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RESEARCH ARTICLE

Remote Monitoring in Heart Failure: Recent Trends and Future Perspectives

Dr. Ruchit Shah[1], Swarna Kedia[2], Madhusmita Rawooth*[2], Kumar Chokalingam[2], Pooja Kadambi[2], Gaurav Parchani[2]

[1] Consultant Cardiologist – Saifee, Jaslok hospital
[2] Turtle Shell Technologies Pvt. Ltd.[2]

*madhusmita@dozee.io

ABSTRACT

Heart failure is linked to serious health problems, high medical expenses, and fatality. A promising approach to enhance the clinical care of heart failure patients and intervene prior to an overt decompensation is remote monitoring technology. Remote Monitoring technologies have shown potential in managing and carrying out medical therapy to improve the health and outcomes for heart failure patients. This review highlights the evidence on currently available remote monitoring technologies and avenues for heart failure patients and discusses the benefits and gaps thereof. The paper specifically focuses on the different categories of interventions, namely technology based, care-program based or a combination of the two, and delves into their outcomes and limitations. Out of the 47 publications included with a minimum sample size of 104 patients, 37 papers demonstrated successful patient compliance and clinical outcomes, while 10 papers hardly demonstrated any successful outcomes. Studies have shown that the use of remote patient monitoring devices lowers patient mortality and re-hospitalization rates while reducing hospitalisations by more than 65%. According to the review research, short- to medium-term advantages such as higher survival rates, lower hospital utilisation, and lower costs are mostly maintained over time. The results demonstrated that patients who used a hybrid (which included both care and technology) strategy of virtual, in-person, and asynchronous care had more convenience, access, improved clinical outcomes, and overall Quality of Life.In addition to these results, remote cardiac monitoring has also been associated with significant cost reductions.

Introduction

The global population of heart failure (HF) patients climbed from 33.5 million in 1990 to 64.3 million in 2017. The 2017 Heart-disease and Stroke statistics update from the AHA (American Heart Association) indicates that the number of patients with heart failure are surging and is estimated to increase by 46% by 2030, with more than 8 million cases worldwide. Some estimates state that once admitted, 25% of patients are readmitted within 1 month and 50% within 6 months [1]. In 2012, the total economic cost of HF was anticipated to be $108 billion annually [2]; this cost is expected to have multiplied over the previous ten years. HF is associated with frequent hospitalisations due to episodes of HF decompensation, many of which can be prevented [3]. Hence, in recent times, there has been an increased focus towards developing evidence-based interventions for reducing the socioeconomic burden of HF.

Remote patient monitoring (RPM) entails the gathering and transfer of clinical-data between a physician and a patient at a remote location via an interface so that the clinician may analyse the data and treat accordingly. Figure 1 shows the general workflow of RPM systems. Symptom monitoring is a key aspect of RPM interventions. With advancements in sensor technology and computing, parameters like heart rate, respiration rate, oxygen saturation, blood pressure, electrocardiogram, physical activity, sleep quality, body weight, etc. can be assessed by several stand-alone technological solutions. These include an array of devices such as holter devices, ECG patches, multi-parameter monitors, wearables, mobile applications and web based dashboards. Substantively, these data could show early warning signs of decompensation, better adherence to dietary and medication regimens, and interventions that, if addressed, could avoid or lessen the need for HF hospitalisation and enable early detection of deteriorating disease while the patient is still at home.

The COVID-19 outbreak has caused a paradigm change in patient management outside of traditional settings. Patients are becoming self-driven and engaged in the management of their own health. The increased usage of digital health management tools and overall focus on making healthcare more accessible, reducing frequent hospital visits, improving patient compliance and outcomes and reducing costs has made healthcare providers as well as policy makers interested in virtual care and remote patient management. Therefore, this paper aims to delve into the recent trends in remote patient monitoring for HF patients and discuss their applications as well as limitations.

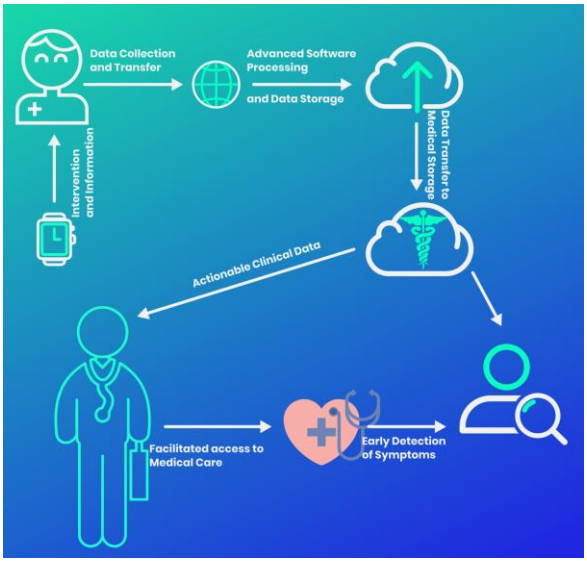

Fig.1. Flowchart demonstrating workflow of Remote patient monitoring (RPM) systems.

Methodology

Design

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was used to perform and report a systematic review of the literature.

Eligibility criteria

Studies were considered as acceptable for inclusion if they satisfied the following requirements: evaluated a program, technology or a combination of the two for home monitoring of Heart Failure patients, had more than 100 participants older than 18 years, and were published in the last 10 years. Review articles, letters, articles without full texts, non-English articles and conference abstracts were excluded from the scope of the review. The outcomes of interest ranged from validation, feasibility (e.g. user experience, acceptability, patient compliance, usability, device fidelity, etc.), patient outcomes, and clinical interventions/escalations, costs (cost-effectiveness, cost-benefit, cost-utility) and the identified gaps and limitations of the interventions.

Search Strategy

A systematic literature search was conducted on PubMed, with the last search run on 3rd July 2022. The references of the retrieved studies were also manually screened to identify any other relevant studies. The search terms used on PubMed are as follows: "Home"[Title/Abstract] AND "Heart Failure"[Title/ Abstract] AND "Monitoring" [Title/Abstract]; and "Home"[Title/Abstract] AND "Cardiac" [Title/Abstract] AND "Monitoring" [Title/Abstract]. The following filters were also applied to get papers that met the inclusion criteria:

- Article Type: Randomised Controlled Trial, Clinical Trial
- Publication Date: Last 10 years
- Language: English

All the hits received in the keyword search were checked for duplicates and consolidated in an excel file. The abstracts of individual references were independently screened against the inclusion and exclusion criteria. Studies that had fewer than 100 subjects were rejected. Full text-articles of the references that matched the inclusion criteria were downloaded and read independently by the authors to determine eligibility (Fig. 2).

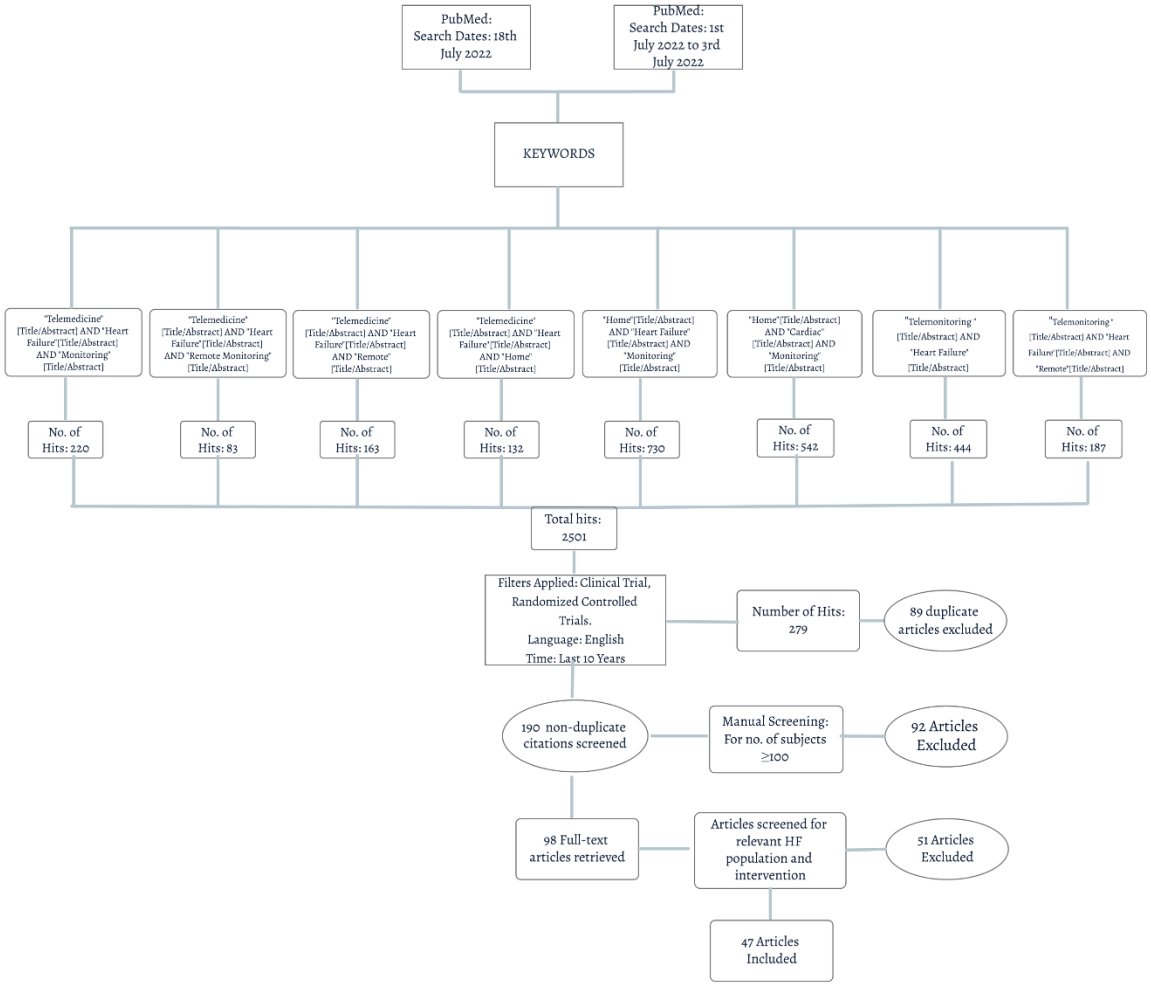

Fig 2. PRISMA flowchart for the literature search

Home-based Remote Vitals Monitoring

Traditionally, HF patients were clinically managed by periodic visits to the clinic. Snapshots from these visits, however, did not clearly depict a patient's physiological condition at home. HF patients need continuous vitals and haemodynamic monitoring for efficient titration of guideline-directed medical therapy. Treatment compliance is essential to improve symptoms and reduce hospital visits. It is often seen that dietary, lifestyle and medication

noncompliance leads to worsening of symptoms and frequent hospitalisations in HF patients.

Remote Monitoring (RM) technology can monitor patient vitals, help clinicians identify early warning signs of health deterioration, thereby allowing them to take timely interventions. The complex and context-specific nature of these interventions makes direct comparisons difficult, studies have identified some key success criteria over time. One of the most important factors in overall patient compliance and adherence is the usability or user-friendliness of the interventions. A better patient outcome is the second, and the third is the applicability or scalability of the intervention for similar patient populations.

Conventional methods for Home-based Vitals Monitoring

Hospitals and health organisations have been active in implementing the right technologies to enhance patient care. It is asserted that the traditional method of healthcare has long been a source of issues, including the inability of clinicians to conveniently access patient information, the lack of adequate time, space, and staff for patient monitoring, and the diagnoses being written illegibly on paper. These problems are made worse by the fact that healthcare organisations must offer higher-quality services to a growing number of patients in hospitals and nursing homes. According to the NICE, physiological measurements such as body temperature, heart rate, respiration rate, systolic blood pressure, state of awareness, and oxygen saturation should be monitored [4].
Traditionally, a nurse or healthcare assistant would visit a patient to check on their vital signs and compare them to the information collected before. The severity of the patient and the nurse's judgement, which might be subjective, may also have a role. Additionally, it's possible that the frequency of visits may rise if the nurse notices that a patient's condition is getting worse. However, this can only occur if the patient is observed effectively and often. This approach to patient monitoring requires a lot of labour, making human resources the most crucial component of this service. It can take 15 to 30 seconds to obtain the patient's pulse rate, another 30 seconds to obtain the patient's respiration rate, and so on. Charts are typically used to record the measurements. However, the number of nurses working in hospitals varies, and as a result, the staff-to-patient ratio affects how well patients are monitored [4].

Care-based Remote Vitals Monitoring at Home

Remote patient monitoring lowers access barriers by providing care to patients when and where it is needed. It can be used to link patients with doctors in remote areas, hospitals, and homes. It's a phenomenal strategy for reducing appointment breaches. It makes it possible for many people to remain at home, regain control over their lives, and actively participate in their care. Devices for remote patient monitoring can lessen the length of stay for these patients in hospital.

AMULET was a prospective, multicenter, open-label, randomised, controlled, parallel group investigation conducted in Poland. Patients who experienced an acute HF episode within the past six months and had HF with LVEF ≤49% were randomly assigned to either outpatient telecare (n = 300) or conventional care (n = 305). The likelihood of patients' first unplanned HF hospitalisation or cardiovascular mortality after an episode of acute HF was found to be 31% lower when using the outpatient AMULET telecare model's nurse-led non-invasive assessments to support remote treatment decisions [5]. The OSICAT study was a multicenter, open-label trial undertaken in France that included 937 individuals who had been hospitalized for acute HF ≤ 12 months prior to admission. Patients were randomly assigned to receive telemonitoring (like daily recording of HF symptoms and body weight measurement). Telemonitoring did not result in a statistically significant reduction in unscheduled hospitalizations or all-cause mortality in HF patients. However, telemonitoring lowered the proportional risk of the first unexpected admission in hospital for heart failure by 21% after adjusting for known predictors [6]. According to the BEAT-HF trial, in 1437 patients, a combination of remote patient observation and care transition management did not lower the rate of 180-day all-cause readmission following HF hospitalisation. The intervention had no impact on 180-day mortality or 30-day hospitalizations. However, there was a significant improvement in 180-day quality of life in the intervention group [7].

An integrated self-care intervention evaluated the consequences of heart failure and diabetes mellitus (DM) on physical health, physical activity, and quality of life (QOL) in 134 patients. Patients were randomised to receive either standard care or an intervention. The perceived HF and overall QOL were enhanced by an integrated HF and DM self-care intervention, but not the DM QOL. The combined self-care intervention also resulted in

improved physical performance and self-reported physical activity [8].

The COACH-2 study included 189 HF patients, randomly assigned to either general care (n = 97) or an HF clinic (n = 92). The study's two main goals were patient adherence and guideline adherence. The outcome showed that after obtaining preliminary management in a specialised HF clinic, patients can be transferred to general care for follow-up to ensure patient compliance. Ongoing monitoring with close cooperation among healthcare professionals is essential [9].

A research was conducted on 292 individuals with heart failure to see how hospitalisation and Emergency Department visits affected adherence to daily weight telemonitoring. The results show that rehospitalization reduced adherence to daily weight telemonitoring [10]. A further follow-up study with 538 participants found that lower compliance to weight telemonitoring in a week was associated with increased rehospitalisation and mortality [11].

A substudy of TIM-HF2 trial looked at whether low-risk individuals who were unlikely to benefit from Remote Patient Monitoring (RPM) could be identified using the biomarkers mid-regional pro-adrenomedullin (MR-proADM) and N-terminal pro-B-type natriuretic peptide (NT-proBNP), allowing for more effective intervention allocation. 1583 patients with either a lowered LVEF of 45% or a preserved LVEF of >45% were selected for the study. The outcomes of the study suggest that MR-proADM and NT-proBNP combined might enable safer, much more accurate, efficient, & economical assigning of patients with HF to RPM [12]. A post-hoc study of the e-Vita HF trial, studied 223 patients with a mean LVEF of 35±10%, Telemonitoring did not seem to have an adverse effect on NT-proBNP levels over time in stable and well-treated HF patients' hemodynamic condition [13]. A secondary review of 160 patients of HABIT trial which compared patients of preserved versus reduced ejection fractions (HFpEF and HFrEF, respectively) compared the effects of home B-type natriuretic peptide (BNP) testing and weight monitoring. Prior to decompensation, the BNP and weight of the HFpEF and HFrEF patients varied. In those with HFpEF, a 3-day period marked by an increase in weight of 2 lbs. and/or a BNP increase of more than 200 pg/mL is strongly linked to decompensation [14].

The HOME-HF study was a prospective, global, adaptive, three-arm, randomised clinical trial that enrolled 145 patients and showed the viability of home BNP measurement as well as the possibility of moving average filter (fBNP) as a marker of developing clinical deterioration. At a regular time each day, ideally before breakfast and any morning medications, subjects used the HeartCheck device at home to conduct finger-stick BNP self-tests. The study's data showed that a subject's BNP values showed significant dispersion, which increased with wider monitoring intervals. This was a significant finding that shed light on the unstable nature and natural history of HF syndrome and further supported the idea that patient-initiated home BNP monitoring could play a role in HF management [15].

The Habit Trial in 163 patients proved that home BNP testing is practical and that trials utilising home monitoring to direct therapy are feasible in high-risk patients. Higher variations in risk, both upward and downward are correlated with changes in BNP. The pattern or trend in BNP levels may be utilised to determine when to correlate with in-person clinical examination or therapeutic intervention, or to manage therapy with particular medication modifications without extra office visits [16].

Randomized controlled trials that examined the actual implementation of HF management programmes revealed that building health care systems around the principles of the chronic care model improves both clinical results and adherence to the advice of evidence-based therapy. The study that included 206 patients demonstrated that diuretic adjustment algorithm (DAA) use improved the combined outcome in these outpatients. The advantages of telemedicine to a current comprehensive HF programme were observed across pre-specified patient groupings, and were accompanied by lower hospital expenditures and better patient-centered outcomes[17]. Telemonitoring results in statistically relevant, but clinically small, advancements in health status when compared to usual care [18,19].

The Kansas City Cardiomyopathy Questionnaire (KCCQ) questionnaire score measures the health state of patients, frequency and burden of symptoms, physical and social limits, and the impact that heart failure syndrome has had on their quality of life. Small variations in KCCQ were linked to altered future risk in a research involving 1521 patients with heart failure. Patients were randomized to the intervention pool or the control pool. Over the first six months of treatment, telemonitoring with KCCQ was connected to

statistically significant but mild changes in disease-specific health status [19]. The Danish TeleCare North Heart Failure trial studied 299 patients to see if adding telehealth services to routine care could improve health related quality of life of patients with HF. They found that the Mental Component Summary (MSC) score was higher in the intervention group. The Physical component summary score and KCCQ12 were not different between the two groups [20].

HF patients residing in poor SES (socioeconomic status) neighbourhoods were more likely to experience an all-cause readmission and a combination of mortality or readmission at 6 months. The study demonstrated that the neighbourhood effect remained even after following multivariable correction for demographics, clinical variables, and a wide range of individual SES [21].

There are studies where telemonitoring did not lead to decreased rate of all-cause-deaths or unplanned hospitalizations in Heart Failure patients but resulted in a reduction of the number of days lost due to readmissions for heart failure [6,22]. The HOMES-HF trial comprised a home telemonitoring system for 181 recently hospitalised Japanese patients. This system contained an electronic scale with a body composition metre, a sphygmomanometer, and a device designated as "receiver" that wirelessly gathered physiological data, such as BP, HR, body weight, and body composition, and transferred the information to the central web-server over the internet. Among newly hospitalized patients with HF, telemonitoring with standard care did not reduce the likelihood of all-cause death or rehospitalization in comparison to usual care [23]. The Home Heart Walk (HHW) study, modified a 6MWT to help heart failure patients monitor their own physical health and encourage self-care. It showed that the participants' perceived physical functioning did not increase [24].

Technology-based Remote Vitals Monitoring at Home

Technology based remote patient monitoring is a method of healthcare delivery that employs the advances in information technology to collect patient data outside of conventional healthcare settings by upgrading to smart operations. It ensures the highest level of equipment performance and crucial data accessibility.

The Selene HF trial, which included 912 patients, created a model for predicting acute HF in CRT-D and ICD patients using the baseline Seattle HF Model (SHFM) score and seven RM temporal patterns. Each device employed the Home Monitoring technology, which is characterised by regular automatic device data transmissions over the GSM (Global System for Mobile Communication) network, and was created by BIOTRONIK SE & Co. KG (Berlin, Germany). Under normal circumstances, hospital professionals can access this data on the Home Monitoring webpage. The prediction system displayed a remarkable low false warning rate as well as promising sensitivity. The proposed algorithm was able to accurately predict two-thirds of initial post-implant HF hospitalizations, IVIs, additional HF hospitalizations and final HF hospitalizations with only 0.7 false alerts per patient-year [25].

In 211 patients, a study was done to examine the effectiveness of all existing RM systems in use now and look into the influence of RM transmission frequency on early identification of clinical and device-related events. All four RM technologies were based on either continuous monitoring with regular reporting of diagnostic data plus automatic alerts (like the Boston Scientific Latitude, Medtronic CareLink, and St. Jude Medical Merlin systems) or on periodic remote follow-ups plus automatic alerts (BIOTRONIK Home Monitoring [BHM]). Prior to implant, these devices were assigned to patients, and they were turned on upon check-out. Almost all actionable events could be found by all RM systems. A higher likelihood of early adverse event identification was independently associated with automatic daily remote transmissions. RM effectiveness and efficiency may be increased by increasing transmission frequency [26].

Customised telemonitoring helps patients with HF learn, enhance their capacity for self-care, and feel more self-sufficient. Patients in the ICD and CRT-D subgroups who have chronic systolic heart failure may see a clinical endpoint reduction with daily multiparameter telemonitoring. In populations with worse prognosis and more risk, the absolute benefit appears to be higher. Some studies have also shown that telemonitoring may alter the clinical course of disease but not lower cardiac death and overall cause mortality. The physicians may be assisted by continuous monitoring, data collection, interpretation, and alert settings to manage therapy immediately and make necessary adjustments for a better CRT-D response. Continuous monitoring may lead to improved patient therapeutic management and reduced hospital admissions when compared to periodic out-

patient follow-up [27-30]. An automated telephone assistance strategy for managing 160 heart failure patients in rural and distant areas with limited access to management programmes had an impact on hospitalisation [31].

In a subanalysis of TIM-HF trial, 155 patients underwent tele-accelerometry as part of monthly 6MWTs at home. The device used for tele-acceleration was a three-dimensional accelerometer specifically designed for recording data during the 6MWT with a "start 6MWT" button and automated cessation of data recording after 6 minutes. Tele 6MWT has a predictive value in detecting mortality and HF hospitalization and can be used as an alternative to the 6MWT [32-33].

Hybrid Remote Vitals Monitoring at Home

Hybrid telemonitoring is a promising approach to help patients and doctors manage HF. EFFECT was a prospective, non-randomized, multicenter trial which included 987 consecutive patients receiving ICD/CRT-D implantation at 25 medical facilities in Italy in accordance with the most recent recommendations for the treatment of chronic HF. Following implantation, 987 patients were split into two groups: the standard arm, which would receive regular in-person follow-up visits, and the remote arm, which would receive remote monitoring. Patients with remote monitoring had a better prognosis. This study also aimed to compare and contrast the rates of beta-blocker administration at implantation and at the 12-month follow-up visit between the two study arms. After 12 months in a "real-world" environment, the study's analysis showed that remote ICD monitoring was not related to the beta-blockers dose that was attained. On the other hand, achieving the effective dose of beta-blockers throughout follow-up was independently related to a favourable clinical result [34]. According to a sub-analysis of the same study, when compared to conventional follow-up via in-office visits, remote monitoring is related with a better result in HF patients who undergo ICD/CRT-D. It was connected to a decrease in mortality, cardiovascular hospitalizations, and duration of stay in patients with ICD [35].

The OPTILINK HF Trial (Optimization of Heart Failure Management Using OptiVol™ Fluid Status Monitoring and CareLink™) showed in 1002 patients that how crucial it is to respond appropriately to remote monitoring data with advanced HF who were fitted with an ICD/CRT-D device that can track intrathoracic impedance. Remote monitoring was only able to significantly increase patients' outcomes who were contacted on time and whose therapy was effectively modified, as seen by increased time to cardiovascular mortality or first HF hospitalisation [36]. In a different study, the OPTILINK HF Trial discovered that employing a particular intrathoracic impedance and telemedicine-based HF disease management strategy in patients with severe left ventricular dysfunction, moderate-to-severe HF, and prior implantation of an ICD/CRT-D device did not significantly reduce the rate of all-cause death or CV hospitalisation when compared to traditional clinical assessment [37]. Another trial with 716 patients found that automated, continuous, implant-based telemonitoring of rhythmic and technical parameters significantly decreased all-cause mortality and the composite clinical score in patients with HF treated with ICDs and CRT-Ds [38].

In the MORE-CARE research, 148 patients with NYHA classes III/IV and LVEF < 35% implanted with CRT-D devices were randomized to remote group (with remote monitoring and wireless alerts) versus control group (with clinical follow up without alerts) using the CareLink network. The study's main finding was that a wireless remote method enabled doctors to make clinical decisions 27 days sooner than with regular in-office treatment while lowering the number of overall in-hospital visits [39].

The TeleClinical Care research, which involved 164 patients, attempted to establish the practicality, effectiveness, and financial sustainability of a smartphone app-based model of care for patients discharged from the hospital after being admitted with acute coronary syndrome (ACS) or heart failure. According to the study, 30-day readmission rates were comparable. However, over the course of six months, fewer readmissions, higher adherence to medication, and improved cardiac rehabilitation completion were all demonstrated as long-term benefits [40]. Another study showed how telemonitoring for 30 days following discharge could aid high-risk patients in having fewer readmissions and fatalities against standard treatment [41].

The ITEC-CHF trial, which involved 184 participants, aimed to evaluate patient adherence to self-management suggestions of an innovative telemonitoring effective care programme for chronic heart failure (CHF). The study had a significant impact on CHF self-management in terms of nutrition, medication adherence, and health

maintenance. The high degree of compliance with weight monitoring among study participants highlights the significance of seamless telemonitoring platforms to lower the possibility of patients losing interest in the technology [42].

The CardioBEAT study was developed to evaluate the health economic effects of a specific home telemonitoring system for 621 CHF patients using real costs that were directly gathered from patients' medical professionals. Patients were randomized to two groups: normal care with or without an interactive bi-directional remote monitoring system (Motiva®). The study offers prospective outcome information regarding the clinical and financial effects of home telemonitoring in CHF patients. Its conclusions can be used to make wise political and financial choices about the usage of home telemonitoring systems in the healthcare industry [43].

The TELEREH-HF trial, which had 850 patients, found that functional and quality-of-life outcomes improved after 9 weeks of HCTR (hybrid complete telerehabilitation). The programme had no positive effects on clinical outcomes throughout the 12- to 24-month period that followed the conclusion of telerehabilitation. According to the findings of the study, the improvements made during the 9-week HCTR do not result in an increase in the proportion of patients spending less time in the hospital or a decrease in morbidity or hospitalisation rates on longer-term follow-up [44]. In the same study's subanalysis, 386 patients who were randomly assigned to HCTR were the focus. An EHO-MINI device was used to telemonitor HCTR, allowing it to record ECG data for 16 seconds and transfer it to the monitoring centre over the mobile network. The method of sequential ECG monitoring was employed. Automatic ECG recordings were timed to coincide with exercise training and were pre-set. During the single training session, the EHO-MINI device was preprogrammed to record four 16-second ECGs. The research demonstrated the safety of the cardiac telerehabilitation model for HF patients used in this experiment without any indication of symptomatic cardiac arrhythmias prompting telerehabilitation termination. Sequential ECG monitoring should be considered sufficient to guarantee the security of the cardiac telerehabilitation model for HF patients [45].

In a large Tele-HF randomised controlled study, 1,653 patients who had recent heart failure hospital admissions were enrolled from 33 cardiology clinics throughout the United States. For a period of six months, patients were randomly allocated to receive telemonitoring or standard care. Telemonitored patients were told to weigh themselves every day through a digital scale and report the results using their phone. The number of weight readings affected by end-digit preference was determined by subtracting the expected number of weight readings that ended in a 0 or a 5 from the actual number of such readings. During the six-month testing period, patients with end-digit preference had increased weight variability and generated 2.9 alarms on average, as opposed to 2.3 for other patients, to the telemonitoring system. Inaccurate information will make disease management more difficult because healthcare professionals rely for treatment choices on self-reported weights. These results raise questions because clinically significant weight changes in heart failure patients can occur with as little as two pounds of weight shift, suggesting that rounding can lead to both false negatives and false positives. Efforts to increase reporting accuracy will need to be added to telemonitoring systems that rely on self-reported data [46].

In a retrospective research involving 301 patients, telemonitoring did not, over time, shorten the interval between the onset of the first HF-related hospitalisation or the all-cause death rate [47,48]. Overall expenses, hospital admissions, symptom improvement, or mortality did not decrease as a result of telemonitoring. Lower overall costs or improved outcomes were not produced by a decrease in 30-day readmission rates in the first year [47,48]. In accordance with additional research, 90-day remote self-monitoring was not effective in lowering all-cause hospital and emergency department visits or enhancing quality of life for HF patients from underserved black and Hispanic populations [49]. The SUPPORT-HF 2 experiment, which involved 101 patients, showed that it is possible and patient-acceptable to centrally provide individualised specialised management support utilising commercially accessible, low-cost equipment enhanced by customised software. However, neither the utilisation of evidence-based therapy nor the quality of life in terms of health significantly improved [50].

A research involving 1360 ambulatory adult patients compared the effectiveness of a disease management programme to standard care. Utilizing home tele-monitoring technology (Medic4All®), patients regularly checked their blood pressure, body weight, and pulse rate after a night's sleep. This comprehensive disease management intervention was not superior to

standard care in terms of the primary composite endpoint, which was the interval between the first hospital admission for heart failure aggravation or death from any cause, but it did improve health-related quality of life and depression. With universal access to healthcare, a disease-centered strategy may not be sufficient to significantly reduce hospital admissions and death among people having chronic heart failure [51].

Discussion

It is said that the conventional approach to healthcare has long been a source of problems, such as physicians' inability to easily access patient information, and lack of time, space, and staff for patient monitoring. Since this method of patient monitoring demands a lot of labour, human resources are by far the most important aspect of this service. Remote patient monitoring can bridge this gap and help track a patient's vital signs, thereby assisting physicians in spotting early warning signals of health worsening. This systematic review focused on different interventions for remote patient monitoring of HF patients and discussed their applications as well as limitations. 47 relevant papers were reviewed and analyzed from a pool of 190 papers. This paper examines the long-term advantages and drawbacks of care, technology, and hybrid-based interventions as compared to usual/standard care in terms of survival, unscheduled or re- hospitalisation, all-cause mortality, physical performance, quality of life, and overall costs. These interventions entailed individuals who had been admitted to the hospital with severe heart failure. This review research has shown that the short-to medium-term benefits of either of the interventions are mostly retained over the long run in terms of increased survival rate, decreased hospital admission, and associated costs.

The majority of the studies included in the review (44.7%) were care-based (Fig. 3). Around 18 papers (38.3%) were based on hybrid technology. The percentage of publications focused on technology was very low (17.5%). The findings showed that people had greater convenience, access, improved clinical results, and overall Quality of Life by utilising a hybrid strategy (containing both care and technology) of virtual, in-person, and asynchronous care. The papers in the care section reported that remote patient monitoring could locate low-risk people who otherwise wouldn't benefit from monitoring, enabling more efficient deployment of interventions. Overall, a longer survival time is associated with the long-term advantages of care-based interventions in reducing the occurrence of unexpected readmissions in HF patients. The technology based section examined how HF patients used and perceived modern technology, as well as how technology-based interventions assisted in keeping a watch on the HF patients. Every study mentioned using at least one technological device. The study found that customised telemonitoring helps patients with heart failure learn, improve their capacity for self-care, and feel more self-sufficient. Therefore, using technology to control symptoms benefits both patients and medical professionals. A hybrid-based intervention blends care with technology, which has the ability to provide both flexibility and rigour. The total number of hospital stays and the amount of time it takes for patients to receive care are both decreased through hybrid monitoring. The use of remote monitoring reported improved outcomes in HF patients undergoing ICD/CRT-D. Additionally, better physical performance and self-reported physical activity were outcomes of the combined self-care intervention.

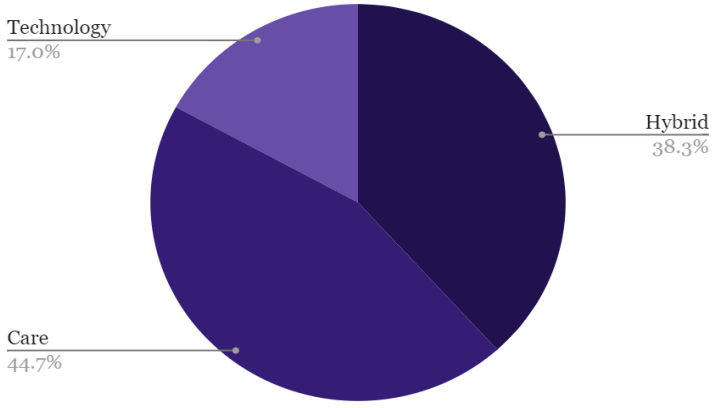

Fig. 3. Distribution of identified papers according to the type of intervention

Out of the 47 studies reviewed in this paper, the average sample size was 660, with the minimum being 104 and the maximum being 1653 (only studies with more than a 100 subjects were selected). 40 of these studies had a control arm while 7 others did not (Fig. 4).

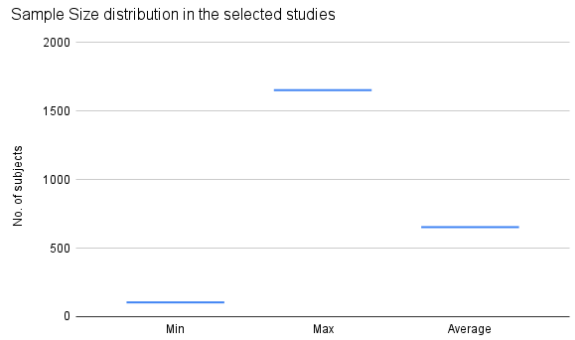

Fig. 4. Sample Size distribution in the selected studies

The aetiology spectrum, incidence and causative factors of HF vary significantly across countries and regions. According to the literature that is currently available, hypertensive heart disease is the main cause of HF in Africa while ischemic heart disease is the real cause in East Asia. According to the International Congestive Heart Failure research, Africa had the highest 1-year death rates for HF (34%) followed by India (23%), Southeast Asia (23%) and China (7%), respectively. These differences in outcomes make it pertinent that HF-related interventions and health policies be designed taking local conditions into consideration [52]. However, among the 47 papers shortlisted for the review, maximum (42.3%) were from Europe, followed by the USA (30.8%) and Australia (11.5%). Asia, which has a high incidence of morbidity and mortality due to HF had very few remote monitoring studies (9.6%), which too were in technologically advanced countries such as Japan, Israel and Singapore. On the other hand, Africa with the highest incidence did not have any. (Fig. 5) This reveals the lack of initiatives in developing regions which have a dire need for such interventions.

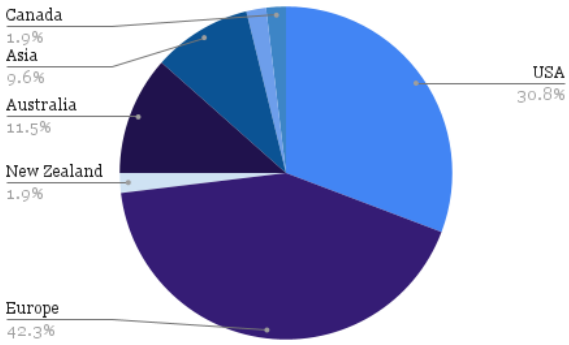

Fig. 5. Geography of the studies selected

Research funding has an impact on both the volume of research effort and the output of researchers in a field. When an investigation like a multicentric research, a randomised controlled trial, an experimental study, or an observational study with a large sample size is planned and funding from an outside source is needed, it might not be viable to carry out the study within the department's or institution's resources. Fig. 6 depicts a pie chart for the studies that disclosed sources of funding, among them most were funded through research grants (35.4%), while a majority were sponsored by private companies (20.8%) and government ministries/agencies (18.8%). Some studies were also funded by government and private partnerships (6.3%) while the rest were self funded.

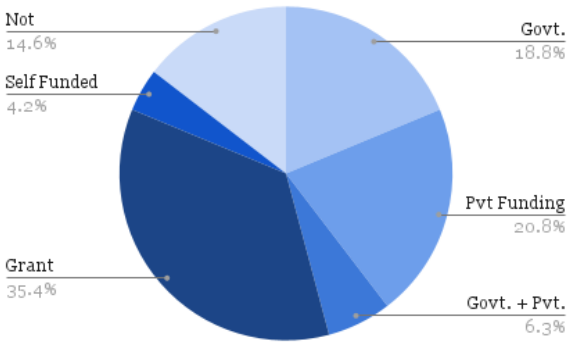

Fig. 6. Different sources of funding

This thorough review included 47 global, large randomised controlled trials and clinical study with more than 100 participants comparing care, hybrid and technology based telemonitoring. From the total of 47 papers included, 37 papers (78.7%) showed positive outcomes in terms of patient compliance and clinical outcomes, while 10 papers (21.3%) showed barely any positive outcomes. These studies were compared, and it was shown that many of the people assigned to the telemonitoring group never used the monitoring system, which may have contributed to the negative outcomes. Other

potential factors include the selection of the patient, the standard of care, and the study design, which may have introduced bias, particularly for occasional subjective outcomes like re-admission. Furthermore, according to some research, home telemonitoring systems lack an interactive communication feature, and the monitoring nurses are not permitted to speak with patients directly, nullifying a response to a device breakdown. According to these studies, patient-centred care may improve the efficiency of home telemonitoring.

Despite the literature's support for telemonitoring's advantages, several randomised controlled studies found no appreciable differences between the telemonitoring intervention and comparator groups in terms of outcome variables like the frequency of ER visits and unscheduled hospitalisations or all-cause mortality [53]. It is also crucial to take into account the circumstances in which telemonitoring may not be the best option. Vulnerable patient populations, such as those with limited internet access or virtual visit devices, as well as older adults with visual, auditory, and cognitive impairments, may find it difficult to communicate effectively via a virtual platform. Most notably, telemonitoring may not be appropriate for patients who are at high risk for decompensation. No matter how innovative the new technology is, if patients are unable to use the tools successfully and are unwilling to use them regularly, results won't change. Understanding user needs and experiences with medical equipment is therefore essential. The creation of successful health behaviour interventions can be aided by understanding how HF patients view the use of technology for self-care and a better knowledge of the problems related to technology access [53]. We included studies in the English language having more than 100 subjects. The studies thus included were not comparable as the study methodology, inclusion and exclusion criteria were different. We need to have a large randomized control trial trying to examine patients of HFrEF, HFmrEF, HFpEF – being compared with conventional vs remote patient monitoring. It's time to see if artificial intelligence and machine learning algorithms can alter outcomes for patients with HF.

Conclusion

In this comprehensive review, the efficacy of a telemonitoring strategy for HF patients combined with care, a hybrid method, or technology was assessed in terms of patient and clinical outcomes. Telemonitoring seeks to enhance self-care, patient education, treatment adherence, and survival as well as forecast and avoid worsening HF events. For patients with HF, there are an increasing number of telemonitoring solutions, but there are many obstacles in the way of successful outcomes. Remote patient monitoring has shown promising benefits for both HF patients and their healthcare providers. Because of connected health equipment used for remote patient monitoring, healthcare practitioners have faster access to precise patient data. Several studies have demonstrated that the usage of remote patient monitoring technologies reduces hospitalizations by more than 65% while also lowering mortality and rehospitalization risks for patients. There was a reduction in the amount of time needed to find clinical events by over 75%. Patients who have remote monitoring equipment have shown a higher survival rate than those who do not. Significant cost savings have also been linked to remote cardiac monitoring in addition to these findings. Patients who use these devices typically need fewer follow-up appointments and hospitalizations to the hospital.

Some contradictory findings have also shown that RPM did not reduce the hospital admission rate and length of stay leading to improved clinical outcomes. RPM systems also require dependable internet connections. Some of the patients struggled to participate in RPM setups because they lacked broadband connection. To comprehend the underlying mechanisms causing such variance in RPM studies, more investigation is necessary. The results of this review can be taken into account alongside RPM's other advantages, such as improved patient autonomy and quality of life.

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