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Review

Chronic disease management in heart failure: focus on telemedicine and remote monitoring

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In the context of the COVID-19 pandemic, many barriers to telemedicine disappeared. Virtual visits and telemonitoring strategies became routine. Evidence is accumulating regarding the safety and efficacy of virtual visits to replace in-person visits. A structured approach to virtual encounters is recommended. Telemonitoring includes patient reported remote vital sign monitoring, information from wearable devices, cardiac implantable electronic devices and invasive remote hemodynamic monitoring. The intensity of the monitoring should match the risk profile of the patient. Attention to cultural and educational barriers is important to prevent disparities in telehealth implementation.

Keywords

Telemonitoring; Heart failure with reduced ejection fraction; Telemedicine; COVID-19

1. Introduction

Heart failure (HF) is a chronic disease characterized by high mortality, often associated with multiple comorbidities that require a multidisciplinary treatment approach [1–5]. Approximately 6 million adults live with HF in the United States. Assuring access of those patients to specialized care, potentially life-saving therapies, and overcoming psychosocial, economic, and geographical barriers is a significant challenge [6–10]. Health care systems have developed disease management programs organized as spoke and hub models to overcome these limitations [11]. Telemedicine and telemonitoring are an integral part of those programs, and their application increased exponentially in 2020–2021 during the COVID-19 pandemic [12, 13].

This review focuses on telemedicine's current role in HF management and provides a practical framework for its application.

2. Telemedicine and telemonitoring in heart failure

2.1 Definitions of telemedicine, telemonitoring, and disease management program

Telemedicine entails utilization of information technology to provide medical care by enabling communication between providers in one location and a patient or provider at another site [14]. Telemedicine encounters can be asynchronous (e.g., reviewing an echocardiogram, laboratory data, or responding to a patient call) or synchronous, real-time interaction (e.g., video consultation of a patient with a left ventricular assist device in a rural area with the advanced HF cardiologist). Telemonitoring is the use of information technology to monitor patients at a distance. Telemonitoring can be continuous or intermittent and occur in the inpatient or outpatient setting [15] (Fig. 1). A disease management program (DMP) is characterized by multidisciplinary involvement of HF nurses and physicians,s integrates all aspects of care and promotes adherence to clinical practice guidelines [16]. Current guidelines support the development and implementation of DMP in HF. Telemedicine usually occurs in the context of a DMP [17–19].

2.2 Telemedicine and telemonitoring in heart failure

2.2.1 Virtual visits

Intermittent patient-provider encounters characterize ambulatory patient care. Virtual visits (VV) are defined as synchronous audio/video interactions between the provider and the patient. The uptake of virtual visits as an alternative to in-person visits before the COVID 19 pandemic was relatively low. The lack of familiarity with technology, regulatory, legal, and reimbursement concerns were among the factors that hinder its widespread application. COVID -19 pandemic led to the disappearance of many of the barriers mentioned above and the rapid adoption of VV [20]. A recent HFSA statement summarizes current evidence and provides recommendations for a successful VV preparation and billing codes to assure the program's sustainability in the pandemic context [21]. Follow-up within 14 days of a HF hospitalization is required to reduce readmissions and improve

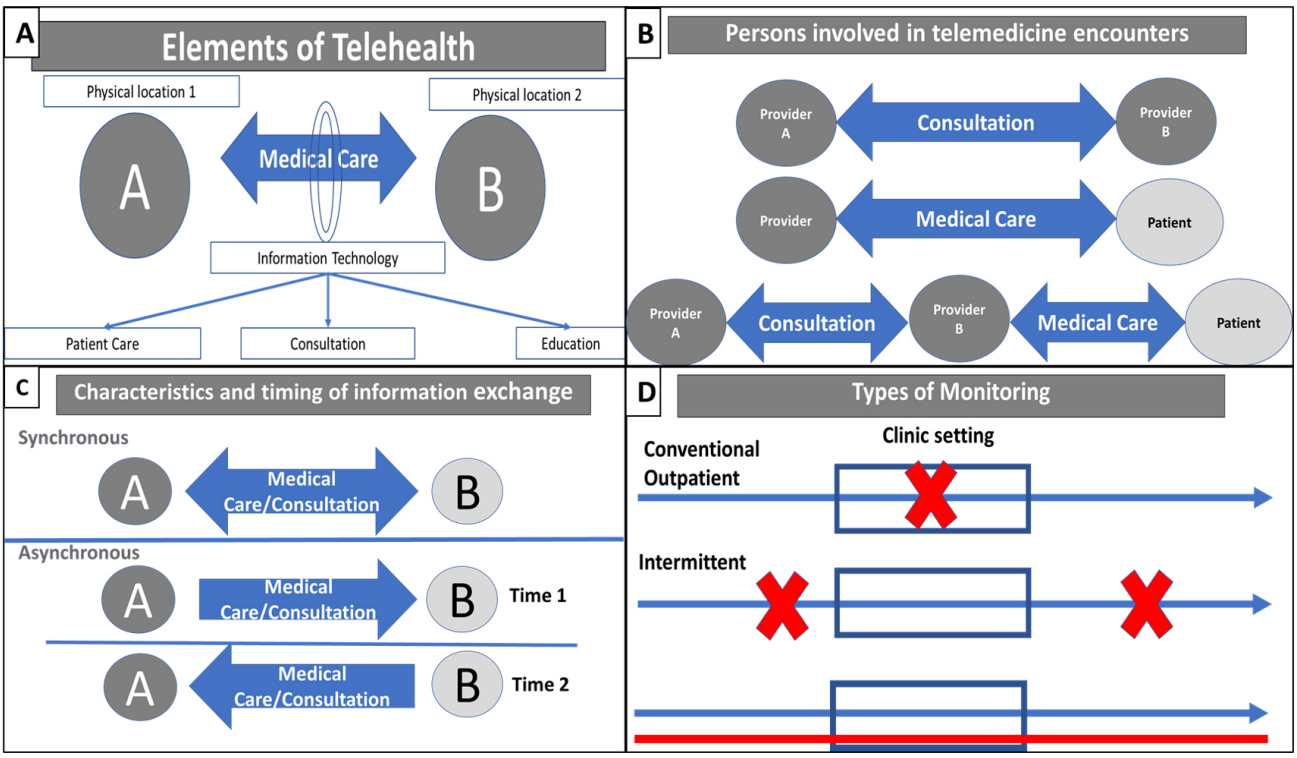

Fig. 1. Framework for telehealth implementation. (A) Elements of Telehealth. (B) Persons involved in telemedicine exchange. (C) Timing of information exchange. (D) Types of Telemonitoring.

outcomes [22]. Recent pre-pandemic evidence shows that virtual visits may be a safe alternative to in-person visits in post-discharge follow-up [23, 24]. The frequency of VV is variable and determined by professional judgment. In the The Randomized Trial of Telephone Intervention in Chronic Heart Failure (DIAL), the phone call frequency ranged from weekly in patients with New York Heart Association (NYHA) III-IV symptoms, recent hospitalization, weight gain of more than 2 Kg, and severe edema to monthly in patients with NYHA I, not hospitalized within the previous year, ≤75 years and those not living alone [25]. Risk stratification tools such as Seattle Heart Failure Model may guide the intensity of telemedicine interventions [4, 26–28]. Electronic medical record capabilities such as MyChart® (Epic Systems Corporation, Verona, WI, USA) provide VV with asynchronous medical care triggered by non-urgent patient concerns. A telemedicine strategy should be tailored to the specific cultural and linguistic characteristics of the patient [29].

2.2.2 Telemonitoring interventions

After the initial or between follow-up in-person or VV encounters, monitoring strategies may help detect parameters associated with increased decompensation risk and provide the opportunity to change trajectories [30, 31]. Early detections and recognition of congestion have been the target of telemonitoring in HF. The first event of congestion is increased filling pressures, followed by autonomic adaptation, decreased intrathoracic impedance, weight gain, and symptoms [32]. Below, we will review the different parameters and strategies that are available for remote monitoring of HF patients.

2.2.3 Scale

Current guidelines recommend daily weight in patients with HF to promote self-monitoring, adjust diuretic therapy, and volume overload detection [18]. A nested case-control study showed that increases in body weight of 2 or more pounds are associated with hospitalization for HF. The weight gain begin at least one week before admission [33]. The interval between weight gain and hospitalization may preclude the prescription of therapeutic interventions, especially if there are barriers to healthcare access. Significant congestion can develop in patients without significant weight gain due to sympathetically mediated volume redistribution in acute HF [31].

2.2.4 Ambulatory blood pressure monitoring

Hypertension is one of the most frequent comorbidities in patients with HF [34] 24-hour ambulatory blood pressure monitoring analysis has shown that most HF patients have blunted blood pressure dipping during sleep [35]. The importance of blood pressure control HF outcomes is increasingly recognized [36]. Home-blood pressure management with goals <135/85 mmHg is emerging as a dominant strategy in hypertension [37]. Blood pressure should be monitored in the morning before intake of medications, using an automatic blood pressure monitor, in a quiet room after 5

min of rest, seated with their back and arm supported. The average of at least two blood pressure measurements should be recorded. Home-blood pressure-guided management of HF hast two objectives. First, to detect hypotension that prevents the titration of guideline-directed medical therapy and may represent progression to advanced HF [38]. Second, to treat hypertension that may impact filling pressures and exercise capacity [39].

2.2.5 Wearables

Wearables are external sensors that capture continuous functional or physiological data. The sensors are incorporated in different form factors such as patches, clothes, or smartwatches. The sensors are connected to other platforms that transmit, collect and interpret the data [40, 41]. Data from wearables include but are not limited to heart rate, blood pressure, activity, lung water content, and arrhythmias. Data processing and analysis may help to diagnose decompensation, monitor response to treatment, and detect potential factors associated with increased risk of decompensation [42, 43].

Atrial fibrillation affects approximately ¼ of patients with heart failure. The presence of atrial fibrillation in heart failure is associated with increases in stroke risk, heart failure hospitalization, and all-cause mortality [44–46]. The Apple Heart Study that recruited 419,297 participants over eight months showed that an irregular pulse detected by a commercial smartwatch had a positive predictive value of 84% for detecting atrial fibrillation on electrocardiogram (ECG) simultaneously with a subsequent irregular pulse notification. Only 0.52% of the patients included in the study received an irregular pulse notification. Although the proportion of patients with HF was low (<4%), this technology holds promise to evaluate HF patients without an indication for electrocardiographic monitoring or cardiac implantable electronic devices (CIED) [47].

The LINK-HF study analyzed the accuracy of a wearable multiparametric sensor to predict HF hospitalization [48]. One hundred patients in the Veteran Affairs Health System were enrolled, and 74% had HF with reduced ejection fraction. The intervention consisted of a disposable multisensor patch placed on the chest that collected continuous ECG waveform, continuous 3-axis accelerometry, skin impedance, skin temperature, and information on activity and posture. Data were uploaded continuously to a cloud via a smartphone. Primary information includes heart rate, heart rate variability, arrhythmia burden, respiratory rate, gross activity, walking, sleep, body tilt, and body posture. Machine learning was used to build a model that would predict heart failure hospitalization. The platform had sensitivity between 76% and 88% and a specificity of 87% to detect heart failure hospitalization precursors with a median time between alert and admission of 6.5 days. The impact of this technology to improve outcomes remains to be tested.

The remote dielectric sensing (ReDS^{TM}, Netanya, Israel) FDA-approved system consists of two sensors located in a vest that can track lung fluid content by collecting changes in dielectric currents across the right mid-thorax. The vest, which is connected to a console, is worn 90 seconds per day [49]. The information is transmitted to the provider using a dedicated web application. The accuracy of the technique has been successfully validated against chest computed tomography. A pilot study that included 50 patients showed reduced HF admissions during the ReDS^{TM} guided medical management compared to the pre and post ReDS^{TM} phase [50]. However, the "Sensible Medical Innovations Lung Fluid Status Monitor Allows rEducing Readmission Rate of Heart Failure Patients" (SMILE^{TM}) randomized clinical trial was terminated by the sponsor [51]. The use of ReDS^{TM} in the post-hospitalization setting has been reported in a non-randomized study [52].

2.2.6 Cardiac implantable electronic devices

CIED such as implantable cardioverter defibrillators (ICD) and cardiac resynchronization therapy defibrillators (CRT-D) improve survival in selected patients with HF and reduced ejection fraction and provide HF-related diagnostic information [18, 53] (Fig. 2A–C). Thoracic impedance is among the HF diagnostic parameters provided by ICD and CRT-D. Intrathoracic fluid content influences the electrical field's impedance created by the current between the implantable pulse generator and the pacing electrode's tip. Congestion is associated with a decrease in thoracic impedance [54, 55]. Intrathoracic impedance and intracardiac filling pressures are inversely correlated. The decline of thoracic impedance starts approximately 2 weeks before the onset of clinical congestion and has a sensitivity of 76.9% to predict HF hospitalization. Persistent low thoracic impedance is associated with increased mortality [56, 57]. The OptiVol fluid index (Medtronic Inc., Minneapolis, MN, USA) calculates the difference between a measured and a reference impedance and is inversely correlated with thoracic impedance. A value greater than 60 is associated with increased mortality [58]. In the OptiLink HF trial, OptiVol telemonitoring failed to reduce HF hospitalization or mortality in patients with advanced HF [59]. Of note less than <60% of the fluid index threshold crossings were followed by a medical contact. In a recent post-hoc exploratory analysis, patients who had a fluid threshold crossing alert and had an appropriate medical contact had a 39% relative risk reduction of the primary endpoint. This study highlight the importance of linking telemonitoring with medical interventions [60]. CorVue^{TM} algorithm (St. Jude Medical, St. Paul, MN, USA) detects the intrathoracic impedance providing 12 daily measurements and comparing to a reference. Impedance is measured from RV ring to can and RV coil to can or LV ring to can. Poor sensitivity for worsening HF has been reported [61].

The Program to Access and Review Trending Information and Evaluate Correlation to Symptoms in Patients With Heart Failure) (PARTNERS) HF prospective cohort study

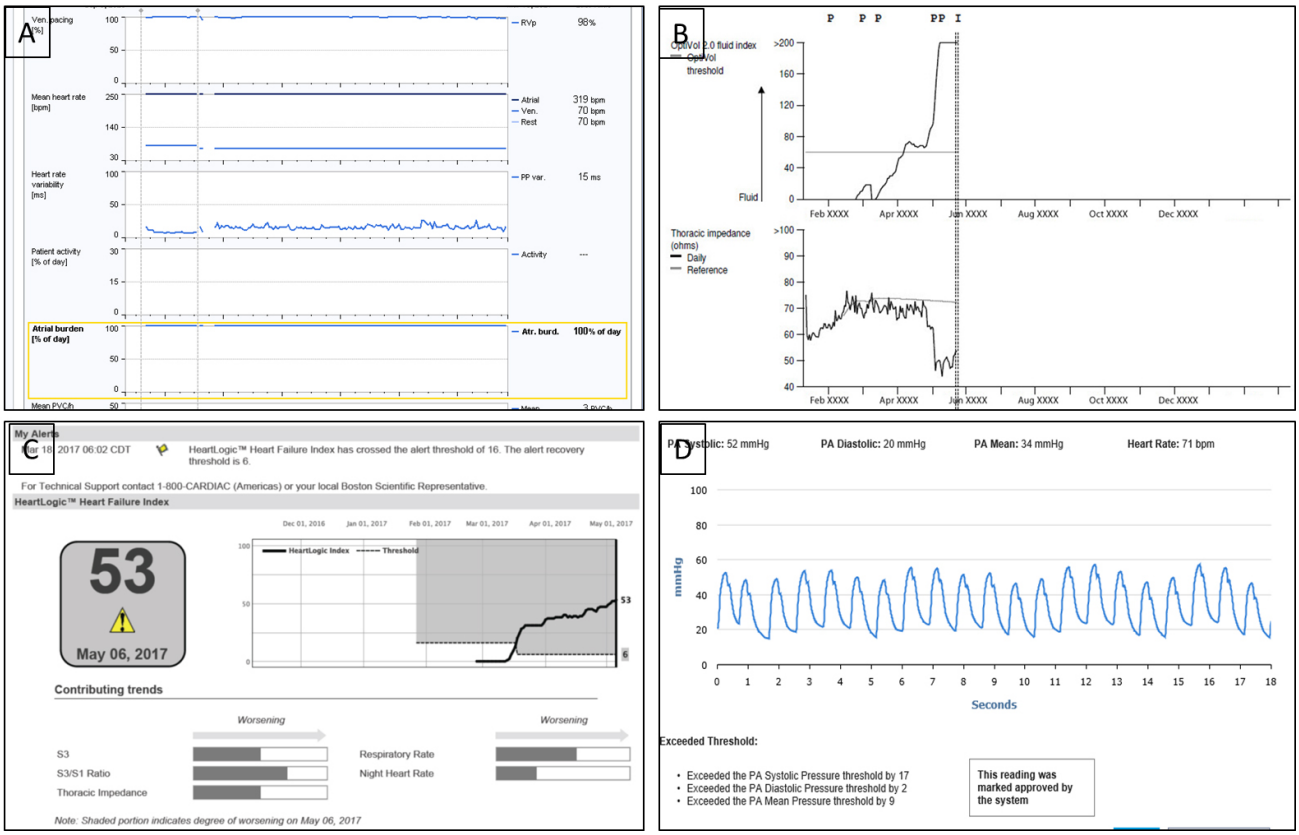

Fig. 2. Telemonitoring Interfaces. (A) CRT-D interrogation showing persistent atrial fibrillation. (B) Optivol tracing: Showing decrease in thoracic impedance and increase in Optivol Fluid index. (C) Multiparametric HeartLogic interface showing an alert parameter. (D) CardioMems interface showing a pulmonary artery pressure waveform and related parameters.

evaluated the hypothesis that using a combined HF diagnostic algorithm would improve the prediction of HF hospitalizations in patients with a left ventricular ejection fraction of ≤35%, NYHA functional class III or IV symptoms who had a CRT-D [62]. The algorithm which was developed and calibrated in an independent data set was considered positive if a patient had 2 of the following abnormal criteria during one month: long atrial fibrillation duration, rapid ventricular rate during atrial fibrillation, high (> or = 60) fluid index, low patient activity, abnormal autonomics (high night heart rate or low heart rate variability), or notable device therapy (low CRT pacing or implantable cardioverter-defibrillator shocks), or if they only had a very high (> or = 100) fluid index. Patients were followed every three months for a year. A positive diagnostic algorithm was triggered in 43% (298 of 694) of the patients. Patients with a positive device diagnostic increased 5.5 times the risk of admission for HF. The frequency of device evaluation influenced the predictive performance of the algorithm. The hazard ratio for HF hospitalization in semi-monthly, monthly, and quarterly assessments were 6.6, 5.5 and 3.1 respectively. The combined diagnostic algorithm was superior to thoracic impedance alone to predict HF hospitalizations. In conclusion, a monthly review of HF device diagnostic data identified patients at a higher risk of HF hospitalizations within the subsequent month.

The "INfluence of home moniToring on mortality and morbidity in heart failure patients with IMpaired lEft ventricular function (IN-TIME)" trial randomized in a 1 : 1 fashion 664 patients with NYHA functional class II or III, LVEF ≤35% and an indication for dual-chamber ICD or CRT-D to telemonitoring in addition to standard care or standard care alone [63]. The telemonitoring intervention consisted of a daily review of CIED data by the on-site investigators and by a coordinating center that assured the awareness of the patient's site of significant events. Ventricular and atrial tachyarrhythmia episodes, low percentage of biventricular pacing, increased frequency of ventricular extrasystoles, decreased patient activity, and abnormal intracardiac electrogram were considered significant events. The primary endpoint was worsening of a composite score at 12 months. The score includes clinical parameters evaluated by the clinician (e.g., HF hospitalizations) and the patient's perspectives captured in a global assessment score. At the end of the study, 18.9% of patients in the telemonitoring group and 27.2% in the control group had worsened composite clinical score (p = 0.013; OR 0.63, 95% CI 0.43–0.90). The main driver of the worsened composite clinical score was higher mortality in the control group. The number of hospitalizations for worsening HF were not significantly different in the telemonitoring and control group. The authors postulate three mechanisms

by which daily monitoring improved outcomes. First, early detection of ventricular and atrial arrhythmias, second early detection of suboptimal device function (e.g., decreased CRT pacing), and third, calls to the patients also detected significant clinical worsening. The PARTNERS HF and IN-TIME studies suggest that in patients with symptomatic HF with reduced ejection fraction and a CIED in place, routine and systematic evaluation of HF diagnostics may help in the early detection of worsening HF and improve clinical outcomes.

HeartLogic HF algorithm (Boston Scientific, Boston, Mass, USA) incorporates information from multiple sensors embedded in the commercially available ICD or CRT-D devices [64, 65]. Information includes first and third heart sounds, respiration rate, rapid shallow breathing index (the ratio of respiration rate to tidal volume), thoracic impedance, heart rate, and patient activity. Sensor changes from the patient's baseline were calculated and aggregated in the HeartLogic HF index. An alert is triggered if the HeartLogic HF index crosses a user-configurable threshold. Patients on alert state and high NT-pro BNP had a 50 fold increased risk of an HF event [65]. The median time from alert onset to HF event was 34 days creating the potential to intervene and reduce the risk of hospitalization [64, 66].

2.2.7 Remote hemodynamic monitoring

2.2.7.1 Right ventricular pressure. The Chronicle (Medtronic Inc., Minneapolis, MN, USA) system consisted of a programmable device that processed and stored information and a transvenous lead with a pressure sensor incorporated near its tip. The lead was positioned in the septum or right ventricular outflow tract. The initial pilot study showed that the device was safe but failed to significantly reduce hospitalizations and emergency or urgent care visits requiring intravenous therapy [67]. The sponsor terminated the pivotal trial because of the development of lead failures in patients included in previous trials [68].

2.2.7.2 Left atrial pressure. Left Atrial Pressure Monitoring to Optimize Heart Failure Therapy Study (LAPTOP-HF) evaluated the safety and efficacy of a left atrial pressure sensor monitoring. A HeartPOD implantable sensor lead (ISL) (St Jude Medical Sylmar, Sylmar, CA, USA) measured the left atrium waveform, core temperature, and the intracardiac electrogram. The ISL could be used as a stand-alone system or as a part of a cardiac resynchronization defibrillator device. The system included a patient advisor module (PAM) of the small phone size that powered the device and allowed the patient to communicate with the implant. One of the unique features of the trial was that the PAM provided interactive medical therapy adjustment recommendations according to the left atrial pressure level and the investigator's input [69]. Although a significant reduction of HF hospitalizations was achieved in the telemonitoring arm, the Data Safety and Monitoring Board stopped the pivotal trial after enrolling 486 patients because of a perceived excess of procedure-related complications [70].

2.2.7.3 Pulmonary arterial pressure. The CardioMEMS^{TM} (Abbott Laboratories, Plymouth, MN, USA) is an FDA-approved wireless pressure-sensitive device that uses microelectromechanical systems (MEMS) technology (Fig. 2D). The microelectromechanical system consists of a coil and pressure-sensitive capacitor encased in a hermetically sealed silica capsule covered by silicone. Two nitinol loops anchor the device to a pulmonary artery branch. Pressures changes cause a shift of the resonant radiofrequency that is captured by an external antenna. The information is converted to a pressure waveform [71]. The CHAMPION trial included patients with HF regardless of left ventricular ejection fraction, NYHA III with a prior HF hospitalization. After undergoing CadioMEMS^{TM} implantation, patients were randomized to pulmonary artery guided therapy and standard of care (treatment group) vs. standard of care alone (control group).

In the hemodynamic treatment group, optivolemic state was defined as:

-Pulmonary artery systolic pressure 15–35 mm Hg.

-Pulmonary artery diastolic pressure 8–20 mm Hg.

-Pulmonary artery mean pressure 10–25 mm Hg.

Definitions and treatment recommendations for hypervolemic or hypovolemic states were provided to the investigators. The trial met the safety and efficacy endpoints at six months with a 98.6% and 100% freedom from device-related complications and sensor failures, respectively, and a 28% risk reduction of heart failure hospitalizations [72]. In 2016, the investigators reported the complete follow-up results from the CHAMPION randomized trial showing that when PA pressure data was available to guide therapy, HF hospitalizations in the initial control group were reduced by 48% [73] An analysis of the Medicare data showed similar reductions in HF hospitalizations and the potential reduction in HF hospitalizations costs [74]. The real world CardioMEMS^{TM} experience is accumulating [75].

Circumstances that should be considered as potential contraindications include: The presence of a chest circumference $>$165 cm; complex congenital heart disease or mechanical right-sided heart valve replacement, hypersensitivity to aspirin or clopidogrel (if patients are not on anticoagulation aspirin 81mg and clopidogrel 75 mg should be prescribed for one month after implant); recurrent ($>$1) deep venous thrombosis or pulmonary embolism and patients with advanced kidney disease with glomerular filtration rate (GFR) $<$25 mL/min/1.73 m^2 who are non-responsive to diuretic therapy or who are on chronic dialysis. Once the device is implanted, an initial phase characterized by intensive medication titration is followed by a maintenance phase in which hemodynamic data is reviewed once a week by the physician. The maintenance phase could be interrupted by an acute phase where hypovolemia or hypervolemia is detected, requiring acute medication changes. A remote pulmonary pressure-guided program usually requires a dedicated nurse

or advanced practice provider with experience in heart failure supervised by a cardiologist. Administrative support is necessary for adequate billing to assure the sustainability of the program [76]. Hemodynamic-GUIDEd management of Heart Failure (GUIDE-HF) ongoing trial to evaluate the safety and efficacy of CardioMEMS^{TM} in patients with HF and NYHA II-IV and symptomatic patients with elevated natriuretic peptides without recent heart failure hospitalization [77]. Studies are ongoing to evaluate the efficacy CardioMEMS^{TM} to improve outcomes in patients with left ventricular assist devices. [78, 79]. The Cordella^{TM} HF System (Endotronix Inc., Lisle, IL, USA) includes a pulmonary artery pressure sensor and a heart failure hub that records symptoms, patient engagement, and vital signs (blood pressure, heart rate, weight, oxygen saturations). This technology showed promising results in terms of safety and accuracy in the initial multicenter feasibility trial, and large pragmatic trials are ongoing [80].

3. Recent telemedicine and telemonitoring trials

A Cochrane Library systematic review of structured telephone support or non-invasive telemonitoring for patients with HF published in 2015, which included 41 randomized controlled trials, concluded that those interventions reduce the risk of all-cause mortality and HF -related hospitalizations [81]. Another systematic review using network meta-analysis technique that included 29 studies arrive at similar conclusions [82]. Hereine, we discuss the findings of five studies that were not included in those reviews (Table 1, Ref. [83–87]). "Efficacy of telemedical interventional management in patients with heart failure" (TIM-HF2) was a randomized, controlled, parallel-group unmasked trial that tested a multifaceted telemonitoring intervention compared with usual care [83]. This trial built upon the TIM-HF experience that showed that remote patient monitoring compared with standard care was not associated with reducing all-cause mortality [88]. A subgroup analysis of TIM-HF showed that patients without depression or recent HF hospitalization were most likely to benefit from telemedicine interventions. The primary endpoint was the percentage of days lost due to unplanned cardiovascular hospital admissions or all-cause death.The intervention consisted of a remote Bluetooth monitoring system (Physio-Gate® PG 1000, GETEMED Medizin- und Informationstechnik AG, Teltow, Germany) that transmitted vital signs and electrocardiogram information directly to the monitoring center. The telemonitoring system consisted of four Bluetooth-equipped measuring devices: a 3-channel ECG, pulse oximeter, blood pressure monitor, and digital Scale. A proprietary custom-made software triaged the information to identify patients that required immediate attention. Patients were provided with a mobile phone to call the monitoring center in case of an emergency [89]. The percentage of days lost due to unplanned cardiovascular hospital admissions and all-cause death was 4.88% (95% CI 4.55–5.23) in the remote patient management group and 6.64% (6.19–7.13) in the usual care group (ratio 0.80, 95% CI 0.65–1.00; $p = 0.0460$). Most of the intervention's benefit was reducing all-cause mortality and unplanned hospital admissions due to worsening HF. One year after stopping the intervention, there were no significant differences in the trial's primary outcome [90].

The SUPPORT-H2 Study recruited high-risk HF patients and showed that a telemonitoring system with the capacity to contact the clinical staff failed to improve the adherence to guideline-directed medical therapy [84]. The small sample size is a limitation of this report. In "Optimization of the Ambulatory Monitoring for Patients With Heart Failure by Telecardiology" (OSICAT), patients with a history of HF hospitalization within the prior 12 months were randomized to telemonitoring or usual care. The telemonitoring intervention failed to reduce all-cause death or hospitalization for heart failure. The telemonitoring system provided an alert that nurses evaluated in working days, and if appropriate, they advised the patient to contact their general practitioner or cardiologist [85]. This contrasted with the intensive monitoring and readily available physician support of TIM-HF2. The Better Effectiveness After Transition – Heart Failure (BEAT-HF) was a negative clinical trial of post- HF hospitalization telemedicine monitoring. Of note, the telemonitoring strategy was not integrated with physician care to allow rapid medical treatment changes [86]. Finally, "The Heart Failure Readmission Intervention by Variable Early Follow-up" (THRIVE) Study showed that a structured phone interview by a pharmacist or a nurse within seven days of discharge had comparable clinical outcomes at 30 days (readmission and death) with an in-person visit with a physician [87].

4. Lessons from the COVID-19 pandemic

COVID-19 pandemic revitalized the interest in telemedicine and prompted regulatory changes needed for rapid deployment. Along with significant biotechnological advances, digital health has an established role in clinical practice [91]. A reduction of HF hospitalization was observed in early 2020 [92]. This was interpreted secondary to the patient's fear of going to a healthcare facility. During the same period, a 154% increase in virtual visits was documented [93]. Virtual visits and telemedicine changed from being rare to become one of the primary forms of health care delivery. This transition was not done without difficulties, and health disparities became more evident [94]. For example, female sex and median household income $<$50,000 $ per year were independently associated with less telemedicine and video use and less video use, respectively [95]. In addition, technology literacy from providers and patients has been recognized as an additional barrier for telehealth implementation [96].

Table 1. Recent trials of telemedicine in heart failure.

Author (Ref.)	Year n°	Design	Primary endpoint	Patients	Intervention	Comparator	Outcome
Ong [86]	2016 1437	RCT	Readmission for any cause within 180 days after discharge	Adults hospitalized for heart failure	Conducted by Registered Nurses: 1-Predischarge education; 2-Regularly schedule telephone coaching; 3-Home tele monitoring of weight, blood pressure, heart rate and symptoms	Pre-discharge education and follow up phone call	No significant difference in primary outcome
Koehler [83]	2018 1571	RCT	Percentage of days lost due to unplanned cardiovascular hospital admissions or death from any cause, during the individual patient follow-up time	Ambulatory patients; NYHA II or III; heart failure hospitalization within 12 months before randomization, and LVEF 45% or lower (could be higher if patients were on diuretics). Depression or recent hospitalization <7 days were key exclusion criteria	Daily transmission of bodyweight, blood pressure, heart rate, analysis of the heart rhythm, SpO2 and a self-rated health status to the tele-medical center; a definition of a patient's risk category; patient education; and co-operation between the tele-medical center, and the patient's general practitioner and Cardiologist	Usual Care defined as follow up in accordance with the current guidelines for the management and treatment of patients with heart failure	Percentage of days lost was statistically reduced in patients allocated to telemedicine
Galinier [85]	2020 937	RCT	All-cause mortality or unplanned hospitalizations at 18 months	Hospitalized for acute HF within 12 months before inclusion, had access to a landline telephone or General Packet Radio Service network	Tele-monitoring program which consisted in: (1) electronic devices transmitted weight and heart failure symptoms to a specialized system that generated alerts and communicated with the nurses (2) Educational HF component: Information pack and phone calls	Usual Care	No significant difference in primary outcome
Rahimi [84]	2020 101	Two-armed partially blinded parallel RCT	Use of guideline-recommended medical therapy for chronic HF and major comorbidities, measured as a composite opportunity score	High risk heart failure patients. Defined by functional class, NT pro BNP and >10% 1-year mortality risk	Tele-monitoring system with integrated risk prediction and disease management service which provided alert and support to healthcare practitioner	Tele-monitoring system without integrated risk prediction and disease management service	No significant difference in primary outcome
Lee [87]	2020 2372	RCT	Readmission for HF within 30 days after discharge	Adults hospitalized for heart failure	Structured telephone visit with a nurse or pharmacist to guide follow-up. Telephone appointments included a structured protocol enabling medication titration, laboratory ordering, and booking urgent clinic visits as needed under physician supervision	In person visit within 7 days	No significant difference in 30-day readmission or mortality. Telemedicine visits non-inferior to in person-visits

RCT, Randomized Controlled Trial.

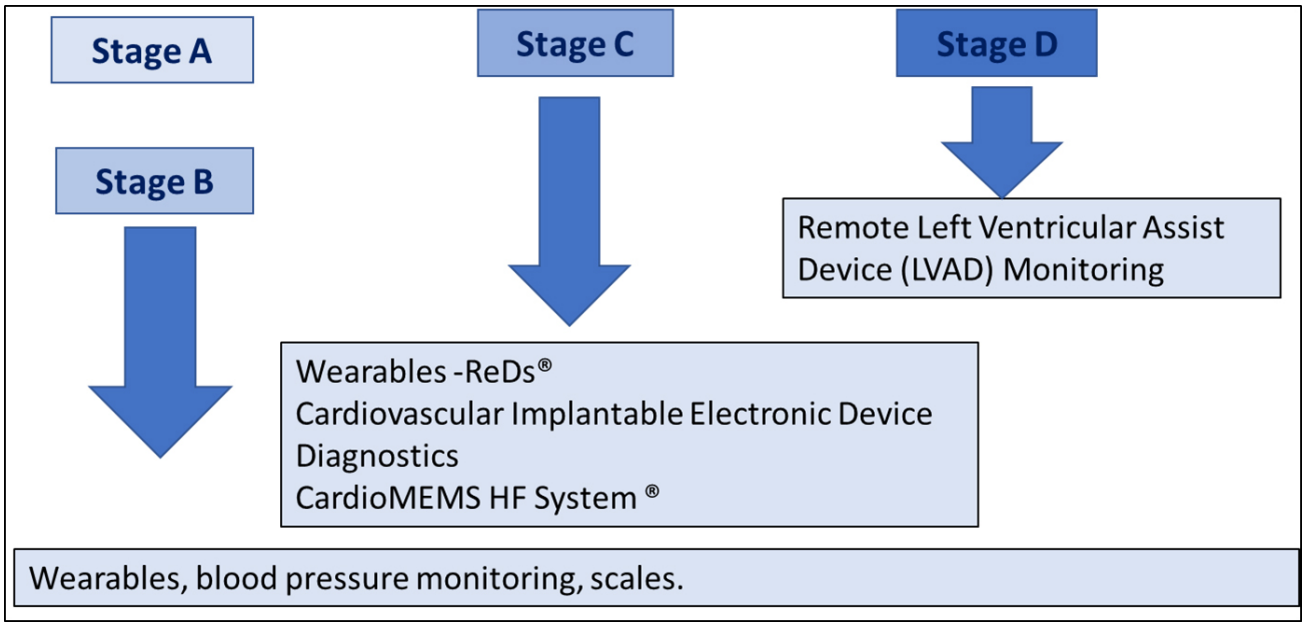

Fig. 3. Telemonitoring in Heart Failure according to AHA/ACC Heart failure stages.

5. Telemedicine in the heart failure clinic

Synchronous virtual encounters are followed by telemonitoring with or without a formal chronic disease management program [21]. For a virtual visit to be successful, there should be patient consent, and the patient should be familiar with the virtual platform. Although most insurances prefer video, the telephone is a valid and valuable option. The VV should follow a pre-defined structure. Medication review is of paramount importance. The patient can check the vital signs during the encounter and if the patient has a CIED, access the latest remote interrogation of the device. Monitoring of activity level is feasible, and if a step counter is available the average steps per day can be noted [97]. In patients with a wearable defibrillator, evaluation of daily step count and changes in body position in addition to electrophysiological parameters can be performed [98]. Use of the video capability to detect jugular venous distention or lower extremity swelling can also be helpful. Benzinger *et al.* [99] described the "Telehealth ten", a patient-assisted medical examination with ten components. During the virtual encounter, the clinician guides the patient to perform a modified physical examination. An after-visit summary with the therapeutic plan and follow-up should be emailed to the patient.

The functional capacity, psychosocial factors and clinical stability dictate the intensity of monitoring. If a patient has a CIED, every effort should be made to maximize the information obtained through device interrogation. If the patient had a recent hospitalization for HF, implantation of a pulmonary arterial pressure monitoring device should be considered (Fig. 3). Of note, barriers for compliance such as financial factors, health literacy, dietary transgressions should be evaluated, and specific interventions should be implemented [100, 101].

6. Conclusions

Virtual visits have increased exponentially during the COVID-19 pandemic. Current evidence support the use of virtual visits to replace post discharge in-person visits. A structured approach is recommended by current guidelines. Tele-monitoring interventions can range from low to high complexity and should match the risk profile of the patient. Regardless of the tele-monitoring platform, the integration with clinical support for medical therapy optimization cannot be overemphasized. Racial and social disparities in telemedicine implementation have been reported and further research is needed.

Author contributions

PA, AB conceived and designed the content; JB reviewed the manuscript and contributed with graphical material; PA, AS, AA wrote the manuscript; PA, AB, supervised and prepared the final version for submission. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

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Conflict of interest

The authors declare no conflict of interest.

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