# Efficacy of a Physician-Led Multiparametric Telemonitoring System in Very Old Adults with Heart Failure

*Claudio Pedone, MD, PhD,*[†] Francesca Flavia Rossi, MD,* Annagrazia Cecere, MD,* Luisa Costanzo, MD,* and Raffaele Antonelli Incalzi, MD*[‡]*

**OBJECTIVES:** To evaluate the effect of an innovative model integrating telemonitoring of vital parameters and telephone support on 6-month survival and hospital admissions of elderly adults with heart failure (HF).

**DESIGN:** Parallel-arm, randomized trial.

**SETTING:** Geriatric acute care ward and outpatient clinic at Policlinico Campus Biomedico (Rome, Italy).

**PARTICIPANTS:** Individuals with HF aged 65 and older (mean age 80) randomly assigned to intervention (n = 50) or control (n = 46). Participants had an average ejection fraction of 46%.

**INTERVENTION:** Telemonitoring system (receives and communicates oxygen saturation, heart rate, and blood pressure readings) and office-hours telephonic support provided by a geriatrician.

**MEASUREMENTS:** Combination of all-cause death and hospital admissions.

**RESULTS:** The two groups were similar with the exception of the prevalence of women and of disability (both more common in the control group). Three patients for each group were lost to follow-up (final analyzed sample size: 90). Incidence of the main outcome was 42% in the control group and 21% in the intervention group (relative risk = 0.51, 95% confidence interval (CI) = 0.26–0.98). The results were unchanged after taking into account the setting of enrollment, sex, and disability (hazard ratio = 0.42, 95% CI = 0.19–0.94).

**CONCLUSION:** Telemonitoring of elderly people with HF is feasible and reduces the risk of death and hospitalization. Further studies are needed to confirm these findings and evaluate the cost-efficacy of the service. **J Am Geriatr Soc 63:1175–1180, 2015.**

**Key words: aged; heart failure; long-term care; prevention; telemedicine**

Several strategies have been tested to prevent rehospitalization of individuals with heart failure (HF),[1,2] including telemedicine and telemonitoring. According to a Cochrane revision, telemedicine has the potential for improving health care and reducing healthcare expenditures for individuals with HF,[3] but results of more-recent trials have been disappointing. In the Telemedical Interventional Monitoring in Heart Failure (TIM-HF) trial, mortality did not change despite monitoring of blood pressure, electrocardiogram, and body weight.[4] In the Telemonitoring to Improve Heart Failure Outcomes trial, an automatic telephone-based daily collection of information about symptoms and body weight did not improve the outcomes,[5] whereas the CardioMEMS Heart Sensor Allows Monitoring of Pressure to Improve Outcomes in NYHA Class III Patients trial, using an implantable hemodynamic telemonitoring system, demonstrated a significant decrease of the rate of rehospitalization.[6] Other trials using implantable devices or noninvasive telemonitoring[7–9] yielded inconclusive results.

A comparative analysis of randomized clinical trials shows that they differ in the number and type of biological signals monitored, in the timing of recording, and in the organization of the medical support.[10] Furthermore, in these trials, the attending physicians did not directly monitor the participants. The current study was planned to evaluate whether a telemonitoring system providing information directly to the physician in charge of individuals' care and including telephone support could prevent hospital readmissions and death in elderly adults with HF. It was hypothesized that a system directly supervised by the attending physician would make therapeutic interventions more timely and effective.

From the *Area di Geriatria, Università Campus Bio-Medico di Roma; [†]Fondazione Alberto Sordi, Rome and [‡]Fondazione San Raffaele, Cittadella della Carità, Taranto, Italy.

Address correspondence to Luisa Costanzo, Area di Geriatria, Università Campus Bio-Medico di Roma, Via Álvaro del Portillo 21, Roma 00128, Italy. E-mail: l.costanzo@unicampus.it

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## METHODS

### Study Design

This was a single-center, unmasked, randomized trial with 6 months of follow-up comparing multiparametric telemonitoring plus telephonic support with standard care. Individuals with a first diagnosis of HF were recruited from the geriatric acute care ward of a teaching hospital, and those with a principal diagnosis of HF were recruited from the outpatient clinic of the same hospital.

HF was diagnosed on the basis of symptoms, objective evidence (including echocardiography when available), laboratory data (N-terminal prohormone of brain natriuretic peptide (NT-proBNP) when available), and response to specific therapy.[11] The only inclusion parameter other than diagnosis of HF was age of 65 and older. The exclusion criterion was severe cognitive impairment. The ethical committee of the Campus Biomedico University in Rome approved the study protocol (#09/2012), which is registered at www.clinicaltrials.gov (NCT0191458).

### Intervention

The intervention included a telemonitoring system and office-hours telephonic support provided by a geriatrician who had access to the telemonitoring system. The telephonic contacts were not scheduled; participants were instructed to use this channel of communication to report new symptoms or problems with the telemonitoring system.

The telemonitoring system consists of commercial measurement devices equipped with a transmitter and a commercial android-based smartphone that receives from the transmitter the readings from the measurement instruments, communicates the readings to the central component of the system in real time, and issues reminders to the patient when measurement is scheduled. The measurement instruments provided to participants were a sphygmomanometer (A & D Engineering, San Jose, CA), a scale (A & D Engineering), and a pulse oximeter (Nonin Medical Inc., Plymouth, MN).

To avoid heterogeneity, the same baseline scheduling was used for all participants throughout the study: weight once a day; blood pressure and heart rate twice a day, and peripheral oxygen saturation three times a day. Participants could perform additional measurements in case of symptoms, and the schedule of measurements could be remotely altered to adapt it to the changing needs of the participants. A monitoring system software allowed real-time access to the information that the devices listed above gathered. The monitoring system was web-based and accessed through a secure connection using a standard Internet browser.

A geriatrician evaluated the data received every day. The monitor system displayed an alert when a measurement was outside a predefined range, which could be customized for each participant, but the system was intended for monitoring only, and participants were instructed to contact their usual healthcare provider in case of emergency.

In case of abnormal readings, the physician contacted the participant to verify whether their symptoms had worsened or new symptoms had arisen. In this event, the participant's adherence to therapy was checked, and if it was unsatisfactory, interventions promoting adherence were administered. Based on the participant's symptoms and signs, an office appointment was scheduled or the participant was referred to the staff of the acute care ward, who made the final decision on the admission and was blinded to participant allocation.

All participants in the intervention group also received standard care (see below).

### Standard Care

Individuals discharged from the acute care ward received detailed instructions about medical therapy and lifestyle counseling, and a follow-up visit was scheduled for 1 month after discharge. A geriatrician was available on week days for 2 hours per day for telephonic support, and participants recruited from the acute care ward and the outpatient clinic were followed up in visits based on their clinical conditions and were seen by geriatricians from the same unit as the study researchers, who were blinded to their study allocation.

### Multidimensional Assessment

Activities of daily living (ADLs, range 0–6 lost functions), instrumental activities of daily living (IADLs, range 0–8 lost functions), and New York Heart Association (NYHA) class were rated. Comorbidity burden was expressed using the Cumulative Illness Rating Scale (CIRS),[12] which has two scales: a comorbidity scale indicating the number of systems with a clinically relevant disease (range 0–13), and a severity scale (range 1–5, with higher values indicating more-severe conditions). Serum concentration of NT-proBNP was measured on admission, and the use of cardiovascular drugs (diuretics, angiotensin-converting enzyme inhibitors (ACE-Is) and angiotensin receptor blockers (ARB), beta-blockers, statins, nitrates) was recorded.

### Outcome

Outcome measures were hospital admissions for any reason or death 180 days from enrollment. All information was gathered from clinical records, when available, or from in-person or telephone interviews.

### Sample Size

An outcome incidence of 50% was anticipated.[5] Because this was an exploratory study, it was decided to allow for a type I error rate of 10%. On these assumptions, it was calculated that a sample size of 50 participants per group would provide 80% power to detect a 25% absolute risk reduction. As shown in Figure 1, 186 individuals meeting inclusion and exclusion criteria were identified; 90 of these refused to participate. Of the remaining 96, 50 were randomized to the intervention group and 46 to the control group using a computer-generated random number list. Three participants in each group were lost to follow-up, and four participants dropped out of the intervention group, leaving a final sample size for the analysis of 90.

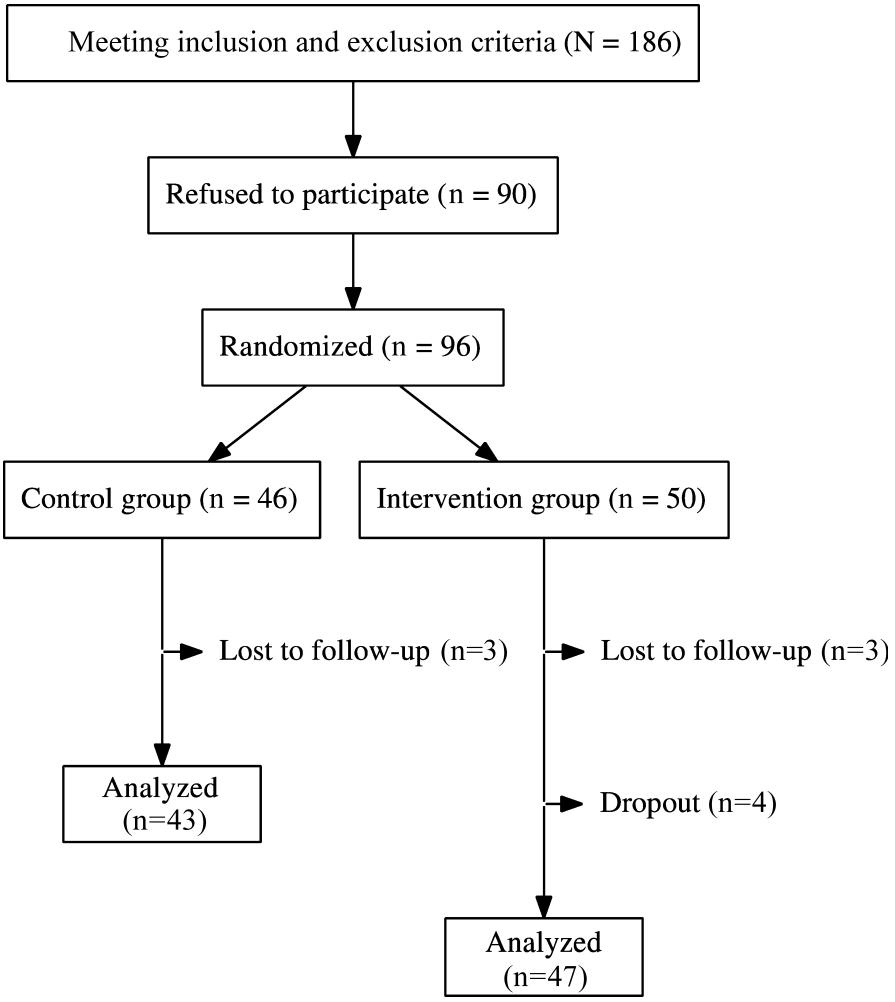


**Figure 1.** Study flowchart.

### Analytical Approach

Descriptive statistics and *t*-tests or chi-square tests were used to compare groups. The risk of the composite outcome was calculated using the product-limit method complemented with the log-rank test. The adjusted relative hazard for the outcome was estimated using a proportional hazards model including site of enrollment (hospital ward or ambulatory setting) as a random effect term. In this model, the number of ADLs was dichotomized using the median (3) as a cutoff variable to avoid the assumption of a linear relationship with the outcome risk. All analyses were performed using an intention-to-treat approach. The analyses were performed using R Statistical Software version 2.14 for Linux.

## RESULTS

The mean age of the sample (80 ± 7, range 60–94) was similar in the two groups, whereas the proportion of men was higher in the telemonitoring group (47%, vs 30% in the control group). Independence in ADLs was better preserved in the telemonitoring group, but there were no differences in the distribution of NYHA class, comorbidity score, NT-proBNP serum concentration, number of drugs taken, or number of admissions in the preceding year. Ninety-one percent of participants were taking loop diuretics, and approximately half were taking ACE-Is, ARBs, or beta-blockers, without significant differences between the two groups (Table 1).

On average, 62% of scheduled measurements were completed; adherence was best for pulse oximeter (70%) and worst for the scale (56%). Sixty-four percent of participants completed at least half of the scheduled measurements.

There were 28 hospital admissions during the 6 months of follow-up (incidence rate 77.9/100 person-years, 95% confidence interval (CI) = 54–112.6), 20 in the control group (incidence rate 129/100 person-years, 95% CI = 84–200) and eight (incidence rate 39/100 person-years, 95% CI = 20–77) in the intervention group (incidence rate ratio = 0.30, 95% CI = 0.12–0.67). Half of the admissions were due to heart failure or related heart diseases (e.g., arrhythmias). More admissions were due to cardiac events in the telemonitoring group (62.5%) than in the control group (45%), although the incidence rate ratio for heart failure hospitalizations was 0.48 (0.14–1.45). The number of observed deaths was 10, seven in the control group (incidence rate 37/100 person-years, 95% CI = 18–76) and three in the intervention

**Table 1. Characteristics of the Sample**

| Characteristic | Control, n = 43 | Telemonitoring, n = 47 | *P*-Value |
|---|---|---|---|
| Age, mean ± SD | 79.7 ± 7.8 | 79.9 ± 6.8 | .88 |
| Male, % | 30.2 | 46.8 | .16 |
| Number of activities of daily living lost, mean ± SD | 3 ± 1.4 | 2.1 ± 1.9 | .01 |
| Number of instrumental activities of daily living lost, mean ± SD | 5 ± 1.4 | 4.1 ± 1.9 | .01 |
| New York Heart Association Class, % | | | |
| II | 32.6 | 31.9 | >.99 |
| III | 55.8 | 57.4 | >.99 |
| IV | 11.6 | 10.6 | >.99 |
| Cumulative Illness Rating Scale score, mean ± SD | | | |
| Severity (range 1–5) | 1.5 ± 0.2 | 1.5 ± 0.2 | .32 |
| Comorbidity (range 0–13) | 1.6 ± 0.5 | 1.5 ± 0.6 | .70 |
| N-terminal prohormone of brain natriuretic peptide, ng/mL, mean ± SD | 7,055.9 ± 10,605.3 | 9,030.9 ± 13,592.2 | .51 |
| Ejection fraction, %, mean ± SD | 48.2 ± 13.5 | 44.4 ± 12.7 | .24 |
| Diabetes mellitus, % | 34.3 | 31.9 | .94 |
| Renal insufficiency, % | 27.9 | 29.8 | >.99 |
| Number of hospital admissions in the previous year, mean ± SD | 0.7 ± 0.7 | 0.6 ± 0.6 | .92 |
| Number of drugs, mean ± SD | 9.9 ± 3.2 | 9.6 ± 3.1 | .66 |
| Drugs, % | | | |
| Beta-blocker | 53.5 | 55.3 | >.99 |
| Loop diuretic | 86.0 | 95.7 | .21 |
| Potassium-sparing diuretic | 30.2 | 34.0 | .87 |
| Angiotensin-converting enzyme inhibitor or angiotensin receptor blocker | 60.5 | 55.3 | .78 |
| Nitrate | 39.5 | 4.4 | >.99 |
| 3-hydroxy-3-methyl-glutaryl coenzyme A reductase inhibitors | 27.9 | 25.5 | .99 |

group (incidence rate 13/100 person-years, 95% CI = 5–39). The incidence rate for the composite outcome was 112/100 person-years (95% CI = 82–154) in the overall population, 190/100 person-years in the control group, and 56/100 person-years in the intervention group; the corresponding incidence rate ratio was 0.30 (95% CI = 0.14–0.59).

The overall proportion of people experiencing the composite outcome was 42% in the control group and 21% in the telemonitoring group (relative risk = 0.51, 95% CI = 0.26–0.98). Figure 2 shows the event-free survival of the two groups. The relative hazard for the composite outcome estimated using an unadjusted Cox regression model was 0.43 (95% CI = 0.20–0.93). The hazard ratio adjusted for sex, disability, and enrollment setting was 0.42 (95% CI = 0.19–0.94). Of the 10 outcome events recorded in the intervention group, two occurred in people who dropped out of the study and two in participants with poor adherence who had not used the telemonitoring system in the days before the event. For the other outcomes, a decline or instability of oxygen saturation preceded three; alteration in heart rate preceded two; and oxygen desaturation, decline in blood pressure, and weight gain preceded one.

## DISCUSSION

These data suggest that a physician-led multiparametric telemonitoring system integrated with telephone support can reduce the risk of all-cause death and hospitalization in elderly adults with HF. The data are in contrast to those from two recent trials,[4,5] but there are important differences between these trials. One intervention[5] was based on a telephone-based voice response system and was therefore hardly comparable with the current intervention. The TIM-HF trial[4] tested a system that was similar to that used in the current study, but peripheral oxygen saturation was not included in the monitored parameters, and the parameters were collected only once a day. Furthermore, the telemedical center provided telephone support once a month, and participants could contact the telemedical centers only in case of emergency. In addition, the population in the TIM-HF trial was on average 13 years younger than in the current study.

A peculiarity of the current trial is that a geriatrician led the intervention. HF prevalence increases with age,[13] with individuals with HF being on average 73 years old[14] and having multiple comorbid diseases;[15] the geriatrician typically provides comprehensive care customized to the complexity of these individuals.[16] Another important feature of the model is that it included "fast track" access to ambulatory visits that was activated in case of abnormalities in the telemonitored data or when new symptoms ensued. Thus, a model of care was tested rather than a simple telemonitoring system. This is an important factor to be taken into account when evaluating telehealth interventions. The results of Whole Systems Demonstrator,[17] a large, community-based trial of telehealth, indicate that the simple implementation of technologies in the context of usual care is not enough to obtain sizable benefits.[18]

A formal cost-effectiveness analysis was not performed. The use of a physician rather than a nurse has an obvious effect on costs, although this should be compared with the cost of hospitalization; data from the current study indicate that, for every 100 people with HF, the intervention may prevent 70 hospitalizations per year com-

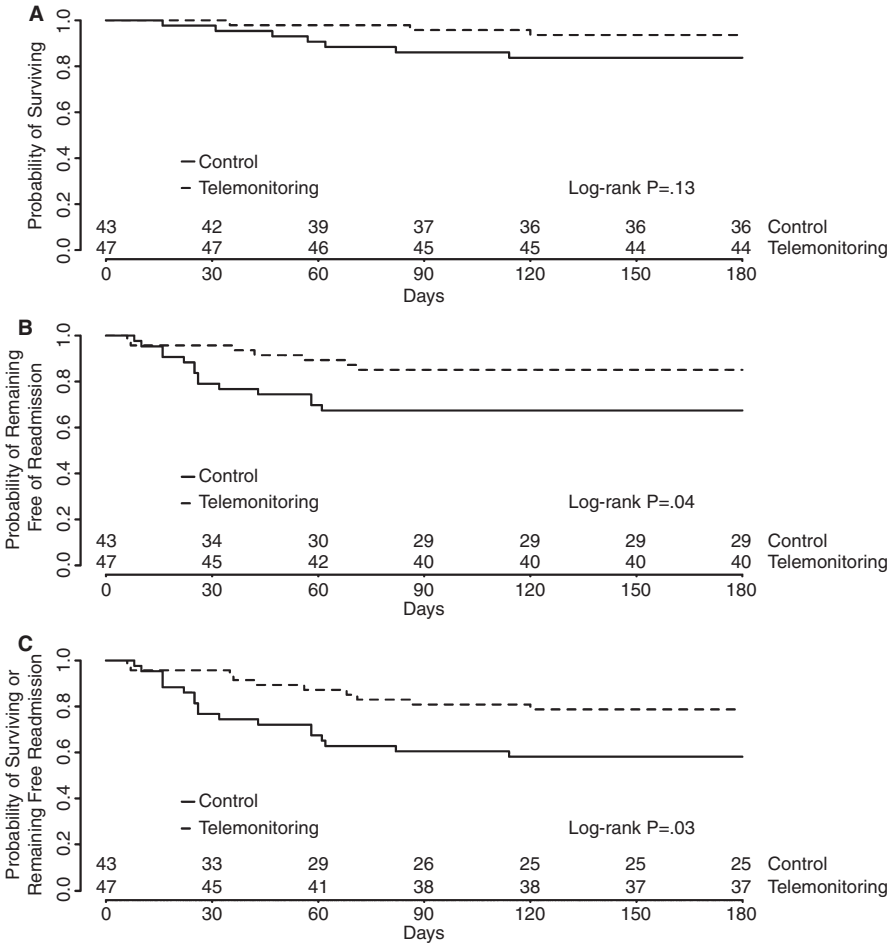


**Figure 2.** Kaplan-Meier estimate of (A) risk of death, (B) hospital admissions, and (C) composite outcome.

pared with standard care. In addition, the telemonitoring hardware is inexpensive thanks to the use of commercial devices, and on a large scale, this may in part offset the costs of the service. Nonetheless, a direct evaluation is needed before any conclusions can be drawn.

This study has several strengths. First, the very old individuals with HF studied are representative of the real-world target population. Second, the core of the technological intervention does not lie in its hardware, which is made up of existing, low-cost devices, but in its software and monitoring system, with obvious implications for costs on a large scale. The use of commercial devices also affects the acceptability of the system, because participants used medical devices to which they were well accustomed. Third, the availability of telephone contact on demand could reassure people that telemonitoring is an add-on to, not a substitute for, physician-patient contact. Finally, the monitoring schedule could be adapted to changing clinical conditions.

Some limitations should also be taken into account. First, the sample was small, with some imbalance in the characteristics of the two groups. This may affect the internal validity of the study, although statistical correction for this imbalance has been performed. Moreover, the prevalence of physical impairment in the sample was high, which makes generalization of the results to the general HF population questionable, although the results may indicate that telemonitoring could be more effective in the population for which it is intended, that is, individuals with difficulties attending frequent ambulatory visits. Second, results pertaining to medical outcomes were shown, but an evaluation of economic and societal implications is needed before the effectiveness of the model of telehealth is established. Finally, the estimated risk reduction is larger than found in previously published trials. Probably because of publication bias, small trials such as this one tend to overestimate the treatment effect.[19] Furthermore, the favorable results might depend partly on the experience in HF management of the geriatrician in charge of telemonitored individuals, although the control group also received care from a geriatrician skilled in HF treatment.

In conclusion, physician-led telemonitoring of elderly adults with HF is feasible and reduces the risk of death and hospitalization. Further studies are needed to test this model in a larger series and to assess its cost efficacy.

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**Conflict of Interest:** The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper.

**Author Contributions:** Pedone, Incalzi: study concept and design. Pedone: data analysis and interpretation, prep-

aration of a draft of the manuscript, critical revision of the article. Rossi, Cecere: participant recruitment, data collection, drafting the paper. Costanzo: data collection and interpretation, revision of the manuscript. Incalzi: critical revision of the manuscript for important intellectual content. All authors provided final approval of the version to be published.

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