


Remote management of worsening heart failure to avoid hospitalization in a real-world setting

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Abstract

Aims From a patient and health system perspective, managing worsening heart failure (WHF) as an outpatient has become a priority. Remote management allows early detection of WHF, enabling timely intervention with the aim of preventing hospitalization. The objective of the study was to evaluate the feasibility and safety of remotely managing WHF events using a multiparametric platform.

Methods and results All patients enrolled in the heart failure remote management programme of the Bordeaux University Hospital Telemedicine Center between 1 January and 31 December 2021 were included in the study. Follow-up data were collected until 1 March 2022. Inclusion criteria were chronic heart failure (HF) with New York Heart Association \geq II symptoms and an elevated B-type natriuretic peptide (BNP > 100 pg/mL or N-terminal-pro-BNP > 1000 pg/mL). Patient assessments were performed remotely and included measurements of body weight, blood pressure, heart rate, symptoms, biochemical parameters, and data from cardiac implantable electronic devices when available. In total, 161 patients (71 \pm 11 years old, 79% male) were followed for a mean of 291 \pm 66 days with a mean adherence to the remote monitoring system of 80 \pm 20%. Over this period, 52 (32.3%) patients had 105 WHF events, of which 66 (63%) were successfully managed remotely, the remaining requiring hospitalization. Freedom from WHF events and hospitalization at 300 days were 66% and 85%, respectively ($P < 0.001$ for the difference). Increased level of BNP was associated with an increased risk of WHF event [hazard ratio (HR) per unit increase in BNP: 1.001; 95% confidence interval (CI) 1–1.002; $P = 0.001$] and hospitalization (HR 1.002; 95% CI 1.002–1.003; $P = 0.002$). A decrease in the level of glomerular filtration rate was associated with an increased risk of hospitalization (HR per unit decrease in estimated glomerular filtration rate: 0.946; 95% CI 0.906–0.989; $P = 0.014$). WHF event recurrence and (re)hospitalization rates at 1-month were similar among patients managed remotely (18% and 12%, respectively) and those requiring hospitalization (21% and 10%, respectively). Iatrogenic complications occurred more often during hospitalization than remote management (26% vs. 3%, $P < 0.001$).

Conclusions Our study suggests that remote management of WHF events based on a multiparametric approach led by a telemedical centre is feasible and safe. Adopting such a strategy for patients with chronic HF could reduce HF-related hospitalizations with expected benefits for patients, care providers, and health care systems.

Keywords Congestion; Heart failure; Hospitalization; Remote management; Remote monitoring; Telemedicine

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Introduction

Chronic heart failure (HF) is a complex syndrome that affects over 63 million people worldwide.¹ The typical course of chronic HF is characterized by periods of clinical stability punctuated by episodes of worsening symptoms that require escalation of therapy, often in a hospital setting. The number and duration of HF hospitalizations are independently associated with an increased risk of death and worsened quality of life.^{2–5} Given the substantial personal and public health as well as financial burdens posed by this condition, avoiding HF hospitalizations is an important goal not only for patients but also for clinicians and health care systems.⁶ Developing safe and effective outpatient WHF management strategies as alternatives to hospitalization, even if feasible for a subset of patients, is therefore increasingly a priority.⁷ Most patients with WHF have a relatively gradual progression of symptoms, providing a window during which successful outpatient intervention may reverse their clinical deterioration and prevent hospitalization. Furthermore, in many instances, inpatient management of WHF consists primarily of escalating patients' diuretic regimens in order to curb the congestion process.⁸ These observations support the hypothesis that a proportion of patients with WHF could be safely and effectively managed remotely. Koehler *et al.* developed a concept of HF remote management with proven benefit on mortality based on monitoring of multiple parameters and symptoms, but also uptitration of drugs, patient education, and management of co-morbidities.⁹ Inspired by this strategy, we have developed a multiparametric remote management platform used by our dedicated telemedical centre aiming to prevent unplanned HF hospitalizations. We sought to evaluate the feasibility and safety of this remote management platform for WHF events.

Methods

All patients enrolled in the HF remote monitoring programme of the Bordeaux University Hospital Telemedicine Center between 1 January and 31 December 2021 were included in the study. Follow-up data were collected up to 1 March 2022 for analysis. All patients had chronic HF with New York Heart Association \geq II symptoms and elevated B-type natriuretic peptide (BNP > 100 pg/mL or N-terminal-pro-BNP > 1000 pg/mL) as per the inclusion criteria used in the French HF remote monitoring programme (ETAPES). The study complies with the Declaration of Helsinki, the locally ethics committee has approved the research protocol, and all patients provided informed consent for study participation.

Multiparametric remote management

Remote management was performed via a multiparametric approach using the CareLine platform (CareLine Solutions™,

Merignac, France), which collected data on various clinical parameters (weight, systolic and diastolic blood pressure measurements, heart rate, and in certain cases peripheral capillary oxygen saturation values), symptom status (using a health status questionnaire), pacemaker/implantable cardioverter-defibrillator data (Medtronic™, Dublin, Ireland), and blood test results (BNP/NT-pro-BNP, creatinine, urea, potassium, sodium, haemoglobin, and ferritin). Patients were provided with a scale to track their body weight (iHealth Lina™, Paris, France) and a blood pressure/heart rate measuring device (iHealth Track™) with automatic wireless transmission to an app (CareLine Solutions™) either installed on their own smartphone or on a dedicated smartphone. Clinical parameters were collected daily, symptoms were assessed weekly, and blood tests results were evaluated on an as needed basis. Alert-triggered transmissions from pacemakers/implantable cardioverter-defibrillators were automatically imported as were the results of routine remote device interrogations every 2–4 weeks. In total, 17 clinical, 15 blood tests, and 21 device-related parameters could be incorporated into individual customizable alerts.

Alerts were reviewed during office hours (weekdays between 8:00 AM and 5:00 PM) by specialized nurses and physicians of the Bordeaux University Hospital Telemedical Centre. These alerts, along with trends in relevant parameters, were used to remotely monitor patients' HF status and to evaluate their response to medical interventions. Patient education and lifestyle advice were systematically provided and emphasized during telephone interactions by the treating team. WHF events (see below), changes in medical therapy, and hospitalizations were prospectively recorded on the remote management platform.

Outcomes

All WHF episodes were retrospectively reviewed and confirmed according to the most recent consensus definition and classification of HF.¹⁰ A WHF episode was considered resolved when relevant signs and symptoms resolved following intervention. Two WHF episodes observed <10 days apart were considered as a single unresolved event. The remote management platform and hospital electronic health records were screened for HF hospitalizations. Interruptions in communications with the platform also prompted investigations for possible HF hospitalization.

Statistics

Categorical variables are expressed as absolute numbers (percentages); continuous variables are expressed as mean \pm standard deviation. Continuous data were compared with the two-sample *t*-test or the Mann–Whitney–Wilcoxon

rank sum test if non-normally distributed. We compared categorical data, with the exact Pearson's χ^2 test or the Fisher's exact test. Adherence with remote monitoring was calculated as the percentage of days with transmitted body weight data divided by all effective surveillance days (length of follow-up minus the duration of hospitalizations). Survival analyses were done on a time-to-first event basis. Cumulative incidence curves for unplanned HF hospitalization and WHF were constructed according to the Kaplan–Meier method, and differences between curves were examined using log-rank tests. Time to an event (first WHF event or first hospitalization) was analysed with the use of Cox proportional-hazards models. Schoenfeld residuals were used in order to assess proportional hazards assumption, and martingale residuals were employed to assess linearity assumption for continuous variables. Statistical significance was defined by $P < 0.05$. Statistical analyses were performed using SPSS software, version 18.0 (SPSS Inc., Chicago, Illinois, USA).

Results

Patient characteristics

In total, 161 patients were included. Patient characteristics are summarized in *Table 1*. The mean follow-up period was 291 ± 66 days. The mean adherence to the remote monitoring system was $80 \pm 20\%$.

Outcomes

Over the study period, 52 patients (32.3%) had 105 WHF events (*Figure 1*). Comparisons of baseline characteristics between patients who have experienced at least one WHF event and patients free from WHF event are available in *Table 2*. Freedom from WHF event at 90 and 300 days were 81% and 66%, respectively. Increased level of BNP was associated with an increased risk of WHF event (*Figure 2*, left panel).

Remote management

Remote management of WHF events was attempted in 73 of 105 cases (69.5%), of which 7 (9.6%) ultimately required hospitalization. Worsening of HF was remotely detected in 65 cases (89%) through body weight increase in 38 cases (58%), a symptom changes in 34 cases (54%), an increased level of natriuretic peptide in 26 cases (40%), a cardiac implantable electronic device alert in 2 cases (3%), and an increase in heart rate in 1 case (2%). The most frequent symptoms disclosed were dyspnoea on exertion (76%), fatigue (62%), worsening of peripheral oedema (53%), and dyspnoea

Table 1 Baseline patient characteristics

Characteristic (N = 161)	
Male sex, n (%)	127 (79)
Age, year	71 ± 11
≥80 years, n (%)	39 (24)
NYHA classification, n (%)	
NYHA II	107 (66)
NYHA III	45 (28)
NYHA IV	9 (6)
HF aetiology, n (%)	
Ischaemic	64 (40)
Dilated cardiomyopathy	61 (38)
Valvular	11 (7)
Tachyarrhythmia	19 (12)
Congenital	8 (5)
Other	15 (9)
Co-morbidities, n (%)	
Atrial fibrillation	105 (65)
Hypertension	61 (38)
Diabetes mellitus	51 (32)
eGFR, mL/min/1.73 m ²	52 ± 23
BNP, pg/mL	605 ± 526
NT-proBNP, pg/mL	3055 ± 4129
LVEF, %	35 ± 11
≤35%, n (%)	102 (63)
Treatments, n (%)	
ACEi/ARB/sacubitril-valsartan	138 (86)
Beta-blockers	146 (91)
Aldosterone antagonists	98 (61)
SGLT2 inhibitors	22 (14)
Furosemide	125 (78)
Furosemide, mg	150 ± 156
Cardiac implantable electronic devices, n (%)	
Implantable cardioverter-defibrillator	89 (55)
Permanent pacemaker	38 (24)
Cardiac resynchronization therapy (CRT)	77 (48)
CRT-D	57 (35)
CRT-P	21 (13)

Patients can have mixed aetiologies.

ACEi, angiotensin-converting enzyme; ARB, angiotensin II receptor blocker; BNP, B-type natriuretic peptide; eGFR, estimated glomerular filtration rate; HF, heart failure; LVEF, left ventricular ejection fraction; NT-proBNP, N terminal pro brain natriuretic peptide; NYHA, New York Heart Association; SGLT, sodium–glucose cotransporter 2 inhibitors.

at rest (26%). Eight WHF episodes were diagnosed during in person evaluation by a physician.

At least one blood test was ordered as part of 61 attempted remote management cases (84%): in 22 cases (30%) to confirm the diagnosis (22 samples) and in 53 cases (73%) to assess treatment efficacy/tolerance (75 samples). Furosemide (40 mg) was introduced in 8 cases (11%) and increased in 52 cases (71%), with a mean absolute increase of 86 ± 60 mg corresponding to a mean relative increase of $96 \pm 54\%$. Iterative increases of dose (up to 4) was necessary in 15 (21%) cases. Hydrochlorothiazide was introduced or increased in 12 cases (16%). At home intravenous (IV) furosemide administration was performed in 4 cases (5%), with a mean dose of 100 ± 10 mg. Another medication (mostly potassium chloride) was prescribed in 19 cases (26%). Over the study follow-up, 121 medication changes were performed. Overall, WHF events were successfully managed remotely in 66 cases (62.9%) (*Figure 3*).

Figure 1 Study profile. During the 15 months' follow-up, 105 WHF events occurred in 52 patients. Thirty of them had exclusively remote management of their WHF events. Thirteen had exclusively hospital management of their WHF events. *Nine patients had both remote and hospital management of their WHF events.

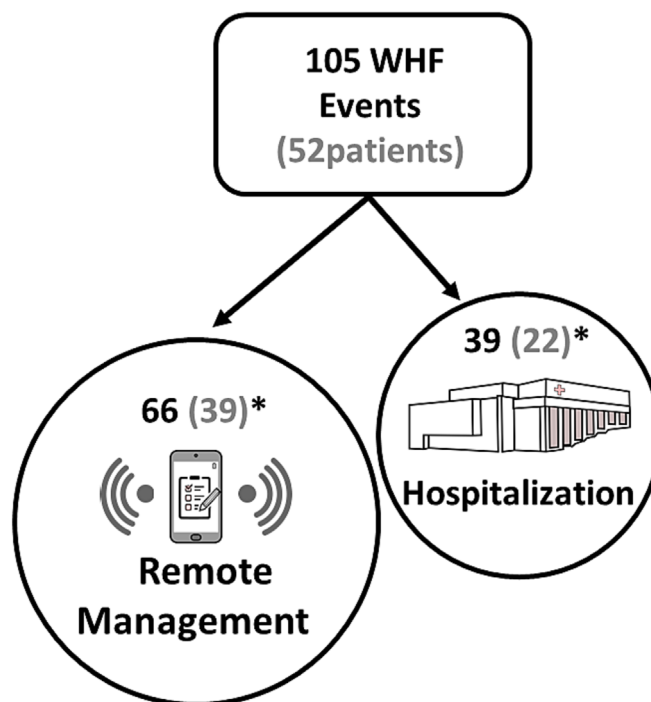


Table 2 Patient characteristics: WHF experience versus no WHF

Characteristic (N = 161)	WHF (52)	No WHF (109)	P
Male sex, n (%)	44 (85)	83 (76)	0.3
Age, years	72 ± 11	71 ± 11	0.4
NYHA classification, n (%)			
NYHA II	25 (48)	82 (75)	<0.001
NYHA III	19 (37)	26 (24)	
NYHA IV	8 (15)	1 (1)	
Ischaemic aetiology, n (%)	22 (42)	42 (39)	0.7
Co-morbidities, n (%)			
Atrial fibrillation	37 (71)	68 (62)	0.3
Hypertension	24 (46)	37 (34)	0.16
Diabetes mellitus	18 (35)	33 (30)	0.6
eGFR, mL/min/1.73 m ²	45 ± 21	56 ± 23	<0.01
BNP, pg/mL	896 ± 651	447 ± 362	0.001
NT-proBNP, pg/mL	4506 ± 5994	2273 ± 2401	<0.01
LVEF, %	35 ± 11	35 ± 11	0.9
Furosemide, mg	173 ± 203	138 ± 124	0.6
Cardiac resynchronization therapy	25 (48)	52 (48)	1

WHF are patients having experienced at least one WHF episode. No WHF are patients without any WHF episode during the follow-up study.

BNP, B-type natriuretic peptide; eGFR, estimated glomerular filtration rate; LVEF, left ventricular ejection fraction; NT-proBNP, N terminal pro brain natriuretic peptide; NYHA, New York Heart Association.

Hospital management

For the remaining 32 of 105 WHF events (30.5%), remote management was not attempted, and patients were directly hospitalized. Including the 7 patients in whom remote management attempts failed, WHF required hospitalization in 39

of 105 patients (37.1%). In half of the cases (19; 49%), the telemedical centre prompted the hospital admission, motivated by the need of IV diuretics (9 cases), renal failure (5 cases), or other reason (ascites puncture, levosimendan infusion ...). A quarter of the episodes required hospitalization in the context of acute WHF. The rest of the hospitalizations

Figure 2 Time to first worsening heart failure (WHF) event (red) and first unplanned HF hospitalization (blue) during the 15-month study period. Freedom from WHF event at 90 and 300 days were 81% and 66%, respectively. Freedom from HF hospitalization at 90 and 300 days were 92% and 85%, respectively ($P < 0.001$ for the comparison between survival curves). Hazard ratios were calculated by means of the Cox model. BNP and NT-proBNP could not be integrated in the same model (because of multicollinearity) but gave similar significant results when substituted to each other.

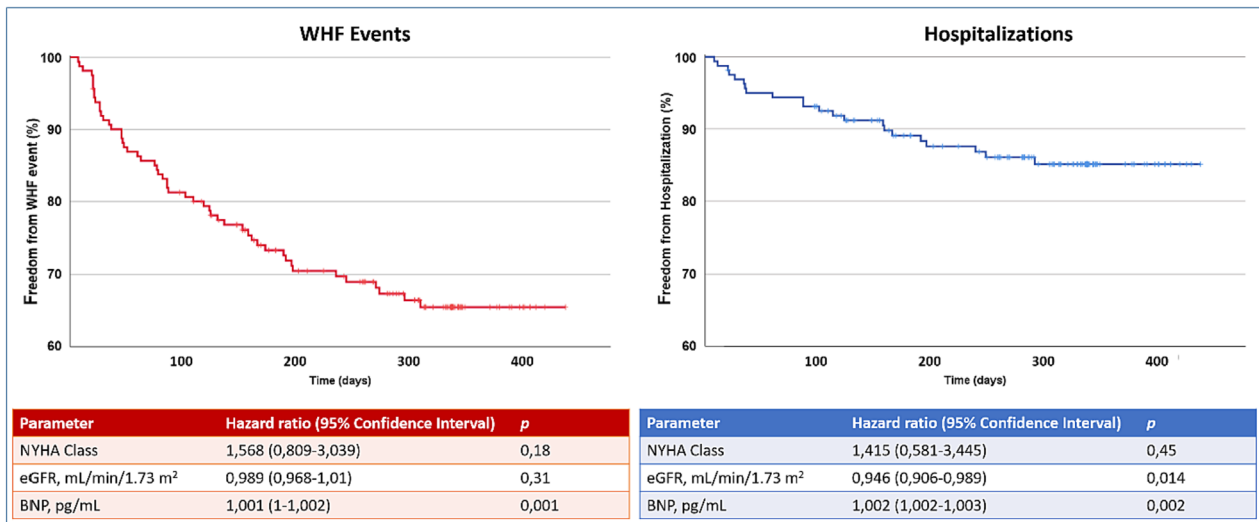
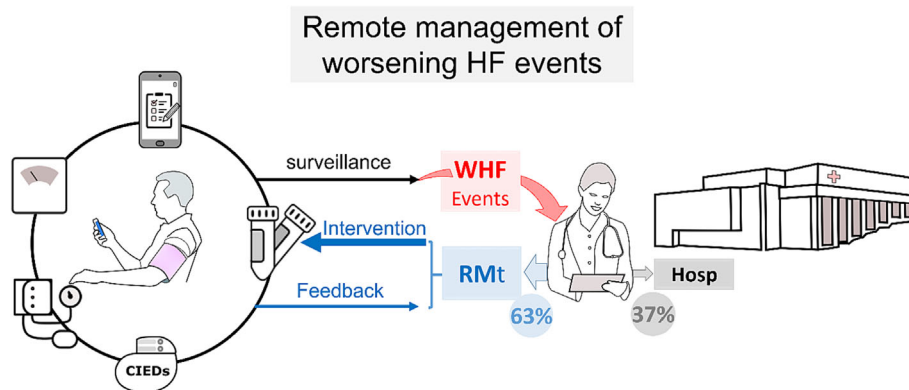


Figure 3 Remote management of heart failure. Remote management (RMt) favours outpatient intervention for worsening heart failure (WHF) events over hospitalization (Hosp). The multiparametric approach allows the medical staff to detect WHF at an early stage (surveillance) and to assess the effectiveness and tolerance of interventions (feedback). CIED, cardiac implantable electronic device.



were prompted by another physician (external to the telemedical centre). The characteristics of the patients who have been hospitalized at least once are available in the *Table 3*. Hospital admission via the emergency department was required in 21 cases, representing 20% of all WHF events during the study and 54% of cases requiring hospitalization. The mean duration of hospitalization was 11 ± 6 days. Overall, freedom from HF hospitalization at 90 and 300 days was 92% and 85%, respectively, which were significantly higher than freedom from WHF at the same time points ($P < 0.001$). Increase in the level of BNP and decrease in the level of glomerular filtration rate were associated with an increased risk of hospitalization (*Figure 2*, right panel).

Safety

Thirteen patients died during the study (two from COVID-19 infection), of whom six had at least one WHF event. No one died within the month following a WHF event that was remotely managed. No patient died during the hospitalization after a failed attempt of remote management.

Remote management of WHF events was associated with a 1-month recurrence rate of WHF of 18% and a 1-month hospitalization rate of 12%. Half of the episodes managed remotely (33/66) were followed by a recurrence of WHF with a mean time of 65 ± 78 days. Thirteen (20%) of the WHF episodes managed remotely were followed by a

Table 3 Patient characteristics: At least one hospitalization versus exclusive remote management of WHF events

Characteristic (<i>N</i> = 52)	HSP (22)	Remote (30)	<i>P</i>
Male sex, <i>n</i> (%)	20 (91)	24 (80)	0.4
Age, years	71 ± 11	73 ± 11	0.9
NYHA classification, <i>n</i> (%)			
NYHA II	10 (46)	15 (50)	0.1
NYHA III	6 (27)	13 (43)	
NYHA IV	6 (27)	2 (7)	
Ischaemic aetiology, <i>n</i> (%)	11 (50)	11 (37)	0.4
Co-morbidities, <i>n</i> (%)			
Atrial fibrillation	14 (64)	23 (77)	0.4
Hypertension	13 (59)	11 (37)	0.16
Diabetes mellitus	8 (36)	10 (33)	1
eGFR, mL/min/1.73 m ²	36 ± 20	51 ± 20	0.01
BNP, pg/mL	1130 ± 764	696 ± 478	0.09
NT-proBNP, pg/mL	8404 ± 9537	2558 ± 1011	0.03
LVEF, %	33 ± 10	37 ± 13	0.3
Furosemide, mg	204 ± 197	152 ± 208	0.17
Cardiac resynchronization therapy	12 (55)	13 (43)	0.57

Remote are patients with exclusive remote management of their WHF episode. HSP are patients hospitalized at least once for the management of a WHF episode.

BNP, B-type natriuretic peptide; eGFR, estimated glomerular filtration rate; LVEF, left ventricular ejection fraction; NT-proBNP, N terminal pro brain natriuretic peptide; NYHA, New York Heart Association.

hospitalization with a mean time of 30 ± 14 days. An iatrogenic complication occurred in 2 of 73 (3%) remotely managed cases (Table S1).

In-hospital management was associated with a 1-month recurrence rate of WHF of 21% and a 1-month re-hospitalization rate of 10%. Half of the episodes requiring hospitalization (20/39) were followed by a recurrence of WHF with a mean time of 41 ± 36 days (*P* = 0.25 vs. remote management). Seventeen (44%) of the WHF episodes managed in hospital were followed by a rehospitalization (*P* = 0.01 vs. remote management) with a mean time of 59 ± 40 days (*P* < 0.01 vs. remote management). Hospitalized patients received an IV diuretic in 95% of cases and another IV drug in 21%. In 67% of hospitalized cases, inpatient management consisted solely of IV diuresis. An invasive diagnostic or therapeutic procedure was performed in an additional 15%. At least one iatrogenic complication occurred during 10 of 39 hospitalizations (26%) (Table S1, *P* < 0.001 when compared with remote management).

Discussion

Our results demonstrate that remote management of WHF events is feasible and viable in a post-COVID real-world setting. Previous attempts to improve the care of patients with HF through the use of digital health solutions have been numerous and markedly heterogeneous in the methods employed and their results.¹¹ The TIMHF-2 randomized trial highlighted that the effectiveness of remote HF management relies on multiparametric surveillance performed by a structured telemedical centre.⁹ We have similarly previously reported on the benefits of such an approach in the context

of the first French COVID-19 'lockdown', during a time of unprecedented constraints on hospitalizations.¹² In the present study, most WHF events (62.9%) could be successfully managed remotely. We observed low 90- and 300-day hospitalization rates (8% and 15%, respectively). Notably, WHF event recurrence, (re)hospitalization, and mortality at 1 month did not differ between patients managed remotely and as inpatient, suggesting that the former approach does not pose a meaningfully higher risk.

The concept of remote management

Our remote management strategy relies on the principle that daily surveillance of multiple parameters allows for early detection of WHF that can prompt timely and proactive interventions, the response to which can be readily evaluated and can in turn prompt further adjustments (Figure 3). The ability to intervene early at the onset of WHF events is central to its design as relatively minor interventions at that stage may prevent the 'downward spiral' of HF decompensation that becomes increasingly difficult to halt and often results in hospitalization.

Chronic HF is not a single pathological entity but rather a clinical syndrome of various signs and symptoms related to various structural and functional abnormalities of the heart and other organs. WHF events are the most common complication of chronic HF but can be difficult to detect at their early stages due to their often insidious onset and highly variable clinical presentation depending on where along the spectra of congestion and hypoperfusion a patient finds themselves at a given time. Therefore, HF surveillance cannot rely solely on the monitoring of weight.¹³ A multiparametric

approach is more likely to detect an evolving WHF event and better assess the response to interventions.

Whereas remote monitoring of HF is a general concept focused mainly on the early detection of WHF events, remote management is a more comprehensive approach that encompasses prevention, detection, and remote care. This is a critical difference, because remote care has the potential to decrease hospitalization. Remote monitoring generally relies on in-hospital evaluation and care, whereas remote management is designed to be performed on an outpatient basis. Remote management requires the involvement of a dedicated telemedicine staff in charge of both evaluating alerts and intervening. This includes telephone support, organizing tests, and adjusting medications (most often titrating loop diuretics). Remote interventions must then be closely evaluated for effectiveness and potential adverse effects (e.g., via assessment of blood pressure and measures of kaliemia and renal function) using the multiparametric platform in a closed-loop manner (Figure 2).

Importance of reducing heart failure hospitalizations

Reducing HF hospitalizations expectedly primarily benefits patients as the number of HF hospitalizations has been shown to be a strong predictor of mortality after adjusting for age, sex, and major co-morbidities.^{2–4} During hospitalizations, patients often experience disturbed sleep, dietary changes, pain, mental stress, and can rapidly decondition—each of which can adversely affect their prognosis.¹⁴ Consistent with this risk, we observed that iatrogenic complications occurred in 26% of HF hospitalizations. Even when aware of their deteriorating health, many patients report that they avoid seeking care because of previous unpleasant hospital experiences.¹⁵ In contrast, home-based management has been shown to improve patients' psychological well-being (i.e., anxiety and depression).¹⁶ Although the risks associated with introducing or intensifying medications that can affect cognitive and physical functioning would be expected to be present when undertaken both on outpatient and inpatient bases, it is likely that the interventions required early in WHF process are less aggressive and if implemented in a timely fashion can avoid the above in-hospital risks.

In addition to the patient-level implications, HF is the leading cause of hospitalization among individuals aged ≥ 65 years and constitutes a substantial economic burden on health care systems.^{17,18} HF hospitalization costs account for 65% of all medical HF costs, which explains why hospitalization is among the most often reported outcomes in relevant trials and the common driver in HF cost-effectiveness models.⁶ Recently, France and Germany, both of whom spend both over a billion euros each year in HF hospitalizations, have implemented remote monitoring strategies for HF patients with a dedicated reimbursement.¹⁹ Remote HF management has

been shown to reduce the number of days lost due to unplanned cardiovascular hospitalizations and all-cause mortality in the setting of a randomized controlled trial with continuous monitoring and assistance (24 h a day, 7 days a week).⁹ We show that this concept is applicable in a real-world setting with a telemedical centre working during standard work hours—a factor that renders this approach more generalizable and may further improve cost-effectiveness.²⁰

Lastly, reducing HF hospitalizations is expected to yield benefits for care providers who often turn to the inpatient option for WHF episodes due to limited resources and ability to intervene safely and effectively on an outpatient basis. Sharing patient care with a dedicated telemedical team could improve care providers' workloads, quality of care, and patient safety.²¹

There is growing awareness of the potential benefit of outpatient approaches for treating WHF. In the context of WHF with congestion, outpatient intravenous diuretic treatment has been proposed as an alternative to conventional hospitalization.²² A panel of HF experts recently promoted such strategy based on day hospital and/or at-home hospitalization.²³ We see this approach as complementary to remote management. In fact, continuous monitoring allows WHF detection at a very early stage and remote management based on increase in oral diuretic doses. In case of refractory symptoms, the most severe patients require IV diuretics, which could ideally be delivered at home or during sequential day hospital sessions with continuous weight, vital signs, and renal function monitoring in between.

Limitations

There are important limitations to the current study. No standardized protocol was set to guide interventions in response to the various customized alerts. Instead, interventions were tailored to individual patient characteristics and based on clinical judgement. However, this is not dissimilar to how WHF events are managed as inpatients. Due to our observational study design, we are unable to assess the effect of our strategy on the occurrence of WHF events. In our study, 44% of patients had WHF events by 300 days. This is similar to the 300-day WHF event rate in the control group of the GUIDE-HF trial, which was approximately 40%.²⁴ This trial had similar inclusion criteria as our study, but WHF events were defined as HF hospitalizations or hospital visits; therefore, ambulatory WHF events may have been missed. The mean duration of hospitalizations in our study was 11 days, which is comparable with the 13 days reported in the French OFICA survey as well.²⁵ These numerical comparisons suggest that remote management does not increase the rate or severity of WHF events. The finding that the treatment of 67% of hospitalized patients consisted solely of an increase in diuretics suggests that there is considerable room for improvement in the ambulatory management of this patient population, as this type of intervention is likely to be manageable in a remote setting.

Lastly, this strategy is not suited for acute or severe decompensations, for which urgent hospitalization is required.

Conclusion

Our study suggests that remote management of WHF events based on a multiparametric approach led by a telemedical centre is feasible and safe. Adopting such a strategy for patients with chronic HF could reduce HF-related hospitalizations with expected benefits for patients, care providers, and health care systems.

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Conflict of interest

Sylvain Ploux, Marc Strik, Romain Eschalié and Pierre Bordachar are stock owners of the CareLine Solutions

Company. F. Daniel Ramirez, Samuel Buliard, Rémi Chauvel, Pierre Dos Santos, Michel Haïssaguerre, Antoine Jobbé-Duval, François Picard and Clément Riocreux declare that they have no conflict of interest. [Correction added on 23 October 2023, after first online publication: The Conflict of Interest statement has been updated in this version.]

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1: Iatrogenic complications details.

References

1. GBD 2017 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: A systematic analysis for the global burden of disease study 2017. *Lancet* 2018;**392**: 1789–1858. doi:10.1016/S0140-6736(18)32279-7
2. Setoguchi S, Stevenson LW, Schneeweiss S. Repeated hospitalizations predict mortality in the community population with heart failure. *Am Heart J* 2007;**154**:260–266. doi:10.1016/j.ahj.2007.01.041
3. Solomon SD, Dobson J, Pocock S, Skali H, McMurray JJV, Granger CB, *et al.* Candesartan in heart failure: Assessment of reduction in mortality and morbidity (CHARM) investigators. Influence of nonfatal hospitalization for heart failure on subsequent mortality in patients with chronic heart failure. *Circulation* 2007;**116**:1482–1487. doi:10.1161/CIRCULATIONAHA.107.696906
4. Ahmed A, Allman RM, Fonarow GC, Love TE, Zannad F, Dell'italia LJ, White M, Gheorghiadé M. Incident heart failure hospitalization and subsequent mortality in chronic heart failure: A propensity-matched study. *J Card Fail* 2008;**14**:211–218. doi:10.1016/j.cardfail.2007.12.001
5. Nieminen MS, Dickstein K, Fonseca C, Serrano JM, Parissis J, Fedele F, *et al.* The patient perspective: Quality of life in advanced heart failure with frequent hospitalizations. *Int J Cardiol* 2015;**191**: 256–264. doi:10.1016/j.ijcard.2015.04.235
6. Urbich M, Globe G, Pantiri K, Heisen M, Bennison C, Wirtz HS, *et al.* A systematic review of medical costs associated with heart failure in the USA (2014–2020). *Pharmacoeconomics* 2020;**38**: 1219–1236. doi:10.1007/s40273-020-00952-0
7. Greene SJ, Mentz RJ, Felker GM. Outpatient worsening heart failure as a target for therapy. *JAMA Cardiol* 2018;**3**:252–259. doi:10.1001/jamacardio.2017.5250
8. Boersma EM, Ter Maaten JM, Damman K, Dinh W, Gustafsson F, Goldsmith S, *et al.* Congestion in heart failure: A contemporary look at physiology, diagnosis and treatment. *Nat Rev Cardiol* 2020;**17**: 641–655. doi:10.1038/s41569-020-0379-7
9. Koehler F, Koehler K, Deckwart O, Prescher S, Wegscheider K, Kirwan B-A, *et al.* Efficacy of telemedical interventional management in patients with heart failure (TIM-HF2): A randomised, controlled, parallel-group, unmasked trial. *Lancet* 2018;**392**:1047–1057. doi:10.1016/S0140-6736(18)31880-4
10. Bozkurt B, Coats AJS, Tsutsui H, Abdelhamid CM, Adamopoulos S, Albert N, *et al.* Universal definition and classification of heart failure: A report of the Heart Failure Society of America, Heart Failure Association of the European Society of Cardiology, Japanese Heart Failure Society and Writing Committee of the Universal Definition of Heart Failure. *Eur J Heart Fail* 2021;**23**:352–380. doi:10.1002/ejhf.2115
11. Inglis SC, Clark RA, Dierckx R, Prieto-Merino D, Cleland JGF. Structured telephone support or non-invasive telemonitoring for patients with heart failure. *Cochrane Database Syst Rev* 2015;**2015**:CD007228. doi:10.1002/14651858.CD007228.pub3
12. Ploux S, Strik M, Abu-Alrub S, Ramirez FD, Buliard S, Marchand H, *et al.* Remote monitoring of patients with heart failure during the first national lock-

- down for COVID-19 in France. *European Heart Journal - Digital Health* 2021;**2**: 487-493. doi:10.1093/ehjdh/ztac044
13. Lyngå P, Persson H, Hägg-Martinell A, Hägglund E, Hagerman I, Langius-Eklöf A, et al. Weight monitoring in patients with severe heart failure (WISH). A randomized controlled trial. *Eur J Heart Fail* 2012;**14**:438-444. doi:10.1093/eurjhf/hfs023
14. Krumholz HM. Post-hospital syndrome – a condition of generalized risk. *N Engl J Med* 2013;**368**:100-102. doi:10.1056/NEJMp1212324
15. Patel H, Shafazand M, Schaufelberger M, Ekman I. Reasons for seeking acute care in chronic heart failure. *Eur J Heart Fail* 2007;**9**:702-708. doi:10.1016/j.ejheart.2006.11.002
16. Tsuchihashi-Makaya M, Matsuo H, Kakinoki S, Takechi S, Kinugawa S, Tsutsui H, et al. Home-based disease management program to improve psychological status in patients with heart failure in Japan. *Circ J* 2013;**77**:CJ-13-0115-933. doi:10.1253/circj.CJ-13-0115
17. Wang G, Zhang Z, Ayala C, Wall HK, Fang J. Costs of heart failure-related hospitalizations in patients aged 18 to 64 years. *Am J Manag Care* 2010;**16**: 769-776. https://www.ajmc.com/view/ajmc_10_oct_wang_769to776
18. Rosano GMC, Seferovic P, Savarese G, Spoletini I, Lopatin Y, Gustafsson F, et al. Impact analysis of heart failure across European countries: An ESC-HFA position paper. *ESC Heart Fail* 2022;**9**:2767-2778. doi:10.1002/ehf2.14076
19. Koehler F, Störk S, Schulz M. Telemonitoring of heart failure patients is reimbursed in Germany: Challenges of real-world implementation remain. *Eur Heart J Digit Health* 2022;**3**: 121-122. doi:10.1093/ehjdh/ztac017
20. Sydow H, Prescher S, Koehler F, Koehler K, Dorenkamp M, Spethmann S, et al. Cost-effectiveness of noninvasive telemedical interventional management in patients with heart failure: Health economic analysis of the TIM-HF2 trial. *Clin Res Cardiol* 2022;**111**:1231-1244. doi:10.1007/s00392-021-01980-2
21. Pérez-Francisco DH, Duarte-Clíments G, del Rosario-Melián JM, Gómez-Salgado J, Romero-Martín M, Sánchez-Gómez MB. Influence of workload on primary care nurses' health and burnout, patients' safety, and quality of care: Integrative review. *Healthcare* 2020;**8**:12. doi:10.3390/healthcare8010012
22. Wierda E, Dickhoff C, Handoko ML, Oosterom L, Kok WE, de Rover Y, et al. Outpatient treatment of worsening heart failure with intravenous and subcutaneous diuretics: A systematic review of the literature. ESC. *Heart Fail* 2020;**7**:892-902. doi:10.1002/ehf2.12677
23. Girerd N, Mewton N, Tartièrre J-M, Guijarro D, Jourdain P, Damy T, et al. Practical outpatient management of worsening chronic heart failure. *Eur J Heart Fail* 2022;**24**:750-761. doi:10.1002/ejhf.2503
24. Lindenfeld J, Zile MR, Desai AS, Bhatt K, Ducharme A, Horstmanshof D, et al. Haemodynamic-guided management of heart failure (GUIDE-HF): A randomised controlled trial. *Lancet* 2021;**398**: 991-1001. doi:10.1016/S0140-6736(21)01754-2
25. Logeart D, Isnard R, Resche-Rigon M, Seronde M-F, de Groote P, Jondeau G, et al. Cardiology on behalf of the working group on HF of the FS of. Current aspects of the spectrum of acute heart failure syndromes in a real-life setting: The OFICA study. *Eur J Heart Fail* 2013;**15**:465-476. doi:10.1093/eurjhf/hfs189