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Effect of a telemonitoring-facilitated collaboration between general practitioner and heart failure clinic on mortality and rehospitalization rates in severe heart failure: the TEMA-HF 1 (TElemonitoring in the MAnagement of Heart Failure) study

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Aims Chronic heart failure (CHF) patients are frequently rehospitalized within 6 months after an episode of fluid retention. Rehospitalizations are preventable, but this requires an extensive organization of the healthcare system. In this study, we tested whether intensive follow-up of patients through a telemonitoring-facilitated collaboration between general practitioners (GPs) and a heart failure clinic could reduce mortality and rehospitalization rate.

Methods and results One hunderd and sixty CHF patients [mean age 76 ± 10 years, 104 males, mean left ventricular ejection fraction (LVEF) 35 ± 15%] were block randomized by sealed envelopes and assigned to 6 months of intense follow-up facilitated by telemonitoring (TM) or usual care (UC). The TM group measured body weight, blood pressure, and heart rate on a daily basis with electronic devices that transferred the data automatically to an online database. Email alerts were sent to the GP and heart failure clinic to intervene when pre-defined limits were exceeded. All-cause mortality was significantly lower in the TM group as compared with the UC group (5% vs. 17.5%, $P = 0.01$). The total number of follow-up days lost to hospitalization, dialysis, or death was significantly lower in the TM group as compared with the UC group (13 vs. 30 days, $P = 0.02$). The number of hospitalizations for heart failure per patient showed a trend (0.24 vs. 0.42 hospitalizations/patient, $P = 0.06$) in favour of TM.

Conclusion Telemonitoring-facilitated collaboration between GPs and a heart failure clinic reduces mortality and number of days lost to hospitalization, death, or dialysis in CHF patients. These findings need confirmation in a large trial.
Trial registation: ISRCTN39223875

Keywords Heart failure • Telemonitoring • Mortality • Morbidity

Introduction

Chronic heart failure (CHF) is a common, serious, and costly disease whose clinical course is characterized by recurrent hospitalizations due to fluid overload and/or worsening of renal function. A regular adjustment of treatment of CHF patients is needed to lower morbidity, mortality, and healthcare costs.

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The European Guidelines on heart failure stress that education about medication adherence, early warning signs of impending decompensation, support of self-care behaviour, and optimization of pharmacological and device therapy are the main aims of long-term care of heart failure.[1] The potential use of telemonitoring to help in transmitting important parameters is acknowledged, and the important players in the chronic management of heart failure patients are the patient, the primary care physician, and the heart failure management team.[1]

The classical approach used in heart failure teams, with regular telephone contacts, is, however, labour-intensive. Therefore, the question arises of whether a close collaboration between general practitioners (GPs) and the heart failure nurse and/or cardiologist, facilitated by modern communication technology allowing day-to-day follow-up of body weight, blood pressure, and heart rate, may result in an improved clinical outcome.

Methods

Subjects

In this study, 160 CHF patients [mean age 76 ± 10 years, 104 males, mean left ventricular ejection fraction (LVEF) 35 ± 15%], hospitalized in seven hospitals throughout Belgium for heart failure, were included from April 2008 up to June 2010. Patients were considered eligible for the study if hospitalized for fluid overload due to heart failure requiring an increase or initiation of diuretic treatment. All patients had to be treated with an angiotensin-converting enzyme (ACE) inhibitor or angiotensin II receptor antagonist, and with a beta-blocker in the absence of contraindications. Only patients with a sufficient cognitive function to understand the aims of the study and to perform the recordings of body weight, blood pressure, and heart rate were allowed to enter the study. Exclusion criteria were: reversible forms of acute heart failure (acute ischaemia, myocarditis, etc.), heart failure due to severe aortic stenosis, previous residency in a nursing home, inclusion in a cardiac rehabilitation programme on discharge, creatinine clearance <15 mL/min, planned dialysis in the next 6 months, planned biventricular pacemaker or cardiac surgery, life expectancy of < 1 year due to other diseases, severe pulmonary obstructive disease (GOLD III), and/or significant mental or cognitive problems interfering with the daily measurements or intake of medication. From the patients that were eligible based on inclusion and exclusion criteria, four (2%) were not randomized because of lack of agreement of the patient in two cases and of the GP in two cases.

Intervention

All subjects and close relatives received a standard education course concerning heart failure of ~1 h duration by the heart failure nurse before discharge. Topics discussed were the cause and consequences of heart failure, medical treatment, the importance of close monitoring of body weight and symptoms, and advice about diet and exercise. A blood sample for N-terminal pro brain natriuretic peptide (NT-proBNP) was taken on the day of discharge.

Next, patients were block randomized by sealed envelopes to 6 months of intense follow-up facilitated by telemonitoring (TM) or usual care (UC). On the day of hospital discharge, the body weight of all patients was measured, and TM patients were instructed how to use an electronic body weight scale, a blood pressure monitoring device, and a cell phone. Patients were asked to measure body weight, blood pressure, and heart rate daily, at a fixed hour in the morning, by a standardized protocol. The scale and sphygmomanometer were connected by Bluetooth to a dedicated cell phone, which automatically forwarded the results to the central computer. Pre-specified alert limits were determined: for body weight (± 2 kg from discharge body weight), systolic blood pressure [140 mmHg (upper limit) and 90 mmHg (lower limit)], and heart rate [90 b.p.m. (upper limit) and 50 b.p.m. (lower limit)]. When recordings of body weight, systolic blood pressure, and/or heart rate fell outside these limits for two consecutive days, the GP and heart failure clinic were alerted by automatic Email, containing a graph of the evolution of the parameter that caused the alert. At that moment, per protocol, the GP was asked to visit or contact the patient and to adapt the treatment, if he/she felt necessary. The heart failure nurse contacted the patient by telephone 1–3 days after the alert to verify whether the intervention was effective. No routine contacts by telephone were performed by the heart failure nurse. The GP was left free to contact the patient even in the absence of any alerts. The GP and the heart failure specialist were asked to enter all changes in medication into an online website database. The website also allowed the GP to ask the heart failure specialist questions concerning the patient, and the specialist could advise the GP. All patients were followed up for a maximum of 6 months starting from inclusion. When on two consecutive days no measurements were received by the central computer, a 'frequency alert' was generated. This alert was followed up by the call centre of the provider (Symonn nv, Brussels, Belgium). Patients were called by phone to stimulate them to make the recordings, or to help them in the case of malfunction. A regular feedback of these interventions was sent to the investigators.

All patients (both TM and UC) were seen at the outpatient heart failure clinic 2 weeks after discharge, to evaluate the fluid status and to optimize treatment if necessary. Next, patients in the TM group were planned for follow-up in the outpatient heart failure clinic at 3 and 6 months, but were allowed to visit the clinic sooner and more frequently if necessary. The patients in the UC group were followed up by their GP who could refer the patients to their cardiologist if needed. No intervention by the study nurse or the heart failure clinic team was done for this group of patients.

Outcome parameters

In total, four subjects (2%) prematurely dropped out of this study because of a lack of motivation. Data from these subjects were included in the analysis (intention-to-treat). The primary endpoint of the study was all-cause mortality. Other major endpoints that were measured are days lost to death, hospitalization, or dialysis, and number of hospitalizations. Days lost to death and/or renal dialysis was pre-specified and calculated as follows: every patient was supposed to be in follow-up for 6 months (180 days). If the patient died or entered chronic dialysis during the study period, the remaining days until the theoretical end of the study were counted as 'days lost to death' and 'days lost to dialysis', respectively. Entering dialysis thus ended the study for that patient, as the strict daily follow-up and adaptation of dialysis treatment by the nephrologist would interfere with the study protocol asking for the input of the GP in the case of changes in the parameters. These days were added to the number of days the patient stayed in hospital for heart or renal failure. The total cost of hospitalization was calculated using the hospital bills. Ambulatory costs were not included in this analysis.

To decrease the risk of bias in an unblinded study, the data were collected by a data manager not involved in patient care, and not stationed in one of the participating hospitals. The statistical analysis was done by a statistician not involved in patient care. The reason for hospitalization was determined based on the discharge letter and

adjudicated after the end of the study in a blinded way, and the primary endpoint was all-cause mortality, which avoided the difficulty of determining the cause of death.

Medication

To be able to compare the use of medication at the start and the end of the study, dosages of ACE inbitors, angiotensin II antagonists, beta-blockers, and aldosterone antagonists were recalculated as a percentage of optimal dose as defined by Dickstein *et al.*[1] Dosages of loop diuretics were recalculated to equivalent dosage of bumetanide (1 mg of bumetanide was considered equivalent to 40 mg of furosemide).

Ethics

All patients were instructed about the trial and signed an informed consent. The study protocol was approved by the ethics committees of the participating centres. The GP was asked for his co-operation before entering the patient into the study.

Statistical analysis

Study sample size was calculated *a priori*. We based this prediction on the study of Clark *et al.*[2] reporting a significant reduction in all-cause mortality by 38% as result of a telemonitoring intervention in heart failure patients. With the following modalities: alpha 0.05, power 0.8, and effect size w 0.30, we calculated a required sample of 133 subjects. Considering an anticipated drop-out of 20% during follow-up, 160 subjects were required for this study. All analyses were conducted following the intention-to-treat principle. Descriptive statistics are presented as the mean $\pm$ SD and as median. Categorical data comparison between groups was performed using the χ^2 test. Continuous variables were tested between groups by one-way analysis of variance (ANOVA). Mortality and hospitalization frequency was compared between subgroups within various levels of baseline NT-proBNP levels (by terciles) and LVEF ($<$30% vs. 30–45% vs. $>$45%). Survival analysis with a Kaplan–Meier curve was constructed for time to death. Hazard ratios were calculated, and a P-value < 0.05 (two-tailed) was considered as significant. The statistical analysis was done using SPSS version 14.0.

Results

In the period from April 2008 to June 2010, 160 CHF patients were randomized to TM or UC in seven large hospitals, and subsequently followed up for 6 months. Four TM patients quit the study early for motivational reasons. Average age was 76 $\pm$ 10 years, 104 (65%) were male, with no differences in baseline patient characteristics between study groups (see *Table 1*). An LVEF $<$ 40% was present in 66% of the total population.

A total of 83% of all the recordings made by the patients in the TM group were measured and received correctly (86% of body weight measurements, 82% of blood pressure and heart rate measurements). The majority of the GPs (76%) logged in to the website at least once during the study.

Apart from the frequency alerts (related to missing patient recording, see Methods), body weight alerts were most frequent, with only 16% of patients remaining without any alert during the whole period of follow-up (see *Table 2*). Blood pressure alerts and heart rate alerts were much less frequent. When analysing the evolution of the alerts over time, no time trend was found: equal numbers of alerts were generated during any measurement month.

Baseline medication intake was not significantly different between groups ($P > 0.05$, see *Table 3*). During follow-up, changes in intake of beta-blockers, diuretics, and ACE inhibitors were significantly different between groups ($P < 0.05$). The number of changes in prescription of diuretics was significantly higher in the TM group, as compared with the UC group ($P < 0.01$). When calculating all changes in medication prescription together in each group, significantly more changes

Table 1 Baseline subject characteristics

	Usual care		Telemonitoring		*P*-value
	Mean (SD) or *n* (%)	Median	Mean (SD) or *n* (%)	Median	
Gender (men)	54 (67%)		50 (62%)		0.50
Heart rhythm (sinus rhythm)	45 (56%)		45 (56%)		1.00
Age (years)	75.6 (9.8)	77	75.9 (9.6)	77	0.86
Hospitalizations before inclusion	1.4 (1.7)	1	1.7 (2.5)	1	0.32
Body weight (kg)	75 (16)	75	77 (17)	74	0.45
Blood pressure					
Systolic (mmHg)	124 (23)	120	125 (23)	125	0.51
Diastolic (mmHg)	70 (12)	70	73 (12)	72	0.20
Heart rate (b.p.m.)	75 (16)	72	72 (15)	70	0.23
NYHA class	3.0 (0.5)	3.0	3.0 (0.5)	3.0	0.95
LVEF (%)	35.9 (15.1)	35.0	34.9 (15.0)	32.5	0.67
NT-proBNP (pg/mL) on discharge	6818 (7456)	3942	4994 (6836)	2452	0.13
6 min walking test (m)	288 (114)	267	273 (123)	270	0.55

Data are presented as mean (SD).
LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro brain natriuretic peptide; NYHA, New York Heart Association.

Table 2 Number of alerts/patient and number of patients without any alert during the monitoring period

	No. of alerts/patient	No. of patients without alerts
Body weight alerts	16.6 (35.5)	11 (16%)
Blood pressure alerts	8.5 (16.6)	29 (36%)
Heart rate alerts	2.2 (6.1)	58 (72%)
Frequency alerts	45.0 (54.5)	6 (7%)

Data are presented as mean (SD). Frequency alerts were defined as absence of measurement values arriving in the database (due to patients not taking measurements or technical problems).

were observed in the TM group [3.2 (2.8) changes] compared with the UC group [2.3 (2.1) changes] ($P < 0.05$).

Mortality

After 6 months of follow-up, all-cause mortality was significantly different between study groups: 14 (17.5%) subjects died in the UC group vs. 4 (5%) in the TM group ($P = 0.012$; see *Table 4*). The Kaplan–Meier curves representing mortality (see *Figure 1*) confirmed the difference between groups ($P = 0.014$): the curves begin to diverge from ~ 60 days after discharge, and continue diverging during follow-up.

Heart failure-related hospitalizations

The number of heart failure-related readmissions/patient for heart failure showed a trend of difference between study groups: 0.42 ± 0.70 in the UC group vs. 0.24 ± 0.51 in the TM group ($P = 0.056$).

All hospitalizations

The number of hospitalization for all reasons were not different between groups (0.82 ± 0.93 hospitalizations/subject in the UC group vs. 0.80 ± 0.97 hospitalizations/subject in the TM group; $P = 0.934$).

Days lost to death, dialysis, or hospitalization for heart or renal failure

The number of days lost to all heart failure-related events (death, dialysis, or hospitalization due to heart or renal failure) was significantly reduced in the TM group as compared with the UC group (13.1 ± 37.6 vs, 30.2 ± 56.0 days/patient, respectively, $P = 0.025$). The number of days lost to all hospitalizations was not different between groups (8.0 ± 12.8 days lost to all hospitalizations in the UC group vs. 7.1 ± 13.0 days lost to all hospitalizations in the TM group; $P = 0.655$).

Hospitalization costs

Even though the total hospitalization cost for heart failure and/or renal failure was almost double in the UC group (1458 ± 3420 Euro/patient) as compared with the TM group (902 ± 2277 Euro/patient), this difference was not significant ($P = 0.23$, see *Table 5*). The cost for hospitalizations for reasons other than heart or renal failure did not show a significant difference.

Table 3 Medication prescription and implantable devices

	Usual care				Telemonitoring			
	Start of study	End of study	Changes in dose	No. of changes	Start of study	End of study	Changes in dose	No. of changes
Diuretics (mg)	2.0 (2.0)	1.2 (2.0)	−0.8 (2.1)*	0.9 (0.9)*	1.9 (1.5)	1.8 (2.2)	0.0 (1.7)*	1.6 (1.9)*
Thiazides (mg)	2.0 (8.8)	1.2 (6.8)	−0.8 (8.0)	0.1 (0.3)	3.3 (13.4)	2.3 (9.1)	−0.9 (14.0)	0.1 (0.3)
ACE inhibitors (% target dose)	30 (32)	17 (29)	−13 (35)*	0.4 (0.5)	28 (24)	25 (27)	−3 (26)*	0.4 (0.5)
Angiotensin II antagonists (% target dose)	7 (21)	5 (16)	−3 (14)	0.1 (0.4)	7 (18)	8 (22)	1 (14)	0.2 (0.4)
Beta-blockers (% target dose)	33 (36)	19 (30)	−13 (26)*	0.5 (0.8)	27 (28)	28 (30)	1 (28)*	0.6 (0.8)
Aldosterone antagonists (% target dose)	26 (35)	19 (29)	−7 (33)	0.3 (0.5)	24 (34)	16 (31)	−9 (39)	0.3 (0.4)
Implantable cardioverter defibrillator (*n*)	2	2		0	1	1		0
Cardiac resynchronization therapy (*n*)	0	0		0	1	1		0

Data are presented as mean (SD). Dosages of angiotensin-converting enzyme (ACE) inbitors, angiotensin II antagonists, beta-blockers, and aldosterone antagonists are recalculated as a percentage of optimal dose as defined by Dickstein *et al.*[1] Dosages of loop diuretics were recalculated to equivalent dosage of bumetanide (1 mg of bumetanide was considered equivalent to 40 mg of furosemide).
*Significantly different between groups ($P < 0.05$).

Table 4 Study outcome: mortality and hospitalizations

	Total study population	Usual care	Telemonitoring	*P*-value
All-cause mortality	18 (11%)	14 (17%)	4 (5%)	0.01
Dialysis	7 (4%)	5 (6%)	2 (2.5%)	0.25
Hospitalizations for heart failure/patient	0.33 (0.62)	0.42 (0.7)	0.24 (0.51)	0.06
Hospitalizations for renal failure/patient	0.04 (0.21)	0.02 (0.16)	0.06 (0.25)	0.25
Hospitalizations for OR/patient	0.42 (0.75)	0.36 (0.66)	0.48 (0.83)	0.34
All-cause hospitalizations/patient	0.81 (0.95)	0.82 (0.93)	0.80 (0.97)	0.93
Total days lost (HF, RF, death, dialysis)/patient	21.6 (48.4)	30.2 (56.0)	13.1 (37.6)	0.02
Days lost to death/patient	11.4 (36.8)	16.3 (43.1)	6.5 (28.6)	0.09
Days lost to dialysis/patient	6.1 (29.4)	9.1 (36.6)	3.1 (19.6)	0.20
Days lost to HF hospitalizations/patient	3.6 (8.2)	4.6 (9.3)	2.5 (6.7)	0.10
Days lost to RF hospitalizations/patient	0.6 (3.9)	0.1 (1.2)	1.0 (5.4)	0.17
Days lost to hospitalizations for OR/patient	3.3 (9.1)	3.2 (7.9)	3.4 (10.2)	0.89
Days lost to all-cause hospitalizations/patient	7.5 (12.8)	8.0 (12.8)	7.1 (13.0)	0.65

Data are presented as mean (SD).
HF, heart failure; OR, other reasons; RF, renal failure.

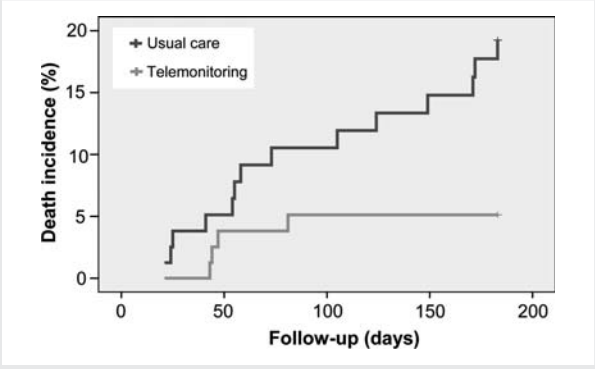

Figure 1 Kaplan–Meier curve: death from all causes ($P = 0.014$).

Subanalysis for left ventricular ejection fraction and N-terminal pro brain natriuretic peptide

An exploratory subanalysis of LVEF and NT-proBNP was done, showing no significant difference in outcome between the different subgroups. A non-significant trend to reduced all-cause mortality ($P = 0.054$) was found only in the subgroup with the lowest LVEF (<30%).

Discussion

The main findings of this study are that an ambulatory post-discharge follow-up of CHF patients through an intense collaboration between the heart failure clinic and the GP, which is facilitated by automatic transmission of body weight, blood pressure, and heart rate, significantly reduced all cause-mortality. In addition, the number of days lost to death, dialysis, or hospitalization for heart or renal failure was significantly reduced.

Several studies have shown that counselling and education of patients and spouses, promotion of patient compliance, daily weight measurements, and easy access to a specialized heart failure nurse can reduce mortality and rehospitalization rate and increase quality of life in severe heart failure.[3–5] Promotion of self-care is seen as a way to mitigate the rising costs of CHF.[3] In most European countries, different systems of (mostly hospital-based) heart failure clinics have arisen.[4] Importantly, only one-third of the heart failure management programmes in Europe include an involvement of GPs, and only in the UK is a GP involved systematically. Several potential reasons can be identified for this: a lack of time or specific knowledge or interest from the GP in heart failure, logistic problems in communication about ambulatory patients, and/or reimbursement issues.

One of the features of the ambulatory follow-up in this study is the use of modern communication technology to facilitate the work of the GP. The GP's attention was focused only on those patients with suspicious changes in body weight, blood pressure, and/or heart rate. The additional feature of having this information sent to the heart failure clinic, which also followed up on the effects of the intervention by the GP, was highly appreciated by representatives of the participating GPs, as it allowed them to change medication more confidently, as a back-up by the heart failure specialist was available. In addition, this feature enabled the establishment of a collaboration between the GP and the heart failure clinic without loss of valuable time: suggestions from the heart failure clinic could be posted in the patient's file on the website, and questions could be asked without interrupting daily clinical activities.

A number of studies have previously assessed the benefits of telemonitoring embedded in a heart failure clinic. A recent Cochrane meta-analysis of these studies[6] showed that all-cause mortality was significantly reduced. In contrast, the recently

Table 5 Study outcome: hospitalization costs (in Euros)

	Total study population	Usual care	Telemonitoring	*P*-value
Cost of HF hospitalizations/patient	1065 (2839)	1382 (3384)	747 (2137)	0.16
Cost of RF hospitalizations/patient	114 (747)	76 (670)	154 (820)	0.50
HF + RF hospitalization cost/patient	1180 (2909)	1458 (3420)	902 (2277)	0.23
Cost of hospitalizations for OR/patient	1420 (3345)	1185 (2886)	1656 (3752)	0.37
Total hospitalization cost/patient	2600 (4363)	2643 (4642)	2557 (4094)	0.90

Data are presented as mean (SD).
HF, heart failure; OR, other reasons; RF, renal failure.

published large Tele-HF[7] and TIM-HF studies[8] showed that telemonitoring did not affect mortality or rehospitalization rate in CHF. The HHH study[9] using a weekly transmission of vital signs showed a reduction in events only in the Italian arm of the study. A number of observations may explain the discrepancy with our results.

In the Tele-HF study, 42.7% of the patients were New York Heart Association (NYHA) class I or II, whereas the severity of heart failure in our study was higher. However, NYHA class III–IV patients in the TM group fared worse for all-cause readmission or death with a statistically significant interaction effect, and the mortality in both studies at 6 months was equal. In the HHH study, > 50% of patients were NYHA I or II on inclusion.

In the Tele-HF study, using a voice-interactive system rather than telemonitoring, compliance with the intervention was poor: at the end of the study follow-up, only about half of the patients were sending their recordings at least three times per week (while daily measurement was asked for in the protocol). Fourteen per cent of patients never used the system, and a further 10% were non-compliant by the end of the first week.[10] In comparison, in our study the fraction of daily measurements transmitted correctly was 83%. The mode of transmission of data is probably one of the main reasons for the difference in adherence between studies: in Tele-HF, patients were asked to send their values manually, whereas in our study (and the TIM-HF study), measurements were transferred automatically.

Also, only body weight was monitored in Tele-HF, while we included heart rate and blood pressure (as in the TIM-HF and HHH studies). This allowed the detection of episodes of arrhythmias and/or hypotension which might precipitate hospitalization or death, and hypertension could be treated more aggressively. The use of only one parameter with a fixed alert level is probably insufficient to detect future problems:[11] the combination of several parameters and several alert levels increasing the urgency of intervention is probably a better approach. In our study, the combination of heart rate, blood pressure, and body weight change helped the treating physician to decide on the optimal treatment adaptations.

The median patient age was 61 years in the Tele-HF study, 60 years in HHH, and 67 years in TIM-HF, compared with 76 years in our study. In the Tele-HF, there was no statistically significant interaction effect for age, but the trend favoured telemonitoring in patients >65 years of age. As suggested by Conraads *et al.*,[12] elderly patients are at risk of developing increases in body weight and congestive symptoms without contacting a healthcare provider.

The TIM-HF included stable heart failure patients, with a rather low mortality (8%/year) compared with Tele-HF and our study population (11%/6 months). Some subgroups of the TIM-HF study[10] may have had a positive effect of telemonitoring, mainly patients with a prior heart failure hospitalization (as in the case of all our patients), an EF >25%, and being non-depressed. Our study population consisted of very sick elderly patients, who all had been hospitalized before for heart failure, who were unable to be included in cardiac rehabilitation, and who retained a very high NT-proBNP on discharge, suggesting a very high risk group for mortality and rehospitalization. The small number of patients treated with cardiac resynchronization therapy (CRT) and/or an implantable cardioverter defibrillator (ICD) is partly explained by the population (elderly patients with low functional class), but also by reimbursement issues in Belgium at the time of the study.

Finally, as outlined previously,[13–15] the organization of the medical response to telemonitored alerts is more important for the effectiveness of the telemonitoring than the sophistication of the devices themselves. For example, as shown in a recent meta-analysis,[2] a somewhat 'primitive' regular telephone contact between a heart failure nurse and a CHF patient may result in a favourable outcome. In the TIM-HF, the alerts were monitored by a physician-led team who had no personal knowledge of the patient, whereas the primary physician remained responsible for the general care of the patient. A communication between them was foreseen at least every 3 months. In our study, all alerts were seen by the primary physician and the heart failure team, with the former being responsible for seeing and treating the patient, while the latter supervised the results of the treatment, and gave advice when needed. The positive results of our study may be explained by the frequent treatment adaptations triggered by alerts, as shown by the significant difference in heart failure medication use in the TM group.

The co-ordination of care by the GP and the heart failure clinic, facilitated by an automatic transfer of clinical parameters, linked with a communication tool between care providers may be considered a 'fourth generation telemedical remote management system', as defined by Anker *et al.*[16]

The role of the patient in responding to changes was stressed by Cleland[11] and Desai[13] in an editorial accompanying the Sense and Tele-HF trials, respectively. Both editorialists refer to the role of

telemonitoring in educating patients towards self-care and self-monitoring, with the possibility of adaptation of treatment by the patient based on measurements, as is done by insulin-dependent diabetics all over the world. The educational value of the monitoring system with feedback to the patient from the primary physician and heart failure clinic may also have contributed to the results of our trial. Few patients in our study remained completely free of any alert, so most experienced a change in medication by their care providers in response to a possible threat of decompensation. By giving the patient part of the responsibility for self-management, the telemonitoring system could evolve from a crisis detection to a health maintenance system. As proposed by Cleland *et al.*[17] 'engaging the largest healthcare workforce in the world', namely the patient, in the treatment of his disease could reduce the stress on healthcare budgets in the years to come.

Are body weight, heart rate, and blood pressure the best clinical parameters for telemonitoring and prediction of clinical deterioration in CHF? This certainly is controversial. Even though international guidelines[5] recommend daily measurement of body weight, and adaptation of treatment in the case of significant changes, this is not uniformly supported. Body weight does not seem to correlate well with symptoms of dyspnoea,[18] and increases in body weight were not associated with rehospitalization in several studies.[19–21] In the Chronicle trial, intracardiac pressures were shown to be high in a significant proportion of 'stable' CHF patients, and to predict rehospitalization even though patients were treated according to changes in body weight.[22] On the other hand, Chaudry *et al.*[23] showed in a large case–control study that body weight begins to rise several weeks before admission, and that an increase of 2 kg of body weight resulted in an almost three-fold increase in risk of readmission. The recent scientific statement on assessment of congestion[24] points to the relative importance of rapid changes in weight as a marker of threatening decompensation, concluding that 'an acute change in body weight is a reasonable marker of fluid balance'. This same statement also pointed to the use of blood pressure reaction to standing in the determination of the fluid status of the patient. In a subanalysis of a telemonitoring study by Zhang,[25] the authors showed that a weight gain of $>$ 2 kg in $<$ 3 days does not accurately predict acute heart failure. Slowly accumulating fluid[23] and thus weight is probably more useful to predict decompensation, even though it is known that volume redistribution without a clear increase can contribute to hospitalization in heart failure.

In our study, we used a 2 kg absolute rise in body weight as a trigger of alerts, which would relate to an increase of rehospitalization risk of at least 2,[23] but potentially more effective algorithms have been proposed.[25] The underlying heart disease may also play a role in the accuracy of weight changes to predict decompensation. Again using intracardiac pressures with an implanted device, Zile *et al.*[26] could show that diastolic pressures rise more rapidly during decompensation episodes in diastolic heart failure than in systolic heart failure.

As proposed in the European guidelines on CHF,[5] the follow-up of severe CHF requires the optimization of pharmacological treatment and support for self-care behaviour. A daily monitoring of body weight, blood pressure, and heart rate allows the early detection of problems such as atrial fibrillation or hyper- or hypotension. It also helps to educate patients (and some GPs) on the importance of measuring some parameters and taking their medication. Anecdotal evidence in a few patients in our experience showed that highly uncompliant patients requiring repeated rehospitalization could be put on the right track by the co-ordinated effort of a heart failure nurse and GP, assisted by the monitoring system. Also the increases in dosages of ACE inhibitors and beta-blockers after discharge was made easy for the GP as he/she had access to the daily measurements of heart rate and blood pressure.

As more and more ICD and CRT devices are used to treat severe heart failure,[27] their built-in capacity for transmission of measured data[28] will necessitate much further study to find the protocol to put this information to optimal use for the patient.[29]

In a time of rising costs for healthcare, the question of cost-effectiveness of a monitoring system should be posed. A cost comparison between telemonitoring and usual care was published by Seto *et al.*[30] All published studies included in this review found cost reductions ranging from 1.6 to 68.3%, mainly attributed to a reduction in heart failure hospitalizations. In our study, only a preliminary cost analysis could be made based on hospital bills. A non-significant reduction in cost should be balanced against the increased cost of the equipment and the more frequent evaluations by GP and heart failure nurses, and with the decrease in mortality (which would tend to increase later healthcare cost). A more in-depth analysis of the total cost to society is planned whenever the data become available.

This exploratory study is limited by a small sample size, which increases the risk of finding false-positive results. The data on time investment by the heart failure team and primary physician are only partly available, which precludes correct determination of differences from other studies. The investigators decided not to use standard treatment schemes in cases of alerts (apart from asking for the existing European guidelines to be followed), and gave responsibility to the treating physician. This obviously may have led to differences in approach in the different centres.

In conclusion, our study showed that an intense collaboration between a GP and a heart failure clinic, facilitated by telemonitoring and automatic transfer of clinical parameters (body weight, blood pressure, and heart rate), significantly reduces mortality and tends to reduce hospitalizations for CHF. As this was a small study, confirmation in larger trials is required.

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