

Neth Heart J (2019) 27:5–15
<https://doi.org/10.1007/s12471-018-1202-5>



Telemedicine in heart failure – more than nice to have?

C. G. M. J. Eurlings · J. J. Boyne · R. A. de Boer · H. P. Brunner-La Rocca

Published online: 10 December 2018
© The Author(s) 2018

Abstract Telemedicine in chronic diseases like heart failure is rapidly evolving and has two important goals: improving and individualising care as well as reducing costs. In this paper, we provide a critical and an updated review of the current evidence by discussing the most important trials, meta-analyses and systematic reviews. So far, evidence for the CardioMEMS device is most convincing. Other trials regarding invasive and non-invasive telemonitoring and telephone support show divergent results, but several meta-analyses and systematic reviews uniformly reported a beneficial effect. Voice-over systems and ECG monitoring had neutral results. Lack of direct comparison between different modalities makes it impossible to determine the most effective method. Dutch studies showed predominantly non-significant results, mainly due to underpowered studies or because of a high standard of usual care. There are no conclusive results on cost-effectiveness of telemedicine because of the above shortcomings. The adherence of elderly patients was good in the trials, being essential for the compliance of telemedicine in the entire heart failure population. In the future perspective, telemedicine should be better standardised and evolve to be more than an addition to standard care to improve care and reduce costs.

Keywords Telemedicine · Heart failure · ehealth and telehealth

C. G. M. J. Eurlings · J. J. Boyne · H. P. Brunner-La Rocca (✉)
Maastricht University Medical Center, Maastricht, The Netherlands
hp.brunnerlarocca@mumc.nl

R. A. de Boer
University Medical Center Groningen, Groningen, The Netherlands

Key message

- Telemedicine in heart failure is rapidly evolving.
- Evidence is conflicting, mainly due to a lack of uniform methods/systems.
- Direct comparison between different modalities is lacking which impedes determination of the most effective method.
- Telemedicine should evolve into more than an addition to standard of care.

Background

Heart failure (HF) is an increasingly prevalent disease, which affects approximately 1–2% of the total population in Europe, despite a tendency towards lower incidence in recent years [1, 2]. The high prevalence is mainly due to the ageing population as the prevalence of HF exponentially increases with age. Not surprisingly, the complexity of the disease is increasing, as well, and the majority of patients with HF suffer from multiple comorbidities [1]. Therefore HF is characterised by high morbidity and mortality, and prognosis improved only slightly despite advances in treatment [3]. The high event rate, particularly repeated hospitalisations, is the main driver of the enormous costs and a substantial reduction in quality of life. In order to prevent these events and to reduce the burden of HF, a multidisciplinary team approach has been advocated [2]. Multiple meta-analyses demonstrated that such an approach indeed reduces the burden of HF [4]. Multidisciplinary treatment not only encompasses optimal therapy of HF, but also involves patient education to improve compliance and self-monitoring by patients. However, such an approach is quite labour intensive, requires many resources and monitoring by



patients is often insufficient. Therefore, telemedicine has been suggested to support patients at a distance regarding both education and monitoring and to improve HF care. The implementation of these monitoring tools has been hypothesised to augment medical control of HF to prevent decompensation, to concurrently gain time and resources when compared with traditional care [5] and to maintain a good standard of care in the treatment of HF patients despite the increasing prevalence.

Telemedicine or telehealth are multiform terms embracing the applications of telematics to medicine to enable diagnosis, monitoring and/or treatment remotely by a variety of communication tools, which may include (smart)phones, mobile wireless devices, with or without a video connection, or implantable devices (that are often part of another device such as ICDs or pacemakers [6]). Until recently, digital applications in medicine were restricted to the use of electronic health records, but lately the technological context has notably expanded: the number of existing internet-connected mobile devices has roughly doubled every 5 years [5, 7].

Technology is rapidly evolving. There are a countless number of apps available related to healthcare. New sensors have been developed and data exchange in real-time enables collection of large datasets. Although many issues are not yet resolved (e.g. data safety), expectations are high and there are already healthcare insurers providing reduction in premiums if e-Health technology is used for prevention or management of diseases. However, the question arises what the exact impact is of this technology on the care in HF, whether it improves quality of life and reduces cardiovascular events, and if it may fulfil its expectations.

Current evidence

Implantable devices

So far, the most convincing evidence for a telemonitoring device relates to the implantable CardioMEMS device (Fig. 1; [8]). This device is implanted into the pulmonary artery (PA) and transmits PA pressures to a central service centre. The treating physician receives the results, including the trends over time of these measurements. The physician is advised to react if PA pressure exceeds a certain threshold which suggests congestion, and when it is below the normal range suggesting dehydration. The study was not powered for mortality but showed significant reduction in HF hospitalisation as a result of improved HF management. This effect was maintained in the long term [9]. A comparable rationale was studied in the COMPASS-HF trial. A sensor on a transvenous lead was positioned in the right ventricle (Fig. 2). The primary endpoint rate was reduced by 21%, but this was not statistically significant. There were lower event

rates than expected which could make the study underpowered for the primary endpoint [10]. The major limitation of these studies was that the treatment recommendation is very generic, with a plethora of interventions being used (diuretics, vasodilators), at the discretion of the caring physician.

Another form of telemonitoring is part of ICD/CRT devices. Such monitoring has not generated uniform results. The IN-TIME trial reported improved clinical outcomes by using multi-parameter monitoring based on information from an ICD device. By a daily check of several parameters summarised in Tab. 1, a composite clinical score indicating worsening of HF was improved by 37% (odds ratio=0.63, 95% CI 0.43–0.90) as compared with usual care [11]. The EFFECT study showed a similar effect with a clear reduction of the combined primary endpoint of all-cause mortality and cardiovascular hospitalisation [12]. Encouraging results were also found in the COMMIT-HF trial, a matched cohort study, using different cardiac device brands for the telemonitoring. They observed a long-term effect of significant reduction in mortality (4.9% vs. 22.3%, $p < 0.0001$), but obviously, this was not a randomised trial [13]. In contrast, The OptiLink HF study could not show any beneficial clinical outcome in advanced HF by using fluid status telemedicine alerts (Fig. 2; [14]). Likewise, the positive effects on mortality and cardiac hospitalisation were not supported in a meta-analysis including 11 RCTs consisting of 5,703 patients; there was only a favourable effect on the number of visits, but no effects on hard clinical outcomes and an increase in unscheduled visits [15]. As to whether the differences can be explained by the use of different devices or different interventions is currently unknown. Therefore, no general recommendation to use monitoring information from implantable devices can at present be made.

Non-invasive monitoring

In general, individual trials of telemonitoring/telephone support compared with usual care did not consistently report positive results on the primary endpoints (Tab. 1). The large TELE-HF study did not generate any clinical proof for the use of telemonitoring (utilising a telephone-based interactive voice response system collecting daily information on symptoms and weight) [16]. A voice response system was used without direct contact between healthcare providers, possibly resulting in the low adherence of 14% never users and only about half of the patients using the system more than three times per week [16]. Unfortunately, there was no post-hoc analysis to determine if good adherence resulted in better outcomes. Also, the impact of weight changes for monitoring may be overestimated as it was not demonstrated to be effective as a predictive marker of impending decompensation [17]. This is supported

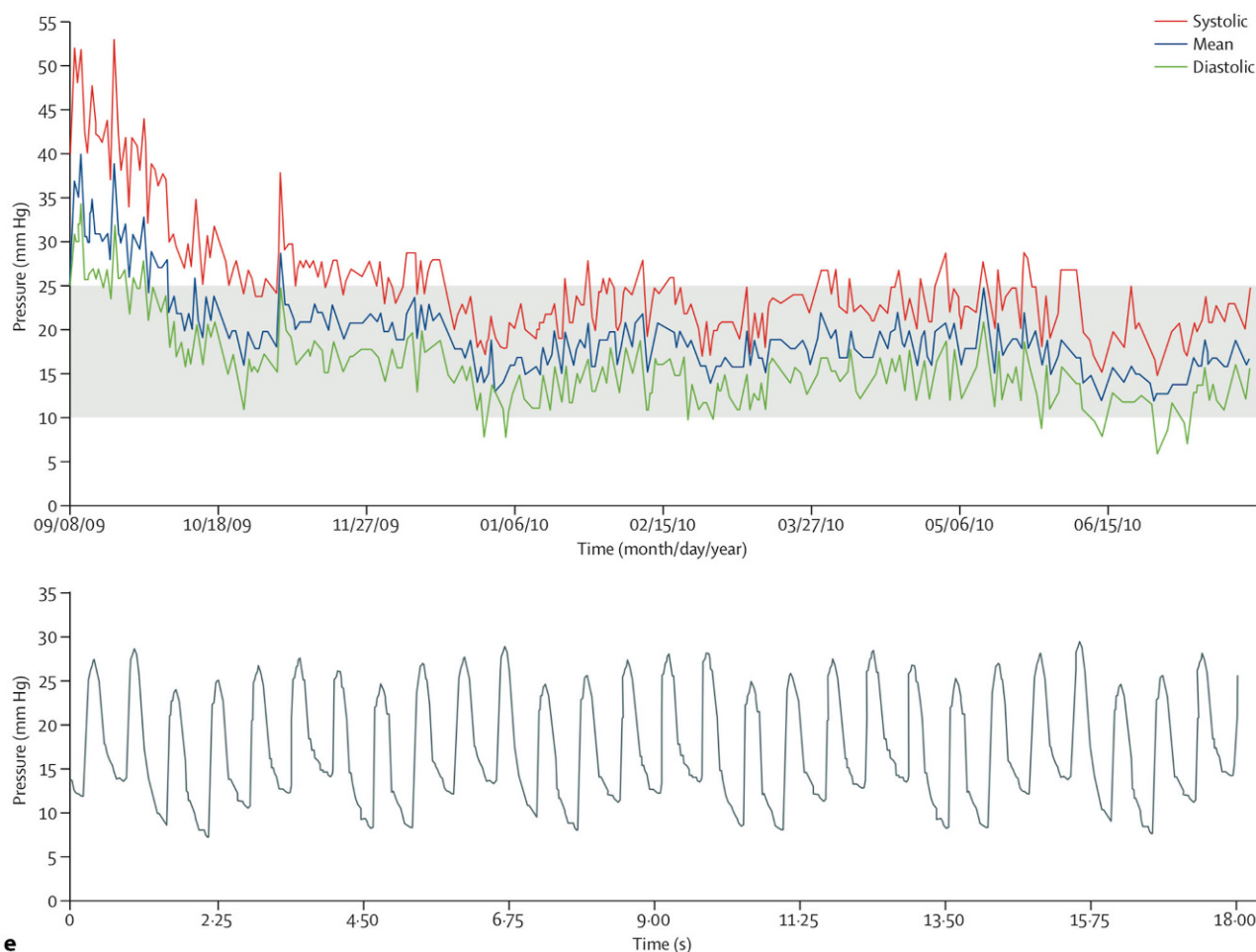
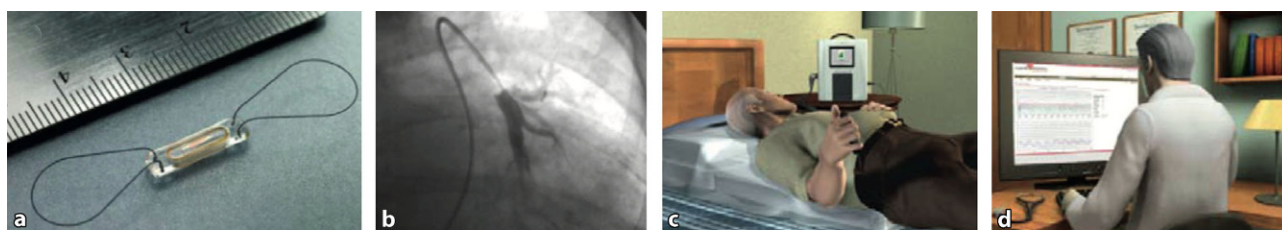


Fig. 1 CardioMEMS, implantable haemodynamic monitoring system. **a** CardioMEMS sensor or transmitter. **b** Transcatheter is implanted into a distal branch of the descending pulmonary artery. **c** The patient is instructed to take daily pressure readings from home using the home electronics. **d** Information transmitted from the monitoring system to the database is im-

mediately available to the investigators for review. **e** Transmitted information consists of pressure trend information and individual pulmonary artery pressure waveforms. With permission from Elsevier, original figure from Abraham et al. *Lancet*. 2011;377:658–66

by the negative WISH trial that compared a self-measurement of patients' weight or by an electronic scales with automatic transmission of the results to the clinic. There was a solid mean of 75% (0–100%) of patient compliance, but there was no significant difference in endpoints between the groups or in sub-groups [18]. Also the MCCD trial showed no benefit of telemonitoring despite very good adherence of the participants [19]. Again, the system was mainly based on data transmission with very little direct contact with the patients. Further, the TIM-HF group failed to

show a positive effect on the primary endpoint of all-cause mortality or composite endpoints comparing usual care with telemonitoring (Fig. 3), but the study was not sufficiently powered [20]. In addition, the CHAT trial showed mixed results with positive effects on the secondary endpoints of all-cause mortality and all-cause hospitalisation with telecommunication, but not on the primary endpoint in HF patients living in rural areas [21]. Very recently, the large TIM-HF2 study found more days alive outside the hospital with the use of structured remote patient

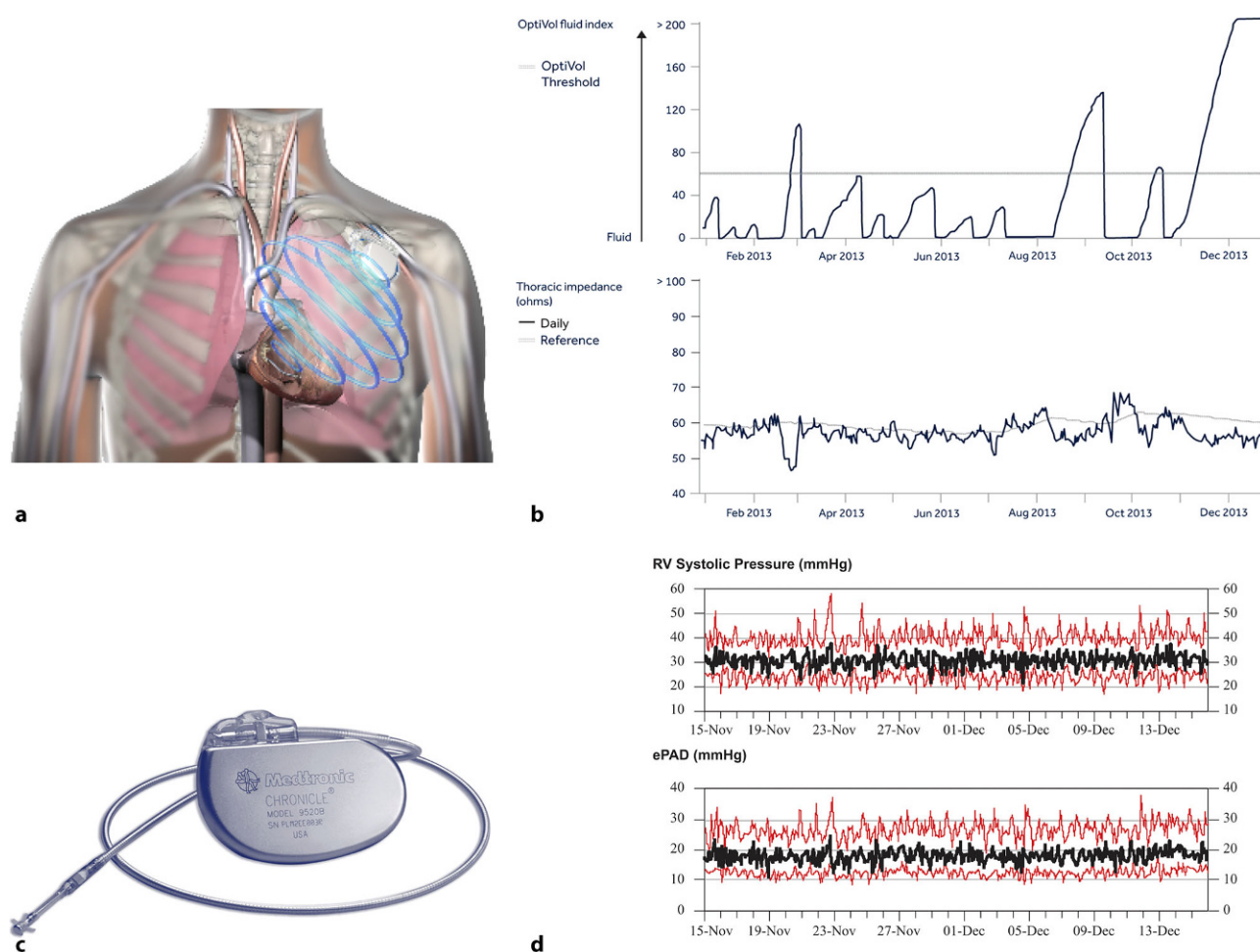


Fig. 2 Examples of invasive monitoring. **a** OptiVOL of Medtronic pacemaker/ICD devices. **b** Results presented for OptiVol with the thoracic impedance (ohms) measured and the OptiVol fluid index, resulting from the difference of measured thoracic impedance and reference thoracic impedance, with threshold. As the patient's lungs become congested, intrathoracic impedance tends to decrease. Similarly, an increase in intrathoracic impedance may indicate the patient's

management interventions as compared with usual care (Tab. 1; [22]). Taken together, the inhomogeneity of the methods used, the devices applied, the patients included and the intervention performed together with the lack of sufficient statistical power may explain the mixed findings of individual trials regarding the use of telemonitoring. Moreover, there is a lack of direct comparison between different modalities, making it impossible to determine which may be the most effective method.

However, several recent meta-analyses and systematic reviews reported that the use of telemonitoring may improve outcomes [23–26]. As a consequence of the mixed trials, these meta-analyses included studies with different inclusion criteria. Despite these differences, all meta-analyses reported reduction in mortality and HF-related hospital admissions. In addition, Kruse et al. concluded that telemedicine is effective in

lungs are becoming more dry. **c** The Chronicle® Implantable Hemodynamic Monitor. **d** Results of Right Ventricle (RV) Systolic Pressure measurements of a sensor on a transvenous lead positioned in the right ventricle and estimated pulmonary artery diastolic (ePAD) pressures. With permission, original figure A/B/C from source: Medtronic Inc. With permission from Elsevier, original figure D from Bourge et al. *Am Coll Cardiol*. 2008;51:1073–9

customer satisfaction [25] and may increase the sense of security [27]. Also, some but not all studies reported positive effects on quality of life [9, 19, 28]. Still, as many randomised trials were neutral, the recommendation by the ESC HF guidelines is restrictive (i. e. recommendation IIB, level B) [2].

Dutch studies

In addition to research design, organisation of health-care may importantly influence outcomes of health-care interventions as telemonitoring. By comparing only Dutch studies, we attempt to create a certain level of similarity, as organisation of care is comparable in all parts of the Netherlands. The first randomised study including a significant number of Dutch patients was the TEN-HMS study [29], which compared telemonitoring with more traditional HF

Table 1 Summaries of different international telemedicine studies

Study	Design	N	FU in months	Intervention	Primary endpoint	Outcome
TELE-HF (2010)	RCT	1,653	6	TM: telephone based interactive voice-response system. Symptoms and weight daily collected	readmission for any reason or death	negative (difference 0.8% points; 95% CI -4.0-5.6; $p=0.75$)
	2 arms: TM vs. UC					
WISH (2010)	RCT	344	12	intervention group: electronic scale automatically transmitted weight	cardiac rehospitalisation	negative (HR 0.90; 95% CI 0.19-1.73; $p=0.32$)
	2 arms: TM vs. UC					
CHAMPION (2011)	prospective single blind multicentre trial	550	15	CardioMEMS: wireless implantable haemodynamic monitoring system of pulmonary artery pressures in addition of standard care	HF related hospitalisations	positive (HR 0.72; 95% CI 0.60-0.85; $p=0.002$)
	2 arms: intervention vs. UC					
TIM-HF (2011)	RCT	710	26	TM: Including daily ECG, blood pressure, body weight	mortality	negative (HR 0.97; 95% CI 0.67-1.41; $p=0.87$)
	2 arms: TM + MTS vs. UC					
INH (2012)	open RCT	715	6	HF nurse: in hospital contact; teaching materials; UTS; blood pressure/heart rate; up-titrating medication (in cooperation with GPs); weekly contact first, later individualised	combined: time to death or rehospitalisation	negative (HR 1.02; 95% CI 0.81-1.30; $p=0.89$)
	2 arms: NTS + UC vs. UC					
CHAT (2013)	RCT	405	12	TeleWatch system follow-up by HF nurses at least monthly regarding: HF clinical status; medical management; social relevant questions	composite of death; HF hospitalisation; withdrawal from study due to worsening HF and improvement of well-being	negative (OR = 1.02; $p=0.91$)
	2 arms: UC vs. UC + NTS					

Table 1 (Continued)

Study	Design	N	FU in months	Intervention	Primary endpoint	Outcome
IN-TIME (2014)	RCT	664	12	TM by ICD:	composite of all-cause death; overnight HF hospital admission; change in NYHA class and change patient self-assessment	positive (OR 0.63; 95% CI 0.43–0.90)
	2 arms: UC + TM vs. UC			Tachyarrhythmia; low % biv-pacing; increase VES; decreased patient activity; abnormal intracardiac electrogram		
MGCD (2014)	RCT	204	26	remote monitoring of:	30-day readmission for the first year	positive
	2 arms: TM vs. UC			daily weight; blood pressure; heart rate; heart rhythm		
EFFECT (2015)	prospective, non-randomised trial	987	12	TM by CIED:	all-cause hospitalisation; Average time to hospitalisation; Costs; Mortality and QoL	negative
	2 arms: UC vs. TM + UC			study protocol did not mandate any specific device programming and was free to enable the available system integrity and clinical alerts for automatic remote notification		
OptiLink HF (2016)	RCT	1,002	22–23	TM by CIED:	combined: all-cause mortality and CV hospitalisations	positive (0.15 vs. 0.27 events/year; incident rate ratio, 0.55; 95% CI, 0.41–0.73; $p < 0.001$)
	2 arms: UC vs. TM + UC			fluid status alerts; automatically transmitted as inaudible text message to the responsible physician		
COMMIT-HF (2017)	observational prospective cohort study	822	36	TM by CIED:	all-cause mortality	positive (HR 0.187; 95% CI 0.075–0.467, $p = 0.0003$)
	2 arms: US vs. TM + UC			automatic transmission of data from the cardiac device. Daily check of the data by 2 physicians and 2 EP nurses		
TIM-HF2 (2018)	RCT	1,571	Max 13	daily transmission of:	percentage of days lost due CV hospitalisations or all-cause death	positive (ratio 0.80; 95% CI 0.65–1.00; $p = 0.0460$)
	2 arms: UC vs. UC + RPM			bodyweight; blood pressure; heart rate; heart rhythm; SpO ₂ ; Self-rated health status		
<p>N number of participants, FU follow-up, RCT randomised controlled trial, TM telemonitoring, UC usual care, NTS nursing telephone support, MTS medical telephone support, RPM remote patient management, CIED cardiac implantable endovascular device, VES ventricular extrasystole, EP electrophysiology, HF heart failure, TM telemonitoring, OR odds ratio, HR hazard ratio, CI confidence interval, PA pulmonary artery, HF heart failure, CV cardiovascular, QoL Quality of Life.</p>						



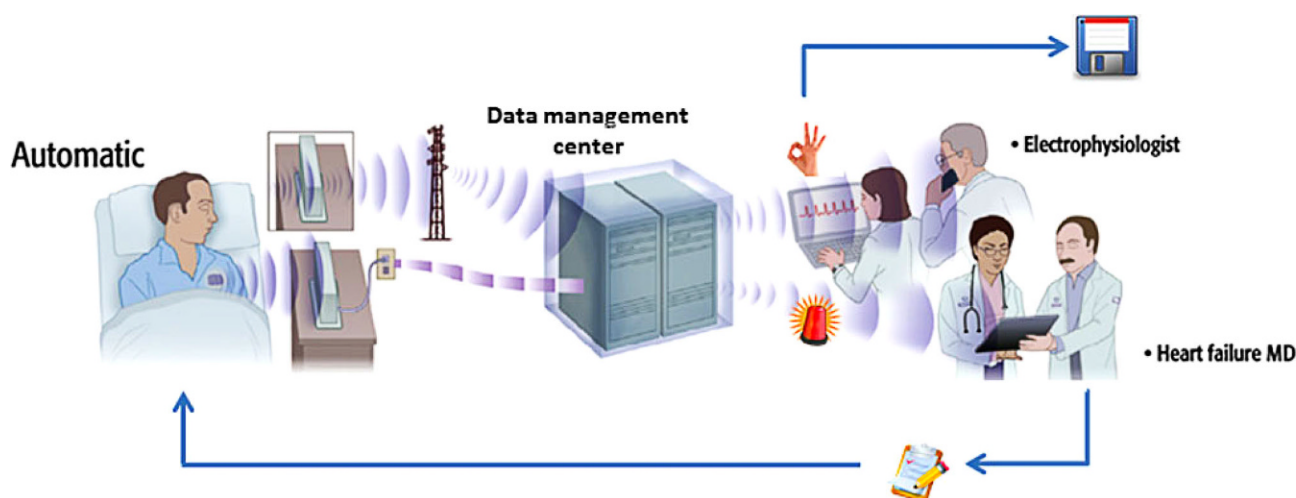


Fig. 3 Telemonitoring system for remote monitoring of arrhythmia and heart failure patients. Multi-parameter data acquisition and transmission should be fully automatic with smooth data flow to medical staff/arrhythmia and heart failure monitoring centre. Optimised data workflow: normal data are automatically stored in a patient's electronic file without further

care as nursing telephone support and usual care. Telemedicine did not differ from nursing telephone support except for prescription of medication, however both had significantly better results compared with usual care for all endpoints (Tab. 2). The Dutch TEHAF study [30] compared the results of using the Health Buddy[®], monitoring signs and symptoms, with usual care. HF hospitalisations and visits to the HF clinic decreased, but the primary endpoint of time to first HF hospitalisation was not significantly improved. The IN-TOUCH study compared an ICT-guided disease management support and an ICT-guided support with additional telemedicine [31]. No significant differences in outcome were found, possibly due to the lack of a usual care group. The e-Vita study, a prospective three-arm study (usual care; usual care plus the heartfailurematters.org website; these two plus an adjusted care pathway with an interactive platform for disease management (e-Vita platform), replacing routine outpatient consultations with HF nurses), could not show any significant benefit [32]. Lastly, an optimised care program using a telehealth application in a pre-post design [33] during a 12-month follow-up found positive effects on most outcomes. Due to the design and the limited study population, the results should be interpreted with caution.

Taken together, the Dutch studies follow the line of the overall evidence with mixed results, explained by the low power of the studies. Endpoints mostly focus on mortality and care consumption, yet they were not powered to detect differences. Possibly, the high standard of usual care may have influenced the results. The challenge is to detect the important aspects of the systems and how to integrate the systems into the daily care process.

detailed evaluation. Alarm threshold crossing triggers detailed data review and potential medical action. With permission from Oxford University Press, original figure from Varma N, Ricci RP. *Eur Heart J.* 2013;34:1885–95 and reprinted/adapted figure in Hindricks G, Varma N. *Eur Heart J.* 2016;37:3164–6

Cost-effectiveness

There is limited evidence regarding cost-effectiveness of telemedicine. The reduction of hospitalisation and the increased self-management of patients embodies the potential of cost reduction in healthcare [25]. The incremental cost-effectiveness of the CardioMEMS device is estimated to be \$ 13,979 per quality-adjusted life year gained [8]. Klersy et al. describe in their meta-analysis on telemonitoring by cardiac devices a reduction of 44% in hospital visits, without affecting mortality, resulting 15–50% cost saving [15]. In the long term, these interventions were calculated to be cost-neutral [34].

Regarding non-invasive telemonitoring, the effects on costs are even less clear. Blum et al. showed no cost-reduction [19] as there was no positive effect in the study (e.g. readmission/hospitalisation). In contrast, Comín-Colet et al. found a significant reduction in HF and cardiovascular readmission with the use of telemedicine, which resulted in a net decrease in direct hospital costs of € 3,546 per patient per 6 months of follow-up [35]. In the Dutch TEHAF study, the probability of being cost-effective was only 48% (threshold of € 50,000), possibly due to the divergence between participating institutions [36]. Because of the heterogeneity of all the studies, populations and no uniform intervention it is difficult to be conclusive on cost-effectiveness.

Potential shortcomings and limitations

One of the shortcomings of telemedicine may be that patients need to be able to use modern technology. This may particularly apply to elderly patients, who usually have less exposure to ICT and may, therefore,

Table 2 Summaries of different Dutch telemedicine studies

Study	Design	N	FU in months	Intervention	Primary endpoint	Outcome
TEN-HMS study (2005)	RCT	426	14–15	TM:	TM vs. NTS:	negative
	3 arms: UC; TM; NTS			electronic monitoring of weight; blood pressure; single lead ECG	days lost because of death or hospitalisation	(difference –4 days; CI –15–6)
				NTS: (nursing telephone support)	TM, NTS vs. UC:	positive
				days lost because of death or hospitalisation	(difference 6 days; 95% CI 1–11)	
TEHAF (2010)	RCT	382	12	Health Buddy:	Time to first hospitalisation	negative
	2 arms: UC; TM			Monitoring signs & symptoms; Education; Support of self-care		(HR 0.65; 95% CI 0.35–1.17; $p=0.151$)
IN TOUCH (2016)	RCT	177	9	innovative ICT-guided-disease management support combined with TM	composite endpoint of mortality, HF readmission and change in health-related quality of life	negative
	2 arms: innovative ICT-guided support; Innovative ICT-guided support + TM			electronic monitoring of weight; blood pressure; ECG (used in case of start-up or up-titration of beta-blockers)		(Mean difference 0.1; 95% CI –0.67–0.82; $p=0.39$)
e-Vita (2018)	RCT	450	12	heart Failure Matters website	self-care	negative
	3 arms: UC; UC + HFM website; care pathway + link to HFM website			care pathway on e-vita platform		HFM vs. UC mean 72.1 vs. 72.7, and EACP vs. UC 76.1 vs. 72.7, respectively (overall $p=0.184$)
Hart Motief Study (2015)	pre-post design	102	12	Motiva telehealth system: providing educational material, reminders of medication and motivational messages	no. of HF-hospitalisations	positive (rate ratio 4.1; 95% CI 2.8–6.3; $p<0.001$)

N number of participants, *FU* follow-up, *RCT* randomised controlled trial, *TM* telemonitoring, *UC* usual care, *NTS* nursing telephone support, *MTS* medical telephone support, *CIED* cardiac implantable endovascular device, *HF* heart failure, *TM* telemonitoring. *OR* odds ratio, *HR* hazard ratio, *CI* confidence interval, *PA* pulmonary artery, *HF* heart failure, *CV* cardiovascular, *QoL* quality of life

either be unable or unwilling to use this technology [37]. Still, a recent meta-analysis shows that patients with a mean age of 70 years or more can quickly adopt telehealth, find its use an acceptable part of their healthcare routine and are able to maintain good adherence for at least 12 months with a beneficial effect in reducing the risk of all-cause mortality and HF-related hospitalisations [38]. The same result is shown in a post hoc sub-analysis of a Cochrane analysis [26, 39]. Still, it must be stressed that it is very likely, though not specifically reported, that patients were selected and these findings might not be applicable to all patients with HF. This is in line with a recent finding that participants and non-participants of e-Health technology in HF differed significantly, particularly regarding age [40]. Nevertheless, these findings are interesting and promising that technology can be developed in a way that it is easy to use for a large proportion of HF patients [38].

Another shortcoming is that the influence of reimbursement adopted by the insurance companies is probably significant but not yet tested. It is also unclear if the reimbursement strategy results in a more structured use of telemedicine. Also, the organisation of care may influence the effects of telemedicine. For this reason, the CardioMEMS system will only be re-

imbursed in the Netherlands within a prospective randomised study to test if the results of the CHAMPION trial also apply to the Dutch healthcare system.

Moreover, it may be argued that the effect of telemedicine may be largest in rural areas where access to good quality healthcare may be more difficult. The current data do not clearly support that notion, but studies did not properly investigate the impact of remoteness of access to care.

Finally, data safety will be an important issue, particularly for next generation devices that may include data from electronic patient records. So far, telemedicine was used mainly as stand alone, limiting data safety issues but also enhanced functionality. Therefore, issues of data safety should be addressed more extensively with further development of (new) devices.

Future perspectives

There are two main goals of telemedicine in HF: improving care and reducing costs. It is not necessarily required that telemedicine devices must strive to achieve both, but the present and future requirements in healthcare will actually favour devices aiming to do so. It is important to much better define which

goals are important to improve outcome, as highlighted above.

Thus far, theoretical considerations have formed the basis for developing telemedicine devices. These included the idea that monitoring patients regarding signs and symptoms, via haemodynamic monitoring or as part of implantable devices such as ICDs (e.g. impedance, heart rate variability, activity levels) would result in a reduction in acute decompensation. This assumption is not sufficiently supported, and it is largely unknown what is required to achieve the best outcome. Best results were achieved with the use of invasive haemodynamic monitoring [8, 9], but this is not applicable to the majority of patients and confirmation in other healthcare systems than initially tested is required [41, 42]. In addition, a similar kind of device use (i.e. ICD/CRT-D devices for remote monitoring) resulted in mixed results [11, 43], which cannot be easily explained. Importantly, the exact action required based on the result of monitoring is left to the care professionals in charge, which obviously may vary significantly. Therefore, there is an urgent need for randomised controlled trials with a clear definition of both monitoring and intervention modalities, as well as collection of comprehensive data from the clinical use of telemedicine devices. Combining such data based on different systems may help define which parts of monitoring and patient education are most effective. However, there is also a great need to sufficiently record and analyse the therapeutic intervention done based on telemedicine systems. So far, there is a lack of such data in sufficiently large patient populations.

Telemedicine has also been advocated to reduce costs in HF care [35], mainly related to reduction in hospitalisation rate. However, there may be also a significant improvement in self-management in HF as well as other chronic diseases [44], possibly resulting in reduction of outpatient visits as shown for another chronic disease [45]. Current systems have limited abilities to foster self-management by patients. Healthcare in Western countries requires a new innovative approach to address chronic diseases such as HF to provide sustainability of care and to limit the excessive costs that may threaten the current system. Thus, changing the approach to care is important, not only regarding adoption and smarter use of modern technology, but also regarding a new vision on both care and health [46]. Therefore, telemedicine should be more than an addition to standard of care. Importantly, chronic diseases usually do not occur in isolation. Most patients with chronic disease have multiple diseases [47]. Future telemedicine devices for HF should consider comorbidities, not only for safety reasons, but to enable real patient self-management that may enable some substitution of traditional care.

Conclusions

Telemedicine is evolving fast, but lacks solid evidence on clinical outcomes and cost-effectiveness in trials, despite positive meta-analysis. The CardioMEMS device showed the most convincing results. For the future, sufficiently powered trials with clear definition of both monitoring and intervention are urgently needed. Telemedicine should evolve to be more than an addition to standard of care. Only then will telemedicine be more than nice to have.

Acknowledgements Drs. Eurlings and Brunner-La Rocca are supported by INTERREG-NWE (NWE702).

Dr. de Boer is supported by the Netherlands Heart Foundation (CVON DOSIS, grant 2014-40, CVON SHE-PREDICTS-HF, grant 2017-21, and CVON RED-CVD, grant 2017-11); and the Innovational Research Incentives Scheme program of the Netherlands Organization for Scientific Research (NWO VIDI, grant 917.13.350).

Conflict of interest The MUMC, which employs C.G.M.J. Eurlings, J.J. Boyne and H.P. Brunner-La Rocca, has received research grants and/or fees from Novartis, Vifor, Abbott, Medtronic, Servier, Roche Diagnostics. They are collaborating in a European project with Sananet, Exploris and Neurogames. Dr. Brunner-La Rocca received research grants and/or fees from Roche Diagnostics, Novartis, Vifor, and Servier. The UMCG, which employs R.A. De Boer, has received research grants and/or fees from AstraZeneca, Abbott, Bristol-Myers Squibb, Novartis, Roche, Trevena, and ThermoFisher GmbH. Dr. de Boer is a minority shareholder of scPharmaceuticals, Inc. Dr. de Boer has received personal fees from MandalMed Inc, Novartis, and Servier.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

1. Conrad N, Judge A, Tran J, et al. Temporal trends and patterns in heart failure incidence: a population-based study of 4 million individuals. *Lancet*. 2018;391:572–80.
2. Ponikowski P, Voors AA, Anker SD, et al. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: The Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC). Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur J Heart Fail*. 2016;18:891–975.
3. Teng TH, Hung J, Knuiman M, et al. Trends in long-term cardiovascular mortality and morbidity in men and women with heart failure of ischemic versus non-ischemic aetiology in Western Australia between 1990 and 2005. *Int J Cardiol*. 2012;158:405–10.
4. Feltner C, Jones CD, Cene CW, et al. Transitional care interventions to prevent readmissions for persons with heart failure: a systematic review and meta-analysis. *Ann Intern Med*. 2014;160(11):774–84.

5. Gensini GF, Alderighi C, Rasoini R, Mazzanti M, Casolo G. Value of telemonitoring and telemedicine in heart failure management. *Cardiac Fail Rev*. 2017;3:116–21.
6. Dorsey ER, Topol EJ. State of telehealth. *N Engl J Med*. 2016;375:154–61.
7. Topol EJ, Steinhubl SR, Torkamani A. Digital medical tools and sensors. *JAMA*. 2015;313:353–4.
8. Abraham WT, Adamson PB, Bourge RC, et al. Wireless pulmonary artery haemodynamic monitoring in chronic heart failure: a randomised controlled trial. *Lancet*. 2011;377:658–66.
9. Abraham WT, Stevenson LW, Bourge RC, et al. Sustained efficacy of pulmonary artery pressure to guide adjustment of chronic heart failure therapy: complete follow-up results from the CHAMPION randomised trial. *Lancet*. 2016;387:453–61.
10. Bourge RC, Abraham WT, Adamson PB, et al. Randomized controlled trial of an implantable continuous hemodynamic monitor in patients with advanced heart failure: the COMPASS-HF study. *J Am Coll Cardiol*. 2008;51:1073–9.
11. Hindricks G, Taborsky M, Glikson M, et al. Implant-based multiparameter telemonitoring of patients with heart failure (IN-TIME): a randomised controlled trial. *Lancet*. 2014;384:583–90.
12. De Simone A, Leoni L, Luzi M, et al. Remote monitoring improves outcome after ICD implantation: the clinical efficacy in the management of heart failure (EFFECT) study. *Europace*. 2015;17:1267–75.
13. Kurek A, Tajstra M, Gadula-Gacek E, et al. Impact of remote monitoring on long-term prognosis in heart failure patients in a real-world cohort: results from all-comers COMMIT-HF trial. *J Cardiovasc Electrophysiol*. 2017;28:425–31.
14. Bohm M, Drexler H, Oswald H, et al. Fluid status telemedicine alerts for heart failure: a randomized controlled trial. *Eur Heart J*. 2016;37:3154–63.
15. Klersy C, Boriani G, De Silvestri A, et al. Effect of telemonitoring of cardiac implantable electronic devices on healthcare utilization: a meta-analysis of randomized controlled trials in patients with heart failure. *Eur J Heart Fail*. 2016;18:195–204.
16. Chaudhry SI, Mattera JA, Curtis JP, et al. Telemonitoring in patients with heart failure. *N Engl J Med*. 2010;363:2301–9.
17. Zile MR, Bennett TD, Sutton SJ, et al. Transition from chronic compensated to acute decompensated heart failure: pathophysiological insights obtained from continuous monitoring of intracardiac pressures. *Circulation*. 2008;118:1433–41.
18. Lynga P, Persson H, Hagg-Martinella, et al. Weight monitoring in patients with severe heart failure (WISH). A randomized controlled trial. *Eur J Heart Fail*. 2012;14:438–44.
19. Blum K, Gottlieb SS. The effect of a randomized trial of home telemonitoring on medical costs, 30-day readmissions, mortality, and health-related quality of life in a cohort of community-dwelling heart failure patients. *J Card Fail*. 2014;20:513–21.
20. Koehler F, Winkler S, Schieber M, et al. Impact of remote telemedical management on mortality and hospitalizations in ambulatory patients with chronic heart failure: the telemedical interventional monitoring in heart failure study. *Circulation*. 2011;123(17):1873–80.
21. Krum H, Forbes A, Yallop J, et al. Telephone support to rural and remote patients with heart failure: the Chronic Heart Failure Assessment by Telephone (CHAT) study. *Cardiovasc Ther*. 2013;31(4):230–7.
22. Koehler F, Koehler K, Deckwart O, et al. Efficacy of telemedical interventional management in patients with heart failure (TIM-HF2): a randomised, controlled, parallel-group, unmasked trial. *Lancet*. 2018;392:1047. [https://doi.org/10.1016/s0140-6736\(18\)31880-4](https://doi.org/10.1016/s0140-6736(18)31880-4).
23. Lin MH, Yuan WL, Huang TC, Zhang HF, Mai JT, Wang JF. Clinical effectiveness of telemedicine for chronic heart failure: a systematic review and meta-analysis. *J Investig Med*. 2017;65(5):899–911.
24. Kotb A, Cameron C, Hsieh S, Wells G. Comparative effectiveness of different forms of telemedicine for individuals with heart failure (HF): a systematic review and network meta-analysis. *PLoS ONE*. 2015;10:e118681.
25. Kruse CS, Soma M, Pulluri D, Nemali NT, Brooks M. The effectiveness of telemedicine in the management of chronic heart disease—a systematic review. *JRSM Open*. 2017;8:2054270416681747.
26. Inglis SC, Clark RA, Dierckx R, Prieto-Merino D, Cleland JG. Structured telephone support or non-invasive telemonitoring for patients with heart failure. *Cochrane Database Syst Rev*. 2015; <https://doi.org/10.1002/14651858.CD007228.pub3>.
27. Lind L, Karlsson D. Telehealth for “the digital illiterate”—elderly heart failure patients’ experiences. *Stud Health Technol Inform*. 2014;205:353–7.
28. Angermann CE, Stork S, Gelbrich G, et al. Mode of action and effects of standardized collaborative disease management on mortality and morbidity in patients with systolic heart failure: the Interdisciplinary Network for Heart Failure (INH) study. *Circ Heart Fail*. 2012;5:25–35.
29. Cleland JGF, Louis AA, Rigby AS, Janssens U, Balk AHMM. Noninvasive home telemonitoring for patients with heart failure at high risk of recurrent admission and death: the Trans-European Network-Home-Care Management System (TEN-HMS) study. *J Am Coll Cardiol*. 2005;45:1654–64.
30. Boyne JJ, Vrijhoef HJ, Crijns HJ, De WG, Kragten J, Gorgels AP. Tailored telemonitoring in patients with heart failure: results of a multicentre randomized controlled trial. *Eur J Heart Fail*. 2012;14:791–801.
31. Kraai I, de Vries A, Vermeulen K, et al. The value of telemonitoring and ICT-guided disease management in heart failure: results from the IN TOUCH study. *Int J Med Inform*. 2016;85:53–60.
32. Wagenaar KP, Broekhuizen BDL, Jaarsma T, et al. Effectiveness of the ESC/HFA website ‘heartfailurematters.org’ and an e-health adjusted care pathway in patients with stable heart failure: results of the ‘e-Vita HF’ randomized controlled trial. *Eur J Heart Fail*. 2018; <https://doi.org/10.1002/ejhf.1354>
33. Veenstra W, Op den Buijs J, Pauws S, Westerterp M, Nagelsmit M. Clinical effects of an optimised care program with telehealth in heart failure patients in a community hospital in the Netherlands. *Neth Heart J*. 2015;23:334–40.
34. Burri H, Sticherling C, Wright D, Makino K, Smala A, Tilden D. Cost-consequence analysis of daily continuous remote monitoring of implantable cardiac defibrillator and resynchronization devices in the UK. *Europace*. 2013;15:1601–8.
35. Comin-Colet J, Enjuanes C, Verdu-Rotellar JM, et al. Impact on clinical events and healthcare costs of adding telemedicine to multidisciplinary disease management programmes for heart failure: Results of a randomized controlled trial. *J Telemed Telecare*. 2016;22:282–95.
36. Boyne JJ, Van Asselt AD, Gorgels AP, et al. Cost-effectiveness analysis of telemonitoring versus usual care in patients with heart failure: the TEHAF-study. *J Telemed Telecare*. 2013;19:242–8.
37. Levy H, Janke AT, Langa KM. Health literacy and the digital divide among older Americans. *J Gen Intern Med*. 2015;30:284–9.

38. Clark RA. Telehealth in the elderly with chronic heart failure: what is the evidence? *Stud Health Technol Inform.* 2018;246:18–23.
39. Inglis SC, Conway A, Cleland JG, Clark RA. Is age a factor in the success or failure of remote monitoring in heart failure? *Telemonitoring and structured telephone support in elderly heart failure patients.* *Eur J Cardiovasc Nurs.* 2015;14:248–55.
40. Wagenaar KP, Hakim N, Broekhuizen BD, Jaarsma T, Rutten FH, Hoes AW. Representativeness of participants in heart failure E-health trials: a report from the E-vita HF study. *J Card Fail.* 2017;23:88–9.
41. Brugts JJ, Manintveld OC, van Mieghem N. Remote monitoring of pulmonary artery pressures with CardioMEMS in patients with chronic heart failure and NYHA class III: first experiences in the Netherlands. *Neth Heart J.* 2018;26:55–7.
42. Angermann CE, Assmus B, Anker SD, et al. Safety and feasibility of pulmonary artery pressure-guided heart failure therapy: rationale and design of the prospective CardioMEMS Monitoring Study for Heart Failure (MEMS-HF). *Clin Res Cardiol.* 2018;107(11):991. <https://doi.org/10.1007/s00392-018-1281-8>.
43. Boriani G, Da Costa A, Quesada A, et al. Effects of remote monitoring on clinical outcomes and use of healthcare resources in heart failure patients with biventricular defibrillators: results of the MORE-CARE multicentre randomized controlled trial. *Eur J Heart Fail.* 2017;19:416–25.
44. Hanlon P, Daines L, Campbell C, McKinstry B, Weller D, Pinnock H. Telehealth interventions to support self-management of long-term conditions: a systematic metareview of diabetes, heart failure, asthma, chronic obstructive pulmonary disease, and cancer. *J Med Internet Res.* 2017;19:e172.
45. de Jong MJ, van der Meulen-de JAE, Romberg-Camps MJ, et al. Telemedicine for management of inflammatory bowel disease (myIBDcoach): a pragmatic, multicentre, randomised controlled trial. *Lancet.* 2017;390:959–68.
46. Brunner-La Rocca HP, Fleischhacker L, Golubnitschaja O, et al. Challenges in personalised management of chronic diseases-heart failure as prominent example to advance the care process. *EPMAJ.* 2016;7:2.
47. Garcia-Olmos L, Salvador CH, Alberquilla A, et al. Comorbidity patterns in patients with chronic diseases in general practice. *PLoS ONE.* 2012;7:e32141.