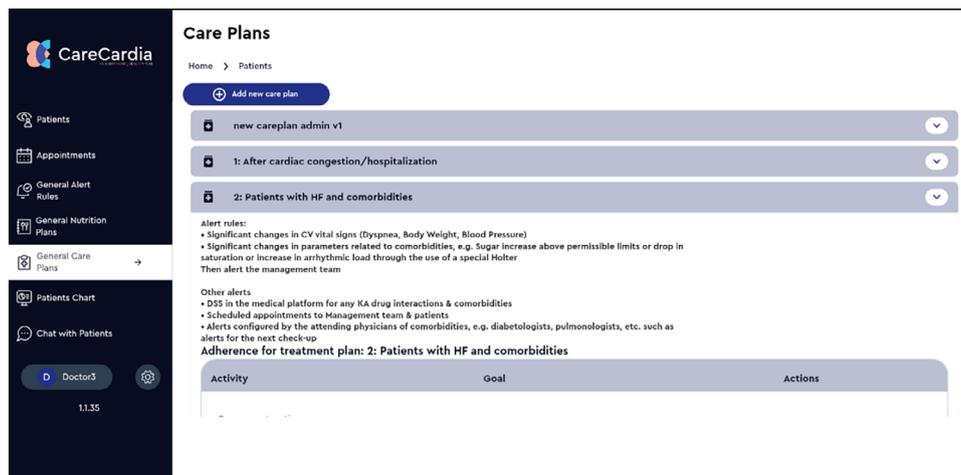
FIGURE 3 | HCP dashboard—list of care plans.

FIGURE 4 | Mobile app: Home screen.

Italy, Sweden and Portugal) interacted with parts of the Care-Cardia solution while guided by the research facilitators of the team. Overall, the CareCardia platform received positive feedback. More specifically, healthcare professionals appreciated the intuitive user interface of the solution, available both via smartphone app and the web. A much-appreciated feature was the AI-driven clinical texts' analysis, alongside the collection of PREMs, PROMs, and validated questionnaires. There was significant praise for the inclusion of template shared care plans tailored to different CHF population groups, which can be further personalised and customised. Both features were seen as important to automate significant clinical office work. The

system's real-time alerts for adverse medication effects and real-time notifications were seen as strengths. Participants valued the capacity to measure health parameters, the interactivity of the exergaming platform, and the solution's overall ergonomic design, addressing patients' daily needs. Features facilitating improved communication between patients, caregivers, and professionals, including an AI-supported chat and effective EHR, were lauded, although some feedback noted concerns with system reaction speed and reliability. The solution's tools were found promising in promoting medication adherence, lifestyle, and nutrition management. While gamification initially appeared less appealing, users found it engaging upon trial. Additional highlights included the ability to print patient summaries and the empathy training component using Virtual Reality (VR).

4.2 | Lessons Learned

During the hands-on sessions several valuable lessons were learnt, that call for further platform development and improvement. Simplifying components needing clinician input is crucial. Ensuring consistent measurement units, even across borders, remains a priority with ongoing validation. Integration with national online medicine subscriptions is being explored. Customising access levels based on each country's healthcare system and workflows is key. CareCardia has been designed with modular architecture and flexible integration layers to accommodate the diverse digital infrastructures across participating countries. It also incorporates configurable data governance rules aligned with national regulations, ensuring compliance with country-specific data protection, interoperability standards [35], and consent management practices. Our platform fosters multidisciplinary collaboration, offering real-time shared care plans and a healthcare professionals' forum. Visual representation of vital patient data and streamlining patient-initiated appointments still need further improvement. An agreement between participants was that social tools like leaderboards and forums cater to patients' social interaction needs. The addition of features like colour-coded alerts and e-pulse system connections was proposed. Terminology and content translations need further validation (especially when it comes to localisation there might be gaps that need our attention) and note-keeping during

hospitalisations needs improvement. For clinicians, seamless navigation across the various sections of the web application is essential to ensure efficiency and minimise cognitive load during care delivery. However, user interaction sessions revealed that the current interface introduces significant complexity in performing key actions, such as accessing patient information or executing other critical functions, hindering usability and workflow integration. Real-world deployment is expected to face challenges such as navigating complex data privacy regulations, addressing digital literacy disparities among users and ensuring clinician buy-in to support sustained adoption.

5 | Discussion and Anticipated Impact

Heart Failure is a long-term condition with episodic deterioration. HF exacerbation remains one of the most frequent causes of hospital admissions with associated increasing mortality [36], whereas the latest studies suggest an increase in related hospitalisations and readmissions [4]. European registry data show that hospitalisation carries a 24% risk of death within one year [37]. Improvement in disease monitoring via identifying various modifiable factors could be an opportunity to reduce the risk of decompensation [38]. In-person clinical assessment is significantly limited when it comes to early recognition of signs of decompensation, as the patients tend to seek professional advice only when their symptoms are advanced [39]. Digital health applications for monitoring key parameters, such as weight, hemodynamics and patient-reported symptoms may help to improve the early detection of HF deterioration.

Several studies have investigated the usability of telemonitoring and its impact on the clinical outcomes in patients with HF [40, 41]. A key challenge in telemonitoring is obtaining objective patient data, especially in the case of HF patients with reduced ejection fraction using CIEDs, like pacemakers, ICDs, and CRT devices. While these devices have sensors and algorithms for remote data collection on signs, symptoms, weight and thoracic impedance, incorporating these biomarkers into telemedicine systems has not demonstrated improved clinical outcomes, including HF mortality or hospitalisation rates [42]. The failure of these technologies may be due to the limitations of the data assessed, rather than the concept of remote monitoring.

Another key challenge here is patient and caregiver engagement in disease management [43]. Key studies [27] have already demonstrated a direct correlation between patient engagement in mobile health apps and improved outcomes in chronic heart disease management, and have shown [44] that older adults are the least likely to use digital health tools, underscoring the need for age-inclusive design and targeted education. Besides age, other persistent barriers to adoption, include data privacy concerns, usability challenges, and the digital divide [45]. Despite rapid technological progress, literature reflects a tension between innovation and the need for more accessible, human-centred implementation [5].

Recent technology advancements enable less invasive methods for early detection of HF decompensation. The ReDS system, comprising a wearable vest and two sensors, noninvasively measures lung fluid content using electromagnetic signals. This data helps clinicians detect early signs of HF decompensation and fluid accumulation, leading to timely treatment adjustments. The system has proven effective in reducing hospital readmissions by 87% in a study of 50 patients and 58% in a study of 268 patients with HF [46]. In addition, the LINK-HF study used a disposable sensor patch with a 7-day battery and a reusable module connected to a smartphone via Bluetooth. This device captures various patient data like continuous ECG, accelerometery, skin measurements, heart parameters, respiration, activity, sleep and posture. It detected vulnerability signals about 6.5 days before hospitalisation, offering personalised risk assessment and intervention time. However, the study has limitations, including a small sample size (100 patients with only two females) and lack of external validation [47].

Lack of information integration across different healthcare settings, sensors and systems, which complicate management of the disease, also poses an important barrier in terms of integrated and seamless provision of care. The current data ecosystem includes several data siloes and noninteroperable systems which pose challenges in integrating those into existing clinical workflows [39, 48]. The design of clinically meaningful systems and methods for homogenising the data and enabling the integration of these data using standards and terminologies will allow incorporating these data into clinical workflows and will ensure the quality of data and clinical content and patient and caregiver accessibility [49]. CareCardia, aims to break existing data siloes, as it builds on a comprehensive interoperability framework, allowing the integration of the solution with diverse EHR systems that conform to HL7 FHIR standard.

Beyond these very interesting and advanced technological solutions, there is a growing number of apps and wearables used as tools for health and lifestyle maintenance. Based on recent evidence, the number of apps dedicated to patients with HF is quite limited [50]. Fewer HF apps have been evaluated in randomised trials. The main focus of these apps is patient education and symptom tracking, while also including alerts prompting users to seek early care for symptoms to avoid further deterioration [51, 52]. Limited clinical data demonstrate that these apps could improve HF patients' awareness regarding the disease, as well as improve their self-management and their quality of life. On top, apps that use gamification techniques [53] to assist patient empowerment, self-management and telerehabilitation adherence can be proven greatly important in increasing the efficiency of telemonitoring systems [54].

Given the above literature findings, CareCardia aspires to offer a holistic platform for the management of CHF based on real-world evidence and backed by cardiovascular science. By adopting and integrating core, clinically validated conceptions alongside innovation components such as AI-driven clinical automation, the platform is positioned to deliver substantial clinical impact and achieve widespread adoption in routine practice. This combination of evidence-based design and innovation addresses real-world clinical needs while enhancing decision-making, care coordination and patient outcomes.

More specifically, CareCardia aims to deliver a wide range of clinical and non-clinical benefits to both patients and health care professionals.

For patients, the anticipated benefits include the following:

- Improve self-management for patients living with CHF: A dedicated module supports patient self-monitoring with informative summaries. Personalised care plans, notifications, and gamification through an e-coaching system may enhance adherence to healthcare provider instructions. The exergaming platform could aid physical rehabilitation at home, while patients can develop problem-solving skills and get empowered by accessing scenario-based educational materials. To promote health equity, the system is designed to be accessible and inclusive, addressing the needs of diverse populations—including those with limited digital literacy, mobility challenges, or lower socioeconomic status—ensuring that all patients can benefit from its features.

- Protect and enhance patients' psychological well-being: CHF may cause patients anxiety and depression. CareCardia focuses on improving this through eCBT techniques, specialised PROMs for mental health monitoring, assistance in stressful situations like multi-pharmacy management, and access to online peer groups to foster a sense of belonging to a community.

- Prevent decompensation episodes and manage HF-related complications: CareCardia continuously monitors patient adherence and lifestyle for early decompensation signs. Clinical predictive models embedded in the decision support system offer patient risk stratification based on clinical guidelines. Ensuring adherence helps prevent HF deterioration and informs patients about related comorbidities, reducing their impact on quality of life.

- Reduce burden for informal caregivers: Informal care involves supporting sick family or friends, especially in chronic conditions like HF. CareCardia aids informal caregivers by providing a comprehensive view of the patient's status and access to shared care plans, and empowering patients to ease caregiver responsibilities.

For health care providers and professionals, the anticipated benefits include the following:

- Reduce time required per patient follow-up for specialised cardiologists and other HCPs: CareCardia collects diverse patient data and presents it to HCPs via a detailed dashboard. The clinical decision support system provides personalised risk estimates, reducing patient consultation time, increasing patient access, and lowering healthcare costs by minimising unnecessary visits and addressing drug interactions.

- Multidisciplinary team coordination and patient management improvement: CareCardia introduces shared care plans while facilitating interoperable data exchange among services and healthcare settings, which could enhance collaboration and communication between HCPs, improving HF management and addressing patient comorbidities. This could result in better therapeutic management, reduced medication-related adverse events, and less frustration for HCPs who often need to adjust treatment plans.

- Informed and enhanced clinical decision-making: Graphical patient data representation offers HCPs quick insights into patient status and disease history. Combined with clinical predictive models, CareCardia may enhance HCPs' ability to identify at-risk patients and those requiring treatment adjustments.

- Improve communication and trust between patients and HCPs: Innovative patient-centred solutions like collection of ePROMs, telerehabilitation via serious gaming, eCoaching, and HCP-patient communication channels enhance the HCP-patient relationship, fostering trust. eCoaching increases patient awareness and self-management, improving adherence to medication plans, a critical factor in reducing decompensation risk and associated morbidity and mortality.

- Personalise treatment and improve consistency with guidelines: As HF is a debilitating condition with high morbidity and mortality, the adoption of new technologies and tools is expected to enhance HCPs' interest in patient engagement. A user-friendly web platform, featuring graphical patient data representation and educational material, aims to provide HCPs with insights into various patient groups' treatments and adaptability. This can lead to a deeper understanding of behavioural patterns and different patient cases.

- Improve services and reduce costs for the healthcare system: Implementing a multidimensional digital solution to streamline HCPs' daily routines and patient interactions will greatly impact healthcare organisations. Utilising a user-friendly CDSS within a multidisciplinary team coordination platform is expected to enhance efficiency, job satisfaction, care quality and value for patients. This leads to better information flow, decision-making and organisational improvements, ultimately providing cost benefits to the healthcare system.

6 | Conclusions and Future Work

Healthcare systems across Europe and globally continue to face significant challenges in addressing the complex and evolving care needs of patients with chronic conditions such as CHF. These challenges include, fragmentation of services, the increasing burden on care providers, and the necessity for long-term, multidisciplinary management approaches. In response, many national healthcare strategies increasingly emphasise the adoption and implementation of patient-centred and interoperable ICT-enabled solutions as key driver for transforming care delivery. Specifically, the integration of such solutions into a single, unified digital platform is widely regarded as a critical enabler for achieving coordinated, continuous, and personalised care. This approach supports the shift toward integrated care models, where diverse stakeholders including patients, caregivers and healthcare professionals, are connected within a shared ecosystem that fosters collaboration and data-driven decision making.

In this work, we have introduced CareCardia, a digital health platform that aims to integrate several features into a modular approach to help patients, informal caregivers, and various healthcare professionals work together to create a shared, person-centred CHF care pathway that spans diagnosis, acute care, and jointly managed long-term care. To accomplish this, CareCardia combines cutting-edge, clinical evidence-based technology into

a single digital platform that will track CHF patients from the time of diagnosis through therapy and care until they receive early supportive care.

To conclude, this paper presents a high-level architecture of the CareCardia solution, along with early validation results gathered from interactions with patients, informal caregivers, and healthcare providers. These initial findings provide valuable insights into system usability, user engagement and clinical relevance. In addition, we highlight key lessons learned and discuss the anticipated clinical and non-clinical benefits of the solution, drawing on preliminary feedback and supporting evidence from existing literature on similar digital health applications.

6.1 | Limitations

This paper mainly presents the technological innovations of the CareCardia solution and preliminary findings, but lacks real-world validation of the corresponding interventions within a larger, more heterogeneous cohort and diverse clinical settings and healthcare systems. The clinical study has been planned and started to gather enough evidence and feedback, but also understand the main barriers and facilitators of adopting our solution in the clinical practice and the daily lives of CHF patients. 250 CHF patients and their caregivers from five different countries—Greece, Turkey, Italy, Portugal, and Sweden—will use CareCardia. Their MDTs will also be involved in validating the concept of CareCardia and the results will be reported in a subsequent publication. The planned clinical validation will focus on key patient-centred outcomes including improvement in symptom control, reduction in heart failure-related hospitalisations and readmissions, enhanced medication adherence, and quality of life measures. These outcomes will be assessed using validated PROMs, digital biomarkers, and care utilisation data collected over the study period.

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