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Telerehabilitation in heart failure patients: the evidence and the pitfalls

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Abstract

Accessibility to the available traditional forms of cardiac rehabilitation programmes in heart failure patients is not adequate and adherence to the programmes remains unsatisfactory. The home-based telerehabilitation model has been proposed as a promising new option to improve this situation. This paper's aims are to discuss the tools available for telemonitoring, and describing their characteristics, applicability, and effectiveness in providing optimal long term management for heart failure patients who are unable to attend traditional cardiac rehabilitation programmes. The critical issues of psychological support and adherence to the telerehabilitation programmes are outlined. The advantages and limitations of this long term management modality are presented and compared with alternatives. Finally, the importance of further research, multicentre studies of telerehabilitation for heart failure patients and the technological development needs are outlined, in particular interactive remotely controlled intelligent telemedicine systems with increased inter-device compatibility.

Key words: telerehabilitation, heart failure, exercise training

List of abbreviations:

American Heart Association	AHA
Cardiac rehabilitation	CR
Cardiovascular implantable electronic devices	CIEDs
European Society of Cardiology	ESC
Heart failure	HF
Quality of life	QoL

Introduction

In Europe, the estimated number of patients suffering from heart failure (HF) lies between 6.5 and 10 million [1]. A rising number of HF patients combined with an increased frequency of HF related hospitalization and rehospitalization combine to place financial stresses not only on health care systems, but even for entire national budgets. The challenge of the future is the effective organization of holistic management for HF patients, as suggested in guidelines of both the European Society of Cardiology (ESC) and the American Heart Association (AHA) [1,2]. The benefits of exercise training for HF patients are well documented and unquestionable. In patients with stable HF exercise training can relieve symptoms, improve exercise capacity and quality of life (QoL) and reduce disability, hospitalization and mortality [1-5]. Cardiac rehabilitation (CR) for HF patients is now widely recognized as safe, with benefits easily surpassing any related risk [1-6]. Therefore, current guidelines strongly recommend exercise training in all stable HF patients [1-3]. Although exercise training is a class I, level of evidence A recommendation, it remains poorly implemented in everyday clinical practice. According to a recent European Survey, less than 20% of HF patients participate in hospital-based and/or outpatient CR programmes [7]. There are numerous factors which hinder the participation in either hospital-based or out-patient CR: logistics (commuting problems), resistance to leaving home, anxiety and depression, difficulties of incorporating hospital based and outpatient exercise trainings into daily life, etc.[8]. That is why the possibility of transferring the location of CR to the patient's home creates a real opportunity to overcome these and other obstacles and to enhance the availability of the important core components of CR. It is nevertheless crucial to ensure training programmes at home are delivered with a high level of safety and psychological comfort. According to most guidelines, exercise training in moderate and high risk patients should be initially supervised. In particular, high risk patients need to be monitored "until safety is established" and patients feel confident enough to continue the training by themselves [2].

Modern technological and telemedical advances have enabled physicians and other health care providers to monitor patients remotely [9,10]. Methods of remote monitoring vary from the 'simple' telephone support to external or implantable devices (Table 1)[9-15]. They are concordant with current AHA guidelines, which state that: "*The use of trans-telephonic ECG monitoring at home has been suggested as a substitute for outpatient visits to the clinic.*"[2]. The indications for the use of cardiovascular implantable electronic devices (CIEDs) are constantly being expanded and more and more patients are being implanted with such

devices. Thanks to the homemonitoring option in CIEDs various physiological parameters can be remotely monitored [15-18]. The recent data from IN-TIME study showed that automatic, daily, implant-based, multiparameter telemonitoring can significantly improve clinical outcomes for HF patients. Such telemonitoring can be considered feasible and effective and many experts now feel should be used in routine clinical practice[19].

Another valid, yet still futuristic option could be monitoring HF patients via hemodynamic devices (left atrial pressure, pulmonary artery pressure) but such devices remain in the research phase at the present time[20,21].

The data from telephone support, external monitoring devices, home monitoring CIEDs and implantable haemodynamic devices can be used in telecare and may provide a basis for safe telerehabilitation (Table 1). The safety of such treatment is due in part to the fact that telemedicine is an effective tool to enable the physician to assess, and by early advice and intervention, maintain patient stability through remote supervision during exercise training. The present article outlines the opportunities offered by telemedicine in terms of telerehabilitation for HF patients.

Telecare in HF patients: Definition

Telecare in HF patients can be defined as monitoring which consists of the transmission of symptoms, signs and/or biological or physiological data from a remote location to another location for data interpretation and decision-making[9,22]. The most basic form of telecare is **structured telephone support**, in which providers (nurses) schedule routine telephone contacts with patients for ongoing assessment.

Telecare also encompasses the concept of **telemonitoring**, in which symptoms (chest pain, fatigue, breathlessness, oedema etc) and/or physiological data (such as heart rate, ECG, weight, blood pressure) derived from external monitoring devices, home monitoring CIEDs and/or implantable hemodynamic devices are transferred automatically to a healthcare provider via a wireless or broadband connection, with targeted follow-up triggered by variances that exceed preset thresholds. Telemonitoring can be conducted manually or automatically. The manual version means that the data is assessed and interpreted by health care professionals. The automated version implies that the data transferred to the monitoring center is assessed by specialized software, generating alarms for health care professionals and/or decision support to optimize treatment.

In addition to telemonitoring, telecare also includes **teleassessment** (active remote assessment), **telesupport** (e.g. supportive televisits by nurses, psychological support),

teletherapy (interactive therapy), **telecoaching** (support and instruction for therapy), **teleconsulting** and **telerehabilitation**. This last concept is defined as a supervised remote comprehensive CR [22,23], and it includes the telecare and telesupervision of exercise training.

The telemonitoring process

Methods of delivery

The technological advances of recent decades have led to the development of the following principal methods of delivering telemedical care: real-time (synchronous), store-and-forward (asynchronous), and hybrid systems. In synchronous systems, the patient and the telecare provider need to be available at the same time; asynchronous methods do not require this [24].

Data transfer

In order to obtain and transfer data on a patient's condition the following technologies can be applied in telemedicine: portable medical imaging devices, personal digital assistants (PDAs) such as smart phones, and many types of wireless communication. The crucial factor for telemedical treatment today is the stable availability of network access, which, in some systems, has reached 99.7% . Specialists distinguish two types of data transfer: the outbound (patient to telemedical center) and inbound (telemedical center to patient) data transfer. The most advanced systems take advantage of automatic algorithms which are capable of evaluating the incoming data, identifying numerous predictors of clinical deterioration as well as prioritizing human contact with patients undergoing telemedical treatment [9,24].

Remote management systems

These are classified according to specific criteria such as the telemedical system's integration with patients' primary care unit, the data transfer type and the telemedical system's reaction and interaction level (i.e. the ability to make instantaneous decisions). Commonly distinguished system generations are presented [9,24]:

- **simple data collection**: recording devices, which transfer data to the telemedical center without simultaneous evaluation and intervention to the recorded data
- **remote patient management systems** (data is transferred and analyzed by the telemedical staff)
- **fully integrated remote management systems**: an advanced version of the previous system which integrates the recording capacity with the assistance of a telemedical care unit by offering the on-time assistance of an on-duty physician.

Telerehabilitation systems

Only a few models of home-based telerehabilitation have been presented to date [10,23-30]. In all, the patients need to preliminary undergo to a training period either in hospital or at home to familiarize themselves with the systems

Heart rate monitoring

Exercise diaries and heart rate monitors are provided and data are recorded in a computer. The telemedical team contacts the patients on a weekly basis via telephone or email to report on their progress. Patients are required to hand in their heart rate monitors and exercise diaries every four to six weeks [25].

Transtelephonic electrocardiographic monitoring

This system has been tested in a public gym, which was equipped with transtelephonic electrocardiographic monitoring kits. If alarming symptoms were detected, a twelve-lead ECGs of the patient was transmitted by qualified trainers in real time via regular telephone lines and assessed by the medical staff at the telecare unit. After ECG evaluation, the cardiologist contacted the exercise trainer to provide instructions for any required intervention [26].

Tele-electrocardiogram monitoring and supervision using a remote exercise training device

In this particular system, special equipment is distributed to the patient. It consists of the following elements: a device for ECG recording, blood pressure measuring and weighing machines, a mobile phone and a mobile phone based data transmission set. Prior to the training session, the patient is requested to answer a series of questions regarding his/her current condition and medications taken. Subsequently, patients would transmit their resting ECG, blood pressure and weight data to the monitoring center and are permitted to begin the training session only if no contraindications are identified. Each set contains the patient's individualized pre-programmed and previously defined training session, exercise duration, breaks and timing of ECG recording. Immediately after the training session, if uneventful, the ECG recording is transmitted to the monitoring centre and analyzed. On the basis of the obtained data, consultants are able to adjust the training workload appropriately or, should the necessity arise, to discontinue the session. The monitoring center receives, stores and analyses patients' medical data and a follow-up report is generated [23,27-30].

Real time electrocardiographic and voice transtelephonic monitoring of cardiac rehabilitation

In this system patients are given a real-time transtelephonic electrocardiographic transmitter and a headset with earphones and a microphone. The system is capable of simultaneously

monitoring up to four patients who are encouraged to take part in conference phone calls. It helps them to interact as a group and allows the monitoring staff to conduct teaching and group therapy sessions [31].

Telemonitoring physical activity using movement sensor

Two movement sensors are being commonly used at the moment: accelerometers and pedometers. The main purpose of an accelerometer is to assess and quantify any motion or movement associated with physical activity. They enable consistent, unhindered and continuous monitoring and provide a count value, which describes the intensity, frequency and duration of physical activity. Pedometers by contrast measure the number of steps taken during a day and may be able to provide calculated distance travelled and energy-expenditure values [32-34].

Mobile phone-based applications for rehabilitation

Various applications measuring different movement types are available for mobile phones, PDAs, etc. Some mobile phones are equipped with an accelerometer function, others offer wellness diary software which collects data on patients' physiological state and other medical information. Health care providers can take advantage of web-portals to individualize goal setting and to evaluate the progress of each participant of the telerehabilitation programme. Educational multimedia content can also be transferred to patients and be viewed by them on demand [35,36].

Gaming systems in rehabilitation

Gaming systems have been developed over the last years and proposed in rehabilitation, for example active video games such as Nintendo Wii Fit. This exercise-based game software transmits the data obtained almost immediately to the Wii console by Bluetooth [37-39]. Only one case analyzing the effect of 12 weeks of Nintendo Wii Fit on daily physical activity of a 74-old patient with chronic HF has been reported. In the course of the study and afterwards, the energy expended by the patient per day, exercise capacity and the motivation to exercise all increased [39]. Although no guidelines for "exergaming" are available, it may play a role in selected patients in the crucial motivation to participate in physical activity, especially among the younger population.

All the above mentioned systems have been proven safe and effective.

Effectiveness of telerehabilitation

The literature reporting on telerehabilitation is rather scarce and mainly focuses on low risk patients [40-42]. These studies have shown favourable effects resulting from telemonitored

CR. Some studies have been conducted, yet the groups analyzed were inhomogeneous, i.e. principally low-risk groups but including a few higher-risk patients [26,31]. Only few studies are wholly dedicated to home-based telerehabilitation of HF patients [25,27-30,43].

One of the first studies to assess telerehabilitation in HF patients specifically was that of Smart et al. who described a 35-week home-based CR model initiated 16-weeks after a hospital-based exercise training programme. Patients were provided with heart rate monitors and exercise diaries. They were also offered scheduled telephone and e-mail consultations. This study showed that home rehabilitation based on heart rate monitoring maintained the oxygen consumption improvement achieved during previous rehabilitation in hospital settings, only in patients with HF adherent to the programme [25].

Giallauria et al. assessed the efficacy of telecardiology in improving the effects of CR during 3 sessions weekly for 8 weeks in post-MI patients. The patients were subdivided into three groups (15 each): outpatient CR, home-based CR with telecardiology monitoring and home-based CR without ECG-monitoring (left ventricular ejection fraction were $35\pm6\%$, $31\pm9\%$ and $34\pm8\%$, respectively). Physical capacity and exercise duration improvement were comparable in patients trained in an out-patient centre and at home with ECG monitoring. Importantly patients who trained at home without telemonitoring failed to obtain favourable effects [43].

There are two randomized studies evaluating telerehabilitation in HF patients. The first one showed that an 8-week home-based telerehabilitation programme based on walking training provided improvements in physical capacity and quality of life similar to that of a standard outpatient rehabilitation programme based on cycloergometer training [27]. The second one, recently published, demonstrated that an 8-week home-based telemonitored Nordic walking training programme was well accepted, safe, effective and had high adherence among HF patients, including those with CIEDs [30].

Safety of telerehabilitation in HF patients

A crucial issue regarding home-based telerehabilitation is the best way to ensuring the safety of HF patients who participate [5-7]. It is crucial because these patients will lack the close and direct contact with medical staff that in-hospital or outpatient programmes can offer.

Published data have to date not reported major adverse events or complications during telerehabilitation, such as deaths or malignant arrhythmias [25-31,40,43]. Nevertheless, some minor events have been noted. Smart et al. reported one patient with a nonfatal myocardial infarction, one with a stroke, and another with a brief hospitalization because of worsening

HF. The authors do not specify whether these events took place during or after the training session[25]. Similarly, Piotrowicz et al. reported on three episodes of paroxysmal atrial fibrillation, including one asymptomatic event diagnosed through ECG monitoring. These arrhythmias had no relation to exercise training and occurred while performing routine daily activities. They led to the temporary suspension of the training programme, yet when sinus rhythm and clinical stabilization were restored, the patients continued their exercise training [27,28]. In another study the same authors describe that a low percentage of patients (5.3%) reported skin reactions caused by the electrodes [30]. The data available so far suggest that the benefits of regular physical training outweigh the risks it may entail. Table 2 lists factors which influence the safety of telerehabilitation.

Psychological aspects of telerehabilitation – quality of life, depression and anxiety.

Heart failure progression is usually associated with a decline not only in physical functioning but also in psychological well-being, with depression becoming more prevalent. Both physical and psychological deterioration common and have an unfavourable effects on patients' daily life activities, QoL and eventually their hospitalization and mortality rates [44]. Patients with HF are more reluctant to undertake exercise than to comply with other recommendations (e.g. diet and medication) and are also more likely to adhere to a home-based exercise programme than to a supervised one [45]. Telerehabilitation may serve as a helpful strategy for continuing monitoring and management of a patient allowing face-to-face intervention, including relatives (e.g. spouse) in a familiar environment and as part of the everyday way of life. Reducing depressive feelings which work as a barrier for exercise training, may enhance exercise adherence and ultimately health-related QoL [45].

To date only a small number of studies have been dedicated to studying the psychological aspects of telerehabilitation [25,27,29,30]. Smart et al. showed that QoL and depression improvements achieved during a 16-week outpatients programme were maintained in the adherent HF patients during 35-week home-based telerehabilitation extension [25]. Giallauria et al. reported an improvement in anxiety levels and a trend to limiting depression in the telerehabilitation group compared to the group which exercised at home without telemonitoring. In this study the evaluation of QoL demonstrated no change or improvement in telerehabilitated patients in contrast to worsening of QoL parameters in most patients rehabilitated at home without telemonitoring [43]. Piotrowicz et al. assessed QoL changes in HF patients during 8-weeks of home-based telemonitored CR versus standard outpatient-based CR. This study demonstrated that in HF patients telerehabilitation provided a similar

improvement in total QoL index compared to standard rehabilitation; yet there were differences in QoL subscales. Patients who underwent home-based telerehabilitation recorded an improvement mainly in the mental categories. In contrast patients in the standard rehabilitation group improved their general physical well-being [29]. Telerehabilitated patients, apart from benefiting from exercise training, might receive parallel psychological telesupport and teleassistance from the telemonitoring team (nurse, physician, physiotherapist) [25,27,29,30]. Patients might also become more independent in performing their everyday tasks, their mental and physical condition might improve, and their life might become less affected by the limitation resulting from HF, although as yet these remains speculative possibilities until the appropriate studies are performed.

It is noteworthy that cardiac telerehabilitation programmes extended their goals towards longer durations of exercise participation, along with improved QoL, reduced anxiety and depressive symptoms by involving health professionals (e.g. doctors, nurses, physiotherapists) [46,47]. They also focus on prompt patient-centered interventions, promoting self-care practices and maintaining high-level patient and clinician interaction [48].

Acceptance and adherence to telerehabilitation (overcoming common barriers to exercise training)

Several factors interact to influence adherence to exercise, yet there is no clear set of variables that have been established to help identify people who are likely to exercise, keep exercising or attend exercise programmes [49]. Barriers to exercise intervention adherence include:

- the severity of the disease (e.g. a high symptom burden),
- social and economic issues (e.g. inadequate support from relatives or financial resources to attend fitness centres),
- the health care team or health care system (e.g. no place in a rehabilitation programme or no reimbursement) [8,50],
- for some patients the lack of direct contact or face-to-face meetings might decrease their adherence,
- problems with technology and not possessing the technical expertise to establish systems and to troubleshoot information and communication technologies .

Despite these inconveniences, the published data which evaluates adherence to, and acceptance of telerehabilitation are promising both among low-risk and high-risk patients [27,30,42,43]. Patients' adherence to therapy can often be improved by resolving the problems related to these factors [51]. Other successful strategies may include:

- cognitive behavioral strategies such as those used in motivational interviewing, and strategies that enhance patient self-efficacy for exercise, patient education and support from peers, family and friends [8],
- adapting an exercise programme to patients' preferences and eliciting support from others,
- allowing patients to choose the best programme for their needs and circumstances [50],
- eliminating the need to travel and enabling patients to choose the most suitable training modality.

Published data have demonstrated that patients will accept several models of home-based telerehabilitation. In the majority of cases they did not report any significant problems related to operating the telemonitoring equipment. They understood the need for interactive collaboration with the monitoring centre, enjoyed it and were very satisfied with the telemonitoring team support [27,29,41-43].

Giallauria's results demonstrated that adherence to telerehabilitation was 100% in comparison to 87% in hospital rehabilitation and home-based rehabilitation without telemedicine[43]. In the study of Piotrowicz et al. all patients undergoing home-based telemonitored rehabilitation completed their 8-week exercise programme in contrast to 20% of ambulatory rehabilitated patients who discontinued rehabilitation[27]. Also in another study by the same authors it was reported that all patients completed an 8-week home-based telemonitored Nordic walking training. The majority (94,7%) of the patients were adherent and only 5.3% were partially adherent [30]. All authors reporting on cardiac telerehabilitation programmes agree that the adherence to telerehabilitation seems to be equal to or superior to the adherence to out-patient CR [25-31].

Advantages and limitations of telerehabilitation

Every new technology and methodology, apart from having benefits, also has certain limitations. Table 3 lists the advantages and disadvantages of home-based telerehabilitation [25-31,40-43,52].

Conclusions

The main challenge of CR at the moment is the need to overcome its currently unsatisfactory accessibility. In doing so there is a need to even out regional differences in availability and uptake. A promising solution to these problems seems to be home-based telerehabilitation. According to the available evidence, it is clear that such treatment is technologically and logistically implementable and thus offers an effective and safe way of rehabilitation accepted

by patients and the caregiver-team. Various telerehabilitation models based on different technological, methodological and logistic solutions are available. Nevertheless, there are but a few reliable CR models for HF patients. This specific group of patients requires individualized programmes, procedures and the monitoring of numerous symptoms and parameters referred to as “tailored comprehensive home-based telerehabilitation”.

Although specialized medical equipment for this modality is being constantly developed, the most promising solution seems to be the creation of mobile phone applications, since they can be commonly used thanks to mobile Internet technologies and their increasing accessibility.

As of now there exist no studies evaluating the cost-effectiveness of home based telerehabilitation in HF patients, yet there are suggestions that the costs of rehabilitation might be reduced thanks to this method and its further development. The next step in technological research should be the creation of interactive remotely controlled intelligent system for telerehabilitation and establishing a platform to ensure compatibility between different devices applied in telemedicine.

All the HF patient home-based programmes should offer comprehensive CR and, thanks to the application of advanced technologies, are capable of providing care and assistance in different settings while patients are away from their medical unit.

Future challenges

The future challenge for clinicians involved in training programs for patients with HF is to create a multicenter research collaboration dedicated to home-based telerehabilitation in HF patients. This trial should be designed to evaluate the utility and safety of this model of rehabilitation in routine clinical care, including its effectiveness, degree of patient adherence and acceptance as well as cost-effectiveness. The results might permit the introduction of telerehabilitation programmes into guidelines as an alternative to outpatient cardiac rehabilitation for a selected group of patients with HF.

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Table 1 Methods of telemonitoring

Devices	Object of monitoring
Telephone, mobile phone, Internet	<p>Symptoms:</p> <ul style="list-style-type: none"> - dyspnea - breathlessness - peripheral oedema - fatigue - chest pain - palpitations - syncope - psychological status
External devices	<p>Parameters:</p> <ul style="list-style-type: none"> - ECG (heart rate, conduction disturbances, arrhythmias, ST segment changes, silent ischaemia) - blood pressure - body weight - saturation - respiration - lab test (i.e. glucose, INR etc)
Cardiovascular implantable electronic devices (CIEDs)	<p>Parameters:</p> <ul style="list-style-type: none"> - mean heart rate over 24 h - heart rate at rest - patient activity - frequency of ventricular extrasystoles - heart rate variability - right ventricular pacing impedance - painless shock impedance
Haemodynamic implantable electronic devices	<p>Parameters:</p> <ul style="list-style-type: none"> - pulmonary artery pressure - left atrial pressure

Table 2 Factors influencing telerehabilitation safety.

<ul style="list-style-type: none">-the correct risk stratification of patients for rehabilitation-the contraindications to exercise training-concomitant HF device therapy (ICEDs) and the regulation which states that the training heart rate must be 10-20/min below the ICD intervention threshold-patients with initial educational sessions (self-evaluation)-the tailoring of training for each specific patient-efficient day-to-day qualification to an appropriate training session using a special training consent procedure before each training session, after initial evaluation of the clinical symptoms and resting ECG by telemonitored team at the monitoring center-the rating of perceived exertion and ECG immediately after or during each training session-exercise acceptance by patients combined with their willingness to perform it-the presence of a caregiver who accompanies the patient during exercise and who would be able to provide first aid and call professional medical help in case of emergency

Table 3 Advantages and limitations of telerehabilitation

	Strengths	Limitations
Patient issues	<p>Familiar surroundings: exercise at home, on one's own, at one's own pace and at a chosen time</p> <p>Real time video conferences (advanced telemonitoring systems)</p> <p>Ability to continue rehabilitation in case of problems with adhering to hospital-based program</p> <p>Elimination of transportation related issues (time and cost saving)</p> <p>Furthering patient independence in performing everyday tasks</p>	<p>Technological skills /trouble shooting</p> <p>Missing face-to-face contact with medical staff and other patients (simple telemonitoring systems)</p>
Professional issues	<p>Ability to treat more patients</p> <p>Ability to combine with telemonitoring</p> <p>Increased control of patient adherence</p>	<p>No 'hands on' real time contact (immediate medical attention unavailable in case of emergency)</p> <p>Education classes more difficult via telephone</p>
Health care system	<p>New equipment and technology becoming rapidly available</p> <p>Low cost, depending on its use (replace vs. add to existing care)</p>	<p>Reimbursement</p> <p>Lack of legal principles</p> <p>Lack of comprehensive telemedical integration system</p>