Opportunities and Challenges in Implementing a Virtual Ward for Heart Failure Management

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Abstract—The management of heart failure and post-heart surgery has been a major interest in healthcare. The cardiac unit has improved over time, undergoing significant innovations to improve the quality of services and patient outcomes. Researchers play a significant role in progressing innovative solutions, from co-design and idea conception to conducting impact analyses. These often involve identifying correlations between interventions and outcomes to improve the quality of care. In the context of heart failure, there is an ever-increasing workload that is impacted by the lack of resources, and staff, and the increasing number of elderly population with heart conditions and associated co-morbidities. The COVID-19 pandemic has compounded these existing challenges. These challenges provide the impetus for seeking technological interventions. In the UK, The National Health Service encourages such initiatives where patients are looked after via digital technologies, under the *Virtual Ward* concept. This paper adopts a two-pronged approach, exploring the needs of the patients and clinicians and the potential of digital technologies to address those needs. By evaluating current challenges, the current state of the technology, and its limitations, this paper provides insights for future interventions that facilitate a *Virtual Ward* for the management of heart failure in the community.

Keywords—Heart failure management; virtual ward; technological challenges

I. INTRODUCTION

Heart failure is quite common amongst older people, with more than 10% of those over 70 years old experiencing it [1]. In heart failure patients, about 17% may pass away within a year from any cause, and up to 44% may need rehospitalisation within that same time frame. At the same time, the cost of inpatient care puts a considerable burden on the care system in England [2]. According to statistics from the British Heart Foundation [3], the costs related to heart and circulatory diseases are approximately £10 billion each year. In the UK, about 7.6 million people have heart and circulatory diseases and as people get older and the population grows, more people may develop these conditions. Currently, there are roughly 4 million men and 3.6 million women with heart and circulatory issues. It is predicted that more than half of people in the UK will experience a heart or circulatory problem during their lives [3]. Surprisingly, there are about twice as many people dealing with heart and circulatory diseases in the UK compared to those with cancer and Alzheimer's combined. Every year in the UK, approximately 49,000 individuals under 75 succumb to heart and circulatory diseases. In recent years,

hospitals have encountered various challenges [4], including staff shortages, economic burden, increased population as well as an increase in chronic conditions and the impact of the COVID-19 pandemic [5].

Improving Heart Failure (HF) management has been a long-standing challenge in medical research [6] driven by the goal of enhancing healthcare quality, patient survival rates, and satisfaction with medical protocols. However, healthcare systems, specifically cardiac units, have been significantly impacted in recent years due to staff shortages and economic burdens [2]. These challenges have resulted in medication errors [7], food delivery mistakes, lack of attention and care, and in some cases, fatalities due to carelessness [7]. Moreover, the average length of hospital stay decreased from 8.2 days in 2000/01 to 4.5 days in 2018/19 [8]. This reduction reflects an emerging shift towards alternative care delivery models, including home care options. While hospitals strive to provide optimal care, they cannot substitute for home comfort. Research indicates that most patients strongly desire to expedite discharge and return home as soon as they regain consciousness [9], typically within three to four days. However, the transition from hospital to home-based care for managing HF and post-heart surgery presents complex challenges. Patients with a history of HF require continuous monitoring, proper medication management, regular checkups, maintaining a healthy diet, and rehabilitation sessions to support their recovery [10]. Despite patients who desire early discharge and prefer home-based care due to comfort preferences and economic issues, it is important to acknowledge the complexities and challenges associated with a community health setting.

The establishment of a virtual ward can benefit this group of patients. A virtual ward can be defined as a remote monitoring and healthcare management system that enables medical professionals to oversee and support patients in their own homes, and bridges this gap by delivering hospital-level care in a familiar environment.

This paper examines the current needs of patients with HF and the challenges they face in hospitals and homes. We then explore current state-of-the-art technological solutions for looking after patients at home and highlight their limitations and shortcomings. Specifically, we explore the technology from the perspective of the *Virtual Ward* concept and its potential to provide hospital-level care within the comfort of

patients' homes. This paper aims to contribute to the ongoing discourse on enhancing patient care in cardiac healthcare settings by critically assessing existing approaches and their shortcomings with the idea of informing a new list of requirements for future innovations in this domain.

In Section II, we first outline the current needs and challenges in managing HF. Following this, we discuss current technological solutions designed to address these needs, and analyse their shortcomings in Section III to identify the gaps that require further exploration and resolution.

II. NEEDS AND CHALLENGES IN HF MANAGEMENT

Healthcare systems today are facing several challenges. They deal with increasing numbers of patients, limited resources, and changing healthcare needs. This section discusses existing work in the healthcare domain and identifies those needs and challenges [2].

Existing literature highlights strain on the healthcare system in the UK and worldwide due to the increasing population [4], shortage of medical staff, gaps in monitoring patients [2], medication errors [7], and patients food delivery errors [11]. These issues often result in the potential impact on morbidity and mortality [7]. The aftermath of COVID-19 further added to these challenges [5] with an increased number of patients, shortage of staff, beds, ventilators, and Intensive Care Units (ICUs) [5]. HF is one of the critical health issues to manage that requires immediate attention and such issues cannot be escalated for later resolution due to high mortality rates [5]. This underscores the importance for researchers to explore different and better ways of taking care of patients to handle current and future crises at hospitals. In the following subsections, we have explored individual challenges in healthcare units that affect patients in general, with a focus on HF management and cardiac units.

A. Challenges in Medication Management

In a study [12], researchers investigated hospital prescribing errors by staff and nurses in Georgia and Colorado. The results revealed that approximately 19% of medications were administered wrong, either at the wrong time, in an incorrect dose, or unauthorised manner. This highlights the urgency for innovative approaches to avoid prescription errors. Moreover, insights from the Norwegian Incident Reporting System from 2016 to 2017 [7] have been shared. In this report, 3,557 medication errors were reported, and most of the errors occurred during medication administration (68%), followed by prescribing (24%) and preparation/dispensing stages (6%). The leading types of errors were dosing errors (38%), omissions (23%), and incorrect medication prescribing (15%). Alarmingly, over half of all errors were harmful (62%), with 5.2% causing severe harm, and 0.8% resulting in fatalities. Apart from medication errors during the hospital stay, such errors also occurred during the admission and discharge times. A study comprising 904 patients found that 29.4% of patients have experienced at least one unintended medication [13]. These unintended medication errors were serious or very serious in

36% of patients and potentially moderate in almost 40%. This risk later increased with proceeding treatments. The general practitioners or nurses were identified as the most effective sources of administering wrong medicines.

Another paper focused specifically on the National Health Service (NHS) in England [2] has revealed economic burden and medical errors within hospitals. According to the annual national estimate, there is a substantial number of medication errors with 237 million across the medication process, with primary care accounting for 38.4% of these. The economic burden associated with definitely avoidable adverse drug events is estimated at £98,462,582 per year, resulting in 181,626 bed-days consumed and causing or contributing to 1708 deaths. This led to hospital stays and the cost of hospital admission to £83.7 million; causing 627 deaths in primary care, while secondary care resulted in extended hospital stays counting to £14.8 million cost, and causing or contributing to 1081 deaths.

B. Diet Management Challenges

In addition to medication, diet management is also an important part of recovery for all patients and most importantly for heart failure patients. Studies identified that proper diet management helps control risk factors such as high blood pressure, high cholesterol levels, and obesity [14]. For many people, HF can stem from obesity, as there is a strong correlation between obesity and HF [15]. Therefore, diet management holds significance. Typically, during hospital stays, patients receive food as directed by doctors. However, many errors were seen in the past in the diet management of patients. A case study conducted in Thailand highlighted many complaints about wrong food delivery, making up 37.4% of all complaints in 2017 [11]. The primary reasons found for food delivery errors included wrong orders (not passing on the right information), catering the wrong food to patients, and errors made by doctors in prescriptions. Research also found instances of malnutrition in patients with chronic or severe illnesses, particularly in hospital settings. It has been revealed that malnutrition is often not recognised or underestimated, leading to increased morbidity, mortality, longer hospital stays, and higher treatment costs [16].

C. Monitoring Issues

Monitoring patients at hospitals has often been a challenge across various departments, specifically in those units where continuous monitoring is required, such as in cardiology wards or mental health wards [17]. These wards encounter difficulties in monitoring patients due to the limited manpower. The increasing number of patients places considerable strain on the existing resources. To overcome the issue of manual monitoring and shortage of staff, researchers have developed some monitoring tools, like remote physiologic monitoring devices, to monitor patients' vital signs, symptoms, and other health indicators remotely [18]. However, there are technical issues such as inconsistent data transmission, missing data points, or malfunctioning in these devices leading to unreliability of

remote monitoring systems. Moreover, the patient's discomfort presents another challenge as many older adults or those with cognitive impairments may not be able to use and properly activate the monitoring devices. Thus, monitoring patients remains an open challenge in hospitals as well as in remote monitoring setups.

D. Challenges with Rehabilitation Programs

Physical rehabilitation plays a crucial role in HF management and post-heart surgery. Rehabilitation programs help patients regain their strength, enhance cardiovascular health, improve overall quality of life, and most importantly reduce the potential risk of future cardiac problems. Researchers have examined several challenges associated with rehabilitation programs including limited access to services due to high cost, geographic barriers, and issues with personalisation to individual needs and delivery [19]. Another challenge associated with rehabilitation programs is the lack of interdisciplinary collaboration among different practitioners including psychologists, surgeons, and therapists [19]. Additionally, studies identified a shortage of staff in cardiac rehabilitation centres, which poses a significant challenge since cardiac rehabilitation programs require specialised expertise to provide tailored rehabilitation based on individual patient needs [20]. Neglecting the need for rehabilitation programs leads to decreased quality of life, with increased disabilities, injuries, or chronic health conditions among cardiac patients. Therefore, it is important to address the problems faced in rehabilitation programs [19].

E. Struggles with Emotional Needs

Recognising the crucial link between physical and mental health is crucial [21]. People coping with heart disease, and congestive HF encounter beyond their physical challenges. They encompass an emotional battle of social isolation, fear, and uncertainties about other aspects of life since their everyday life is challenging. Despite the advancement in medical technology, the psychological aspect also needs attention, as patients often decline certain treatments because of fear, which poses a challenge for medical staff and effective management [21].

HF and chronic heart diseases not only affect older people, but also children. Children with heart problems and their families suffer through emotional stress, financial burdens, and physical exhaustion in this process [22]. Many individuals often turn to spiritual support for comfort, hope, and strength [17]. Therefore, medical practitioners must provide comprehensive and tailored support and acknowledge their emotional needs thereby enhancing the overall quality of life of patients and families impacted by heart failure.

F. Post-Open Heart Surgery Delirium

In addition to medicine errors, diet management problems, and emotional and physical therapy problems, HF patients often face delirium after open heart surgery [23]. Delirium is a state of mind where people get severe confusion and cognitive difficulties, and this can occur from a multitude of causes.

Notable amongst them are side effects of medicines, stress and trauma, and sleep disturbance. To address this challenge, there is a need to train medical staff and patients to help support and perform daily activities during recovery, so that the risk of delirium is reduced.

III. CURRENT SOLUTIONS AND THEIR SHORTCOMINGS

The field of HF management has witnessed significant innovations. In this section, we aim to highlight current research efforts and proposed solutions, with special attention on addressing the shortcomings of these proposed solutions, summarised in Table I, laying the groundwork for future improvements in research.

A. Cost Effective AI Applications to Address Staffing Gap and Monitoring

In the realm of Artificial Intelligence (AI) applications in healthcare, several studies show the promising potential [12]. Advancements in varied medical specialities such as anaesthesiology are significant [24] and indicate that most complex anaesthetic tasks will be performed by robots in the near future. Additionally, wearable devices show potential to enhance patient monitoring. A wearable system mHealth has been developed that replaced the physical follow-up with remote electronic visits, i.e. this device measures the blood pressure, temperature, electrocardiogram (ECG), and weight of patients [25]. The experiment was conducted on 730 adult patients and results showed that automatic measurements with mHealth device can enhance the Postoperative Atrial Fibrillation (POAF) after heart surgery within three months. Such systems showcase the importance of remote monitoring in improving patient outcomes. Several new remote care systems have been launched that are surpassing human capabilities [26], by offering real-time monitoring, analysis, reminders, and personalised rehabilitation programs and care. A study on patients who had undergone a heart procedure called Transcatheter Aortic Valve Replacement (TAVR) revealed that smartwatches have effectively detected cardiac issues such as irregular heart rhythms post-hospital discharge [27]. This highlights their potential as valuable tools for remote monitoring and follow-up care. Integration of smart systems addresses the problems in traditional systems [19]. However, advanced monitoring systems have some limitations, including the lack of electroencephalogram (EEG) monitoring, and insufficient focus on chronic disease or specific contexts such as HF. Additionally, these systems need more clinical validation to enhance their efficacy.

B. Smart Diet and Weight Management Applications

People with heart problems should maintain a healthy diet and weight [15]. Existing works such as Speak4Diet app [14] monitor dietary intake and identify deficiencies in nutrients. This AI-based app analyses and tracks the composition of the user's diet and provides personalised recommendations for improvement. While such apps demonstrate considerable potential, there is room for improvement including consistent

TABLE I
SUMMARY OF CHALLENGES, CURRENT SOLUTIONS, AND SHORTCOMINGS IN HEART FAILURE MANAGEMENT

Needs and Challenges	Current Solutions	Shortcomings and Problems
Medication Management	Automatic Medication Dispensing System [28] Smart Medication Error Reporting Tool [29]	Limited functionality of Automated System [28] Medication Errors [12], [7], [2], [13]
Dietary Management	Improved Food Delivery Systems [30] Mobile App for Tracking Dietary Intake [14]	Food Delivery Errors [11] Lack of Personalised Dietary Plans Malnutrition in Patients [16]
Cost and Space Management [2]	AI applications in Nursing [31]	Implementation Challenges [5] Health Inequalities [4] Shortage of Staff and Beds [8] Economic Feasibility Issues [8]
Patient Monitoring	Self Management App [32] Remote Monitoring [18]	Technical Issues With Remote Monitoring [18] Staff Shortage Leading to Health Inequalities [4]
Emotional Needs of Patients [21]	Emotional Wellness Sessions with Psychologists Socially Assisted Robot for Cardiac Rehabilitation [26] Comprehensive Support Programs [33]	Depression and Anxiety [21] Lack of Corporation by Patients in Treatment [9] Lack of Emotional Awareness [22]
Physical Rehabilitation Programs	Virtual and In-person Rehabilitation Programs [34] AI-based Exercise Prescription [35]	Lack of Personalisation for Heart Patients [20] Lack of Interdisciplinary Collaboration [34]
Post-open Heart Surgery Delirium [23]	Staff and Patient Training Programs	Lack of Delirium Awareness [36] Inadequate Support Systems [23]
Heartbeat Abnormality Detection	Heart Sound Abnormality Detection [37] Diagnosis of Heart Rhythm Abnormalities [38]	Limited Clinical Validation [37] Data Privacy Concerns [5]
Prediction of Heart Failure	Early Screening Programs [10] Data-driven Risk Prediction Models [39]	Limited Clinical Trials [10] Interpretation Challenges [40]

user adherence, minimising data entry errors, limitation to food database, refining portion size estimation, and enhancing the sophistication in tailoring advice to individual health goals, preferences, and dietary restrictions.

The sudden weight gain in heart failure patients can signal underlying cardiovascular issues and it is recommended that patients weigh themselves regularly [15]. A weight gain of three to five pounds in a week or two to three pounds in a day signals that the heart is not pumping blood properly. There are existing applications for weight management such as an explainable AI tool for predicting weight loss success for people who are trying to lose weight [41]. Similarly, another chatbot has been introduced to assist people in managing their weight loss journey and provides motivational and sentimental support [42]. Despite achieving a good accuracy such as above 80%, there are concerns regarding adoption and trust. Moreover, the weight monitoring applications for managing HF patients should be contextually aware of the purpose of identifying correct trends. Future research is required to address these concerns. Apart from monitoring heart patients, an application focused on HF management can also help address the issue of obesity.

C. Automatic Medication Management Systems

Effective medication management stands at the top of care for HF treatment and post-care. Researchers have introduced an automatic dispensing machine that handles medicines dispensation automatically [28]. This machine was developed to help people living in faraway places like tribal areas where getting medicine can be hard. The machine holds basic and emergency medicine and can also check vitals like blood pressure and temperature. When it is running low on medicine, it can be refilled based on remote information. A smart medication error reporting tool has also been introduced for

enhancing the patients' safety [29]. Moreover, a systematic review has revealed the efficacy of mobile health apps in helping heart patients stick to their medications [43]. These apps generally demonstrated acceptable usability. However, ensuring the accuracy of medication administration and contributing to usability and effectiveness remains a significant challenge and further work is required in this domain to fully realise the potential of these systems.

D. Personalised Rehabilitation Programs

Irfan et. al [26] studied 43 patients to find the effectiveness and acceptability of socially assistive robots in personalised care at cardiac rehabilitation programs. The results derived from 26 patients(who finished the whole program), showed the effectiveness of robot assistance and personalising in the rehabilitation program, particularly during intense training. However, some failures in sensor data recognition were noticed, suggesting the need for future work to enhance sensor data recognition. Researchers have made significant efforts in therapy programs, such as AI-based personalised prescription by GPT-4 model [35]. Moreover, AI-based rehabilitation has been explored for patients with cerebrovascular accidents to reduce psychological stress [44]. Virtual reality-based therapy programs have been proposed to manage postural dizziness [45], and wearable robotic exoskeletons have been developed to enhance upper-limb rehabilitation [33]. Furthermore, researchers are utilising smartphones to study gait patterns to gain insights into an individual's personality [46]. Additionally, individual patient profiles are considered for tailored medical therapy [47].

Despite the potential of such effective therapy programs, these programs lack comprehensive clinical evaluations, encounter implementation challenges in real-world environments, and demonstrate a lack of precision. Therefore, more

efforts are needed to enhance the usability and universality of these programs.

E. Early Diagnosis of Cardiac Complications and Abnormalities

The prediction of any health issue is critical in healthcare as it enables early identification and timely intervention for improved quality of life. Researchers have presented numerous works for the prediction of different diseases [32]. In another study [48], researchers proposed advanced methods for HF prediction using deep learning and a dataset of real healthcare records. This approach was effective for anomaly detection and risk factor refinement early intervention. Additionally, many similar researches open avenues for electronic health record data to explore HF, revealing significant variations in left ventricular ejection fraction [49]. Furthermore, [50] have proposed a motion-based analysis method for survival prediction of HF patients and their work highlights its potential for assisting clinical practitioners in personalised therapy planning for patients. Another study presents extensive insights on survivors of adolescent/adult Hodgkin lymphoma to develop prediction models for coronary heart disease and HF [40]. The model was accurate at predicting the risk of heart problems about two to three decades in advance. Such models can help doctors to screen and treat heart issues in Hodgkin lymphoma survivors at an early stage.

Despite significant progress in the research domain, clinical validation and real-world implementation represent crucial limitations in current solutions. Improvement in these areas will bridge the gap between technology and medicine, leading to better healthcare systems.

F. The initiative of Virtual Ward Care for HF Management

Addressing the issues in managing HF, including those encountered at hospitals in general and post-COVID-19 challenges, alongside meeting the patients' preferences, it is conceivable that the implementation of a *Virtual Ward* capable of managing complete HF care at home could be an effective solution. Despite the problems associated with different technological interventions highlighted earlier, with the rapid evolution of AI, robotics, and wearable technology, new solutions can be derived to overcome these limitations. Drawing inspiration from successful *Virtual Ward* models designed for acute respiratory infection and frailty, the NHS has also introduced the idea of a *Virtual Ward* care for people with HF [6]. The objective is to provide personalised care, monitoring, medication recommendations, personalised therapy, and individualised dietary prescriptions at patients' homes. This will also reduce the processes of admissions and re-admissions to the hospital, resulting in cost savings and supporting a near-real-time decision-making system. The focus lies in enhancing digital systems to remotely monitor patients, early identification as well as prediction of deterioration, timely intervention, and managed load.

Existing literature highlights challenges in current cardiac units and healthcare systems. Assistive technologies have a high potential to significantly improve HF management and promote home-based *Virtual Wards* [32]. Tasks such as early detection of declining cardiac function before they become clinically apparent, optimisation of remote monitoring systems and predictive analytics for hospital readmission risk assessment are more suitable for an AI-based system to excel. These functionalities hold significant promise if provided with clinical validations and personalisation.

IV. CONCLUSION AND FUTURE WORK

In this paper, we have explored current challenges for HF patients from a UK perspective and presented some of the current technical solutions to provide home care for HF patients in the UK and worldwide. Managing HF is becoming more complex, with the current solution facing specific challenges if implemented in people's homes. While existing technologies facilitate the rapid transition of patients to their own homes, we have pointed out shortcomings and the potential for future improvement, highlighting the need for more advanced systems. Emerging technological solutions, such as the NHS *Virtual Ward* Care initiative, show the potential to improve patient care and better management. Future work in this domain can also contribute to the evolution of care pathways for HF, including the assessment of the effectiveness of such technological innovations.

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