International Journal of Cardiology 220 (2016) 408–413

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Review

Telerehabilitation in heart failure patients: The evidence and the pitfalls

Ewa Piotrowicz [a,*], Massimo F. Piepoli [b], Tiny Jaarsma [c], Ekaterini Lambrinou [d], Andrew J.S. Coats [e,m], Jean-Paul Schmid [f], Ugo Corrà [g], Piergiuseppe Agostoni [h], Kenneth Dickstein [i], Petar M. Seferović [j], Stamatis Adamopoulos [k], Piotr P. Ponikowski [l]

[a] Telecardiology Center, Institute of Cardiology, Warsaw, Poland
[b] Heart Failure Unit, Cardiology, G da Saliceto Hospital, Piacenza, Italy
[c] Faculty of Health Sciences, University of Linköping, Linköping, Sweden
[d] Cyprus University of Technology, Cyprus
[e] Monash University, Melbourne, Australia
[f] Cardiology Clinic, Tiefenauspital, Bern University Hospital, Bern, Switzerland
[g] Cardiology Division, IRCCS Fondazione 'S. Maugeri', Centro Medico e di Riabilitazione di Veruno, Via per Revislate 13, 28010 Veruno, Novara, Italy
[h] Centro Cardiologico Monzino, IRCCS, Milano, Italy
[i] University of Bergen Stavanger University Hospital Stavanger, Norway
[j] Polyclinic of the Clinical Centre of Serbia, Department of Internal Medicine, Belgrade University School of Medicine, Serbia
[k] Heart Failure-Transplant Unit, Onassis Cardiac Surgery Center, Athens, Greece
[l] Department of Heart Diseases, Faculty of Health Sciences, Wroclaw Medical University Military Hospital, Wroclaw, Poland
[m] University of Warwick, Coventry, UK

ARTICLE INFO

Article history:
Received 2 June 2016
Accepted 27 June 2016
Available online 28 June 2016

Keywords:
Telerehabilitation
Heart failure
Exercise training

ABSTRACT

Accessibility to the available traditional forms of cardiac rehabilitation programs in heart failure patients is not adequate and adherence to the programs 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 programs. The critical issues of psychological support and adherence to the telerehabilitation programs are outlined. The advantages and limitations of this long term management modality are presented and compared with alternatives. Finally, the importance of further research, multicenter 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.

1. 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 programs [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

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

* Corresponding author at: Telecardiology Center, Institute of Cardiology, Alpejska 42, 04-628 Warsaw, Poland.
E-mail address: epiotrowicz@ikard.pl (E. Piotrowicz).

http://dx.doi.org/10.1016/j.ijcard.2016.06.277
0167-5273/

other obstacles and to enhance the availability of the important core components of CR. It is nevertheless crucial to ensure training programs 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 hemodynamic 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.

1.1. 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.

Table 1
Methods of telemonitoring.

Devices	Object of monitoring
Telephone, mobile phone, internet	Symptoms: - dyspnea - breathlessness - peripheral oedema - fatigue - chest pain - palpitations - syncope - psychological status
External devices	Parameters: - ECG (heart rate, conduction disturbances, arrhythmias, ST segment changes, silent ischemia) - blood pressure - body weight - saturation - respiration - lab test (i.e. glucose, INR etc)
Cardiovascular implantable electronic devices (CIEDs)	Parameters: - 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
Hemodynamic implantable electronic devices	Parameters: - pulmonary artery pressure - left atrial pressure

1.2. The telemonitoring process

1.2.1. 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].

1.2.2. 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].

1.2.3. 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.

1.3. 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