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Postdischarge Noninvasive Telemonitoring and Nurse Telephone Coaching Improve Outcomes in Heart Failure Patients With High Burden of Comorbidity

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ABSTRACT

Background: Noninvasive telemonitoring and nurse telephone coaching (NTM−NTC) is a promising postdischarge strategy in heart failure (HF). Comorbid conditions and disease burden influence health outcomes in HF, but how comorbidity burden modulates the effectiveness of NTM−NTC is unknown. This study aims to identify patients with HF who may benefit from postdischarge NTM−NTC based on their burden of comorbidity.
Methods and Results: In the Better Effectiveness After Transition - Heart Failure trial, patients hospitalized for acute decompensated HF were randomized to postdischarge NTM−NTC or usual care. In this secondary analysis of 1313 patients with complete data, comorbidity burden was assessed by scoring complication and coexisting diagnoses from index admissions. Clinical outcomes included 30-day and 180-day readmissions, mortality, days alive, and combined days alive and out of the hospital. Patients had a mean of 5.7 comorbidities and were stratified into low (0−2), moderate (3−8), and high comorbidity (≥9) subgroups. Increased comorbidity burden was associated with worse outcomes. NTM−NTC was not associated with readmission rates in any comorbidity subgroup. Among high comorbidity patients, NTM−NTC was associated with significantly lower mortality at 30 days (hazard ratio 0.25, 95% confidence interval 0.07−0.90) and 180 days (hazard ratio 0.51, 95% confidence interval 0.27−0.98), as well as more days alive (160.1 vs 140.3, *P* = .029) and days alive out of the hospital (152.0 vs 133.2, *P* = .044) compared with usual care.
Conclusions: Postdischarge NTM−NTC improved survival among patients with HF with a high comorbidity burden. Comorbidity burden may be useful for identifying patients likely to benefit from this management strategy. (*J Cardiac Fail 2022;00:1−10*)
Key Words: Heart failure, noninvasive telemonitoring, nurse telephone coaching, burden of comorbidity.

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Heart failure (HF) affected 6.2 million American adults from 2013 to 2016, and the prevalence continues to increase with the aging population.[1] Overall, 15%−20% of HF hospitalizations will require readmission within 30 days, making HF the condition most likely to require readmission and contributing significantly to health care costs in the United States.[2,3] Additionally, 55% of Medicare patients with HF have 5 or more other chronic conditions,[4] which significantly complicates medical care and contributes to increased morbidity and mortality.[5−7] Patients with 30-day readmissions have higher comorbidity burden than those not readmitted and are often readmitted for noncardiac reasons.[2] The increased care burden in this population requires careful posthospitalization management to optimize medication regimens and manage comorbidities. The identification of benefit- and risk-based subgroups may allow for more efficient resource allocation and patient assignment in the postdischarge care of patients with HF.

Noninvasive telemonitoring (NTM) incorporates objective data collection via devices such as scales or blood pressure and heart rate monitors into telephone-based care transition models. Other telemonitoring programs may collect subjective data only or data from invasive monitoring devices such as pulmonary artery pressure monitors, pacemakers, or defibrillators.[8] Individual trials of NTM in patients with HF have shown mixed results for HF-associated readmissions and all-cause mortality.[9−14] The analysis of the data in the original Better Effectiveness After Transition-Heart Failure (BEAT-HF) trial showed a trend toward decreased mortality at 30 days, but not at 180 days, with NTM and nurse telephone coaching (NTM−NTC), but no improvement in readmission rates.[10] A more recent meta-analysis conducted in 2015 suggested an overall decrease in all-cause mortality and HF-associated readmissions; however, the authors were unable to identify the factors that explained substantial heterogeneity across studies.[15] A contemporaneous overview of systematic reviews concluded that sufficient and high-quality studies to clearly indicate which types of technologies and strategies provide optimum clinical benefit and to which patient subgroups are still lacking.[16] In the most recent review of this topic, Faragli et al[17] argued that “the profile of patients who can potentially benefit from telemedicine should be further investigated,” including in terms of the presence of specific comorbidities, because they can affect the outcomes of patients with HF negatively.

A now well-documented phenomenon, called heterogeneity of treatment effects, explored in a recent article in the *Annals of Internal Medicine*, indicates that treatment effects can vary widely in key subgroups and can differ from the average effect.[18] Given the importance of comorbidities among patients with HF, the purpose of this secondary analysis of the BEAT-HF data was to determine if the association between postdischarge NTM−NTC and readmission and mortality rates varies among patients with HF with different comorbidity burdens and to explore if comorbidity subgroups could be used as a potential clinical marker to guide allocation of postdischarge monitoring.

Methods

The experimental design of the BEAT-HF trial has previously been described in detail elsewhere.[10,19] In brief, the BEAT-HF study was a randomized controlled trial conducted across 6 academic medical centers in California between October 12, 2011, and September 30, 2013. The study enrolled patients aged 50 years or older who were admitted for acute decompensated HF. All patients provided written informed consent for participation before enrollment in the study. The intervention consisted of predischarge HF education conducted by a study nurse; regularly scheduled telephone calls from a nurse coach in a centralized call center; NTM of weight, blood pressure, heart rate, and symptoms via a digital-related symptoms list; and phone calls from the nurse coaches triggered by abnormal results, over a study period of 180 days. For simplicity, the intervention will be referred to as NTM−NTC for the remainder of this article. Usual care consisted of predischarge HF education as routine at each medical center, often including a single postdischarge phone call. The original BEAT-HF study reviewed medication use among study participants and found that there were no clinically meaningful differences in the use of angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, β-blockers, digoxin, loop diuretics, or aldosterone antagonists between the intervention and control groups.[10]

This post hoc secondary analysis includes BEAT-HF participants with known vital status at 180 days after discharge and nonmissing coded comorbid conditions at enrollment admission in the index study ($N = 1313$). Patients excluded owing to missing data on comorbid conditions were significantly younger than those with nonmissing data (65.7 years vs 73.0 years), but they were equally distributed between the NTM−NTC (54.2%) and usual care (51.6%) groups. There were no significant differences between included and excluded patients in gender, race, ethnicity, or Medicaid insurance status in either study arm.

Comorbidity Measure

The burden of comorbidity was measured by using coded complications and coexisting diagnoses (CCs) from the index admission, following a previously published methodology that produced an index of comorbidity scoreable from coded diagnostic information and specific to HF.[20] The distribution of the sum of comorbid conditions was approximately normally distributed, suggesting that subgroups could be clustered into clinically relevant groups (see Supplemental Fig. 1). Three subgroups were defined: within 1 standard deviation (SD) above or below the mean number of CCs as moderate and the 1 SD ± tails as having low and high burdens of comorbidity, respectively. SD cut-offs were rounded down and up to the nearest whole number for the low and high comorbidity subgroups, respectively, to make the greatest distinction among subgroups.

Statistical Analyses

The outcomes of interest included 30- and 180-day readmissions assessed for all patients regardless of mortality status; all-cause mortality at 30 and 180 days; and days alive and days alive and out of the hospital at 180 days after discharge. Numerical variables were summarized by mean ± SD and/or range. Categorical variables were summarized by frequencies and percentages. In bivariate analyses, readmission and mortality outcomes were compared across the comorbidity subgroups (low, moderate, or high) by the Cochran−Armitage trend test.

General linear models were used to evaluate the impact of NTM−NTC on the continuous study outcomes of days alive and days alive and out of the hospital stratified by comorbidity subgroups. Kaplan−Meier survival curves comparing the NTM−NTC and usual care groups were created for each comorbidity subgroup, with differences between study arms assessed by the log-rank test. Multivariable Cox regression was used to estimate hazard ratios (HR) and 95% confidence intervals (CIs) for mortality outcomes within each comorbidity subgroup. A supremum test confirmed proportional hazards. Age and gender were included as covariates in all models.

We first tested the hypothesis that the effect of NTM−NTC on days alive and days alive and out of the hospital would vary with the burden of comorbidity using a general linear interaction model with age and gender included as covariates. The model included a term for the interaction of NTM−NTC with the comorbidity subgroups (a categorical-by-categorical variable interaction), which was significant ($P = .032$). Hence, moving forward, we performed separate analyses for the 2 continuous outcomes within each of the 3 comorbidity subgroups. Because of the significant interaction, we also analyzed readmission and mortality separately in each of the 3 comorbidity subgroups. A 2-sided 0.05 significance level was used throughout. SPSS version 24 and SAS version 9.4 were used for the statistical analyses.

The BEAT-HF trial was approved by the University of California, Los Angeles Institutional Review Board, and all other study institutions were subject to the University of California, Los Angeles, Institutional Review Board review. A data and safety monitoring board was convened for the study and reviewed data during the study enrollment period. All participants gave their informed consent before enrollment in the trial. The study was registered at clinicaltrials.gov (NCT01360203).

Results

Description of the Sample

There were 708 males (53.9%) and 605 females (46.1%) included in this analysis (Table 1). The average age was 73.2 ± 12.1 years (range 50−103 years). Race was identified as White in 65.4%, Black or African American in 21.6%, and other in 13.0%. There were no significant differences in demographic characteristics between the NTM−NTC and usual care groups (Supplemental Table I). Table 1 displays the characteristics of the total sample and stratified by each of the 3 comorbidity subgroups. The low comorbidity subgroup was younger and less likely to have Medicaid as a primary or secondary insurance payer.

Burden of Comorbidity

Patients had a mean of 5.7 ± 2.4 comorbidities (range 0−16). The distribution of the burden of comorbidity was approximately normal (Supplemental Fig. 1). Burden of comorbidity subgroups were defined as: low (0−2 comorbidities, $n = 98$, 7.5%), moderate (3−8 comorbidities, $n = 1059$, 80.7%), and high (≥9 comorbidities, $n = 156$, 11.9%). The most prevalent comorbidity was hypertension (81.3%). Supplemental Table 2 includes a complete list of comorbid conditions identified in the sample. A higher burden of comorbidities was positively associated with 30-day readmission, 180-day readmission, 30-day mortality, and 180-day mortality, and inversely related to days alive in the 180-day period of observation (Table 2).

Intervention Effects Overall and in Comorbidity Subgroups

Consistent with the main results of the BEAT-HF study,[10] there were no differences in this substudy in 30-day and 180-day readmission rates between

Table 1. Demographics for All Study Patients and by Comorbidity Subgroup

		Comorbidity Subgroup			
	Total (*N* = 1313)	Low (n = 98)	Moderate (n = 1059)	High (*n* = 156)	*P* Value
Age, year	73.2 ± 12.2	71.3 ± 13.1	73.1 ± 12.2	75.2 ± 10.6	.035
Age >80 years	36.0	26.6	36.4	39.1	.154
Female sex	46.1	42.9	45.1	54.5	.073
Race					.897
White	65.5	63.3	65.4	67.3	
Black/African American	21.6	21.4	21.6	21.8	
Other/multiple	12.9	15.3	12.9	10.9	
Hispanic ethnicity	6.7	7.1	6.9	5.1	.701
Medicaid as primary or secondary payer	38.6	27.6	38.7	44.9	.022

Value are mean ± standard deviation or percent.

intervention and control groups (data not shown). There were also no significant main effects of treatment group for the outcomes of days alive (F = 1.09, *P* = .297) or days alive and out of the hospital (F = 1.01, *P* = .315) (see Table 3). However, a general linear model analysis demonstrated a significant interaction effect between comorbidity burden and NTM−NTC on the mean number of days alive and days alive and out of the hospital (Table 4). Within the high comorbidity subgroup, patients who received NTM−NTC had significantly more days alive on average (160.1 days vs 140.3 days, F = 3.562, *P* = .029) and more days alive and out of the hospital (152.0 days vs 133.2 days; F = 3.13, *P* = .044) than the usual care group. The NTM−NTC group survived 20 more days on average (out of the 180-day study period) than the usual care group. The mean number of days alive and out of the hospital was also 19 days greater in the NTM−NTC group than in the usual care group.

A survival analysis did not demonstrate significant differences in the number of days alive between the NTM−NTC and usual care groups within either the low or moderate comorbidity subgroups (Fig. 1). Within the high comorbidity subgroup, the risk of death was cut in half for the NTM−NTC group (HR 0.51; 95% CI 0.27−0.98; *P* = .039) with the survival curve for this group closely resembling that of the low and moderate comorbidity subgroups. Although a preintervention (day 0 in hospital) difference is visible on this graph, the separation of curves becomes more distinct by 30 days and 180 days after discharge. The difference in number of deaths between the control and intervention groups was 4 while in the hospital, 9 at 30 days after discharge, and 12 at 180 days after discharge.

The NTM−NTC intervention was not associated with the likelihood of readmission for any comorbidity subgroup. However, patients in the high comorbidity subgroup who received NTM−NTC had a significantly lower likelihood of mortality at both 30 days (3.8% vs 14.8%, HR 0.25, 95% CI 0.07−0.90) and 180 days (18.2% vs 32.5%, HR 0.51, 95% CI 0.27−0.98) after adjusting for age and gender (Table 5).

Dose of Intervention

Within the intervention group, there was no evidence of differences in the amount of intervention received between comorbidity subgroups. There were no significant differences between subgroups

Table 2. Burden of Comorbidity Associated With Patient Outcomes

	Burden of Comorbidity Subgroup				
Outcome	Low (*n* = 98)	Moderate (*n* = 1059)	High (*n* = 156)	Statistical Test	*P* Value
30-Day readmission	8.1	22.5	31.4	χ^2 = 18.08*	<.001
180-Day readmission	31.3	51.4	64.1	χ^2 = 25.00*	<.001
Days alive[†]	166.3 ± 41.8	164.3 ± 43.0	149.8 ± 58.0	F = 7.41	.001
Days alive and out of hospital[†]	164.3 ± 42.6	159.3 ± 44.8	142.2 ± 58.4	F = 10.35	<.001
30-Day mortality	5.1	4.1	9.6	χ^2 = 4.58*	.032
180-Day mortality	11.1	15.3	25.6	χ^2 = 11.38*	.001

Value are mean ± standard deviation or percent.
* χ^2 statistic reported is Cochran-Armitage linear-by-linear association.
[†]Days out of the 180-day study period.

Table 3. Intervention Effects on Mean Days Alive and Mean Days Alive and Out of the Hospital (Estimated Means Adjusted for Age and Gender Effects)

Outcome	Treatment Group	
	Control ($n = 659$)	Intervention ($n = 654$)
Mean days alive* (SE)	161.4 (1.74)	164.0 (1.75)
Mean days alive and out of hospital* (SE)	156.3 (1.80)	158.9 (1.80)

SE, standard error.
*Days out of the 180-day study period.

in the number of phone calls, total minutes on the phone, or days with NTM−NTC data points collected from patients; and participants in all comorbidity subgroups were equally likely to be active users of the intervention (Table 6).

Discussion

NTM−NTC was associated with a reduction in 30-day and 180-day mortality in patients with high comorbidity burden (≥9 CCs) without affecting readmission rates in this multicenter trial. The intervention seemed to decrease mortality in the high comorbidity subgroup to nearly the same level as that of patients in the moderate comorbidity subgroup (3−8 CCs). This finding is notable given the trend toward 30-day mortality reduction (unadjusted HR 0.61, 95% CI, 0.37−1.02, $P = .06$; adjusted HR 0.53, 95% CI 0.31−0.93, $P = .03$) for the intervention arm in the original BEAT-HF trial.[10] Mortality rates were significantly lower with NTM−NTC in the high comorbidity subgroup, which translated to more days alive and out of the hospital for these patients.

Care transition programs have shown promise in helping patients transition safely to the home.[21−23] This analysis demonstrates that telemedicine can improve survival for those at higher risk of mortality related to an increased burden of comorbid conditions. NTM−NTC provides timely, objective information without the need for invasive procedures or implantable monitoring devices. In the patient with a high burden of comorbidities, this strategy may decrease the need for procedures and potential complications. As illustrated during the coronavirus disease 2019 pandemic, health care systems benefit from maintaining care quality despite restrictions on patient travel, marked decreases in community support, limitations in resources such as medical staff and supplies, and major alterations to patients' ways of living. NTM−NTC accomplishes this goal by maintaining remote access to high-quality HF care without additional physical patient contacts and without significant demands on the health care system. The number of data points and the number and length of phone calls were similar across comorbidity subgroups, which made the study findings surprising, because most would expect greater need for care coordination in patients with a high comorbidity burden. Future studies may clarify the ideal frequency of data monitoring and medical intervention or nursing response workflows to maximize mortality reduction in this population.

The decrease in mortality in the high comorbidity subgroup who received NTM−NTC was not accompanied by a difference in readmission rates compared with those who received usual care. This finding in the high comorbidity subgroup is supported by the differences in average days alive (160.1 − 140.3 = 19.8) and average days alive out of the hospital (152.0 − 133.2 = 18.8), which were very similar. These results suggest that the mortality benefit of NTM−NTC in patients with a high comorbidity burden may not be associated with an increased use of inpatient services. Much effort in the United States has focused on decreasing readmissions for HF as a surrogate for high-quality care. The Medicare Hospital Readmissions Reduction Program penalizes hospitals for high rates of readmission for HF and other chronic conditions.[2,24] As a

Table 4. Intervention Effects Within Burden of Comorbidity Subgroups on Mean Days Alive and Mean Days Alive and Out of the Hospital (Estimated Means Adjusted for Age and Gender Effects)

Outcome	Treatment Group	Burden of Comorbidity Subgroup		
		Low ($n = 98$)	Moderate ($n = 1{,}059$)	High ($n = 156$)
Mean days alive* (SE)	Control	167.2 (6.2)	164.0 (1.9)	140.3 (5.0)[†]
	Intervention	163.9 (6.5)	164.5 (1.9)	160.1 (5.1)[†]
Mean days alive and out of hospital* (SE)	Control	165.9 (6.4)	158.9 (2.0)	133.2 (5.1)[†]
	Intervention	161.2 (6.7)	159.7 (2.0)	152.0 (5.2)[†]

SE, standard error.
*Days out of the 180-day study period.
[†]Statistically significant difference between the noninvasive telemonitoring and nurse telephone coaching and usual care groups.

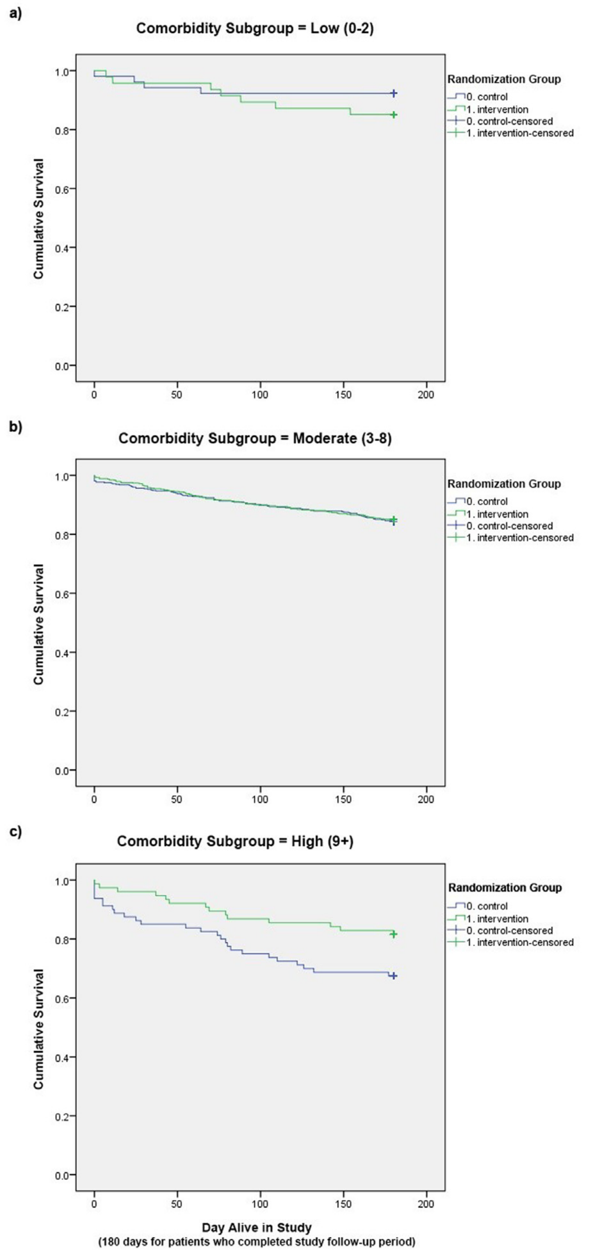


Fig. 1. Kaplan–Meier survival curves for days live within 3 comorbidity subgroups (*N* = 1313).

result, readmission rates for HF have decreased in the United States, but this decrease has also been occurring around the world in countries without penalty programs.[2,25,26] Unfortunately, the Medicare Hospital Readmissions Reduction Program has not demonstrated consistent improvement in outcomes and potentially even resulted in worsening outcomes for patients.[24,27] Improving the overall quality of care, including improving survival and quality of life, may involve the acceptance of readmissions as a part of a broader strategy to improve outcomes, and further research will help to delineate these trade-offs.

The additional days alive and out of the hospital gained by patients in the high comorbidity subgroup who received NTM–NTC are particularly important for patients with advanced disease. Because many patients with HF are not candidates for interventions such as transplantation and device therapy, the potential for posthospitalization care is vital for increasing quality of life for these patients by allowing for more time at home. This strategy also decreases the burden on care providers and the health care system. Future studies examining NTM–NTC in patients with end-stage HF may help to illuminate this benefit. Also, nationwide multicenter research may allow for a more generalizable determination of high comorbidity population subgroups that may consistently benefit from intervention across differing health systems.

Our approach of using comorbidity stratification by CCs has been previously validated in a national HF population,[20] and it requires no additional data collection beyond what is collected automatically for Medicare patients. However, the specific comorbidity count cut-offs used in this study were derived from our own data from 6 sites. Future nationwide research may allow for a more generalizable determination of high comorbidity subgroups that may consistently benefit from NTM–NTC interventions.

Table 5. Intervention Effects Within Burden of Comorbidity Subgroups on Likelihood of Mortality at 30 Days and 180 Days (Hazard Ratios Adjusted for Age and Gender Effects)

		Burden of Comorbidity Subgroup		
Outcome		Low (*n* = 98)	Moderate (*n* = 1059)	High (*n* = 156)
30-Day mortality	Control *n*	3	24	12
	Intervention *n*	2	19	3
	Hazard ratio (95% CI)	0.59 (0.10–3.66)	0.78 (0.43–1.42)	0.25* (0.07–0.90)
180-Day mortality	Control *n*	4	83	26
	Intervention *n*	7	79	14
	Hazard ratio (95% CI)	1.72 (0.50–5.89)	0.94 (0.69–1.28)	0.51* (0.27–0.98)

CI, confidence interval.
*Statistically significant difference between the noninvasive telemonitoring and nurse telephone coaching and usual care groups.

Table 6. Dose of NTM−NTC Received by Intervention Group Patients Stratified by Burden of Comorbidity Subgroups

Intervention Dose Measures	Burden of Comorbidity Subgroup: Low ($n = 98$)	Moderate ($n = 1059$)	High ($n = 156$)	P Value
Number of phone calls	4.7	5.4	4.9	.103
Total minutes on phone	93.8	93.5	82.5	.285
Days with NTM−NTC data points	77.4	84.5	77.0	.565
Active users (≥1 reading per month)	52.8%	55.9%	49.4%	.520

NTM−NTC, noninvasive telemonitoring and nurse telephone coaching.

Patients with HF in the low and moderate comorbidity subgroups did not improve significantly with NTM−NTC. This finding may reflect inadequate tailoring of the intervention to the needs of patients with different levels of comorbidity, inadequate power to find effects in subgroups with a lower risk, or a true lack of effect in relatively low-risk patients. Because BEAT-HF was not powered to detect within-stratum effects on readmissions and mortality, the CIs shown in Table 5 are wide. The BEAT-HF study followed patients only up to 180 days after discharge. It is possible that the effects of NTM−NTC might show benefit in the low and moderate comorbidity subgroups in a longer follow-up study.

Novel developments in wearable technology may demonstrate the capacity to augment noninvasive data collection and improve quality of care at minimal cost.[28] Meanwhile, invasive monitoring approaches such as pulmonary artery pressure monitors may prove useful in select patients.[8] Future studies of stratified care transitions incorporating NTM−NTC may clarify the ideal match between patients and care transition programs. For example, supportive care medicine programs for patients with HF with a moderate to high comorbidity burden may offer opportunities to address end of life care in the context of quality-of-life end points.[29,30] Additionally, future studies are needed to evaluate NTM−NTC in select environments, such as rural populations and in cases of natural disasters such as pandemics that may limit doctor−patient contact.

Limitations

This study was a secondary analysis of a multisite randomized controlled trial. Because it included a subsample of participants with complete coded index admission diagnoses and outcome data, bias owing to missing data may have been introduced into the comparisons with unknown effect. We found only a difference in the average age between those patients included in the analysis and those excluded; patients with missing data were evenly distributed among the comorbidity subgroups and treatment arms.

In conclusion, NTM−NTC improved survival and days out of the hospital among patients with HF with a high comorbidity burden, and successful targeting of this patient population may improve outcomes and extend life.

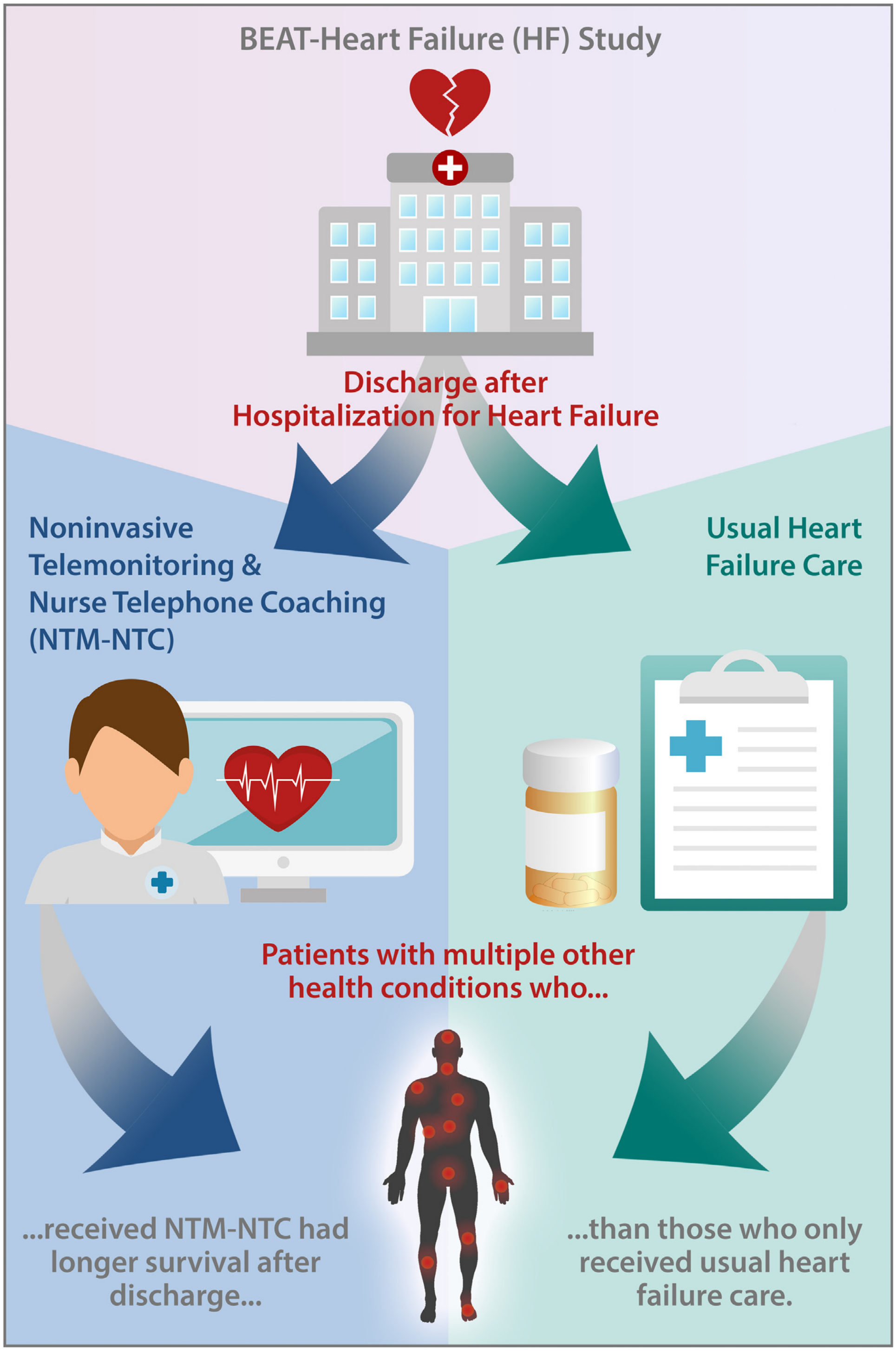
Proposed Social Media Text

Secondary analysis of a randomized controlled trial of noninvasive telemedicine postdischarge care suggests that a subgroup of heart failure patients with high burden of co-existing comorbidity may benefit with lower risk of mortality at 30- and 180-days after hospital discharge.

Lay Summary

- Postdischarge telemonitoring and nurse telephone coaching can help manage care after being hospitalized with heart failure
- Our study looked at the benefits of this approach in different types of patients
- This approach was most likely to improve survival in patients who also had multiple other health problems

Postdischarge telemonitoring and nurse telephone coaching is a specialized approach to help patients with heart failure manage their health care after they return home from the hospital. It allows health care providers to remotely monitor blood pressure, heart rate, and other vital signs and symptoms. It also allows patients to receive regular virtual check-ins and guidance from a nurse without having to leave home. Our study found that patients who have heart failure and have multiple other health problems may be most likely to benefit from this approach in terms of improving survival and staying out of the hospital.



Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.cardfail.2022.11.012.

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