

BMJ Open Changes in vulnerability among older patients with cardiovascular disease in the first 90 days after hospital discharge: A secondary analysis of a cohort study

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ABSTRACT

Objectives (1) To compare changes in vulnerability after hospital discharge among older patients with cardiovascular disease who were discharged home with self-care versus a home healthcare (HHC) referral and (2) to examine factors associated with changes in vulnerability in this period.

Design Secondary analysis of longitudinal data from a cohort study.

Participants and setting 834 older (≥ 65 years) patients hospitalised for acute coronary syndromes and/or acute decompensated heart failure who were discharged home with self-care ($n=713$) or an HHC referral ($n=121$).

Outcome Vulnerability was measured using Vulnerable Elders Survey 13 (VES-13) at baseline (prior to hospital admission) and 30 days and/or 90 days after hospital discharge. Effects of HHC referral on postdischarge change in vulnerability were examined using three linear regression approaches, with potential confounding on HHC referral adjusted by propensity score matching.

Results Overall, 44.4% of the participants were vulnerable at prehospitalisation baseline and 34.4% were vulnerable at 90 days after hospital discharge. Compared with self-care patients, HHC-referred patients were more vulnerable at baseline (66.9% vs 40.3%), had more increase (worsening) in VES-13 score change ($B=-1.34(-2.07, -0.61)$, $p<0.001$) in the initial 30 days and more decrease (improvement) in VES-13 score change ($B=0.83(0.20, 1.45)$, $p=0.01$) from 30 to 90 days after hospital discharge. Baseline vulnerability and the HHC referral attributed to 14%–16% of the variance in vulnerability change during the 90 postdischarge days, and 6% was attributed by patient age, race (African-American), depressive symptoms, and outpatient visits and hospitalisations in the past year.

Conclusion After adjusting for preceding vulnerability and covariates, older hospitalised patients with cardiovascular disease referred to HHC had delayed recovery in vulnerability in first initial 30 days after hospital discharge and greater improvement in vulnerability from 30 to 90 days after hospital discharge. HHC seemed to facilitate improvement in vulnerability among older patients with cardiovascular disease from 30 to 90 days after hospital discharge.

Strengths and limitations of this study

- This was the first study comparing prospective changes in postdischarge vulnerability for up to 90 days after hospital discharge among 834 older patients with cardiovascular disease in different postacute care options (self-care versus having a home healthcare (HHC) referral).
- Follow-up rates were high, that is, 97% at 30 days after discharge and 94% at 90 days after hospital discharge.
- Potential confounders on HHC referral related to patient sociodemographic and clinical variables were controlled for using propensity score matching.
- The measurement of vulnerability (Vulnerable Elders Survey 13 (VES-13)) includes self-perceived health status and physical function but does not include an objective measure of vulnerability (eg, gait speed). Because of the self-report nature of VES-13, subjects not able to communicate clearly were excluded.
- The specific content and amount of HHC received in the study period were not measured.

INTRODUCTION

Adults aged 65 years or older comprise 14% of the US population,¹ yet they account for over 40% of hospitalisations in the USA.² Cardiovascular disease is the leading cause of hospitalisation in the elderly³ and is associated with complex self-care needs⁴ and postdischarge adverse outcomes.^{5,6} Vulnerability, defined as a lack of functional reserve to stressors that represents a higher risk for health deterioration,⁷ is prevalent (54%) among older adults with cardiovascular disease.⁸ Vulnerability increases the risk of disability,⁹ emergency department (ED) visits,⁸ hospital complications and death.¹⁰ Vulnerability is also dynamic and its level or severity can change in relation to time¹¹ and stressors, such as acute illness and hospitalisation.¹² A vicious cycle is possible, where a higher degree of baseline

vulnerability increases the risk for hospitalisation,¹³ giving rise to further worsening of vulnerability during and after hospital discharge.⁸ To date, few studies have quantified changes in vulnerability after hospital discharge and postacute services that may modify this trajectory for older patients with cardiovascular disease.

In the USA, half of older hospitalised patients are discharged to postacute care that aims to facilitate functional recovery and prevent adverse outcomes.¹⁴ In 2013, for example, the postacute care sector in the USA incurred US\$59.4 billion of medical expenditure.¹⁵ Common US postacute care modalities include: (1) facility-based skilled nursing and physical rehabilitative services for patients who have a substantial need of intensive physical rehabilitation, (2) nursing homes for patients who reside in long-term care facilities prior to the index hospitalisation and (3) home-based Medicare home healthcare (HHC) services for older patients who do not need intensive physical rehabilitation yet are not able to recover independently (ie, with self-care only).^{14 16} In particular, HHC is the fastest growing postacute care modality in the USA that provides multidisciplinary services to over one-third of the non-institutionalised older patients.¹⁵ These HHC services include skilled nursing, physical therapy, occupational therapy, social work and home health aide assistance.¹⁷ Studies have shown that HHC promotes functional improvement,¹⁸ reduces the risk of rehospitalisation¹⁹ and delays nursing home placements.²⁰ Medical expenditures for HHC users were also lower with an adjusted cost saving of US\$6433 in the 365 days after hospital discharge.²¹ As such, it seems that HHC provides efficient and cost-effective services to prevent postdischarge adverse outcomes.

However, evidence has also shown that patients do not benefit equally from postacute care such as HHC, due to the variance in modifiable risk factors for adverse outcomes, such as hospital readmission.²² It is thus important that enough HHC be provided to those at the highest risk for adverse outcomes who also have the greatest potential of functional improvement following HHC. One of these modifiable risk factors is vulnerability, which is found in over half of (54%–89.5%) of older hospitalised patients.^{8 12} To date, no studies have examined how HHC affects postdischarge changes in vulnerability to functional decline among older adults.

To fill this gap in knowledge, we conducted this study with the following objectives: (1) to compare the changes in vulnerability from baseline (ie, prior to the event triggering the hospitalisation) up to 90 days after hospital discharge in older patients with cardiovascular diseases who were discharged home with or without a referral to postacute HHC and (2) to examine factors associated with changes in vulnerability between each assessment point (ie, prior to hospital admission (baseline), 30 and 90 days postdischarge). We hypothesised that HHC-referred patients would had greater improvement in vulnerability during the 90-day period following hospital discharge relative to non-HHC referred patients.

METHODS

Overall design and study population

This study was a secondary analysis of prospective data (October 2011 to December 2015) from a large prospective study about older patients hospitalised for cardiovascular diseases.²³

Participants and setting

Participants in the original study were patients admitted to a major university-affiliated hospital for acute coronary syndromes (ACS) and/or acute decompensated heart failure (ADHF). Exclusion criteria were: (1) age <18 years; (2) inability to communicate in English; (3) inability to participate due to blindness, hearing difficulties, sedation, significant cognitive impairment of dementia, active mania or psychosis or (4) receiving hospice or end-of-life care. Participants were interviewed in person prior to hospital discharge and followed up over the telephone at 30 and 90 days after hospital discharge. This study was approved by the University Institutional Review Board. A detailed description of all study measures collected in the original study is available elsewhere.²³

Subjects in this study reflect a subset of participants in the original study who were ≥65 years old, discharged home from the index hospitalisation and had vulnerability assessments at both baseline and 30 or 90 days after hospital discharge (n=834). The flow diagram of eligibility screening, enrolment and sample selection is shown in figure 1. Overall, 97% (807/834) and 94% (784/834) of the participants in this study completed follow-up assessments, respectively, at 30 days and 90 days after hospital discharge.

Patient and public involvement

In this study, we used deidentified data from the original cohort study with no direct involvement of or interaction with participants in the design, recruitment or conduct of this study.

Variables and measures

The dependent variable was vulnerability, as measured by the Vulnerable Elders Survey 13 (VES-13). The VES-13 is a validated self-report measurement, including items on age, self-reported health, ability to complete common physical tasks and difficulties with (independent) activities of daily living (ADLs). According to total VES-13 score, vulnerability was categorised into three categories: being not vulnerable (0–2), vulnerable (3–6) and extremely vulnerable (7–10).⁷ The VES-13 has strong predictive validity (receiver operating characteristic curve 0.78) for long-term functional decline and mortality.^{7 9 13 24} When assessing baseline vulnerability, patients were asked to recall functional status prior to hospital admission.

The independent variable was the HHC referral, which was determined at hospital discharge by hospital personnel for patients who are homebound and in need of skilled nursing/therapy services, as verified by a physician.²⁵ Willingness to accept the HHC referral was confirmed with the patient.

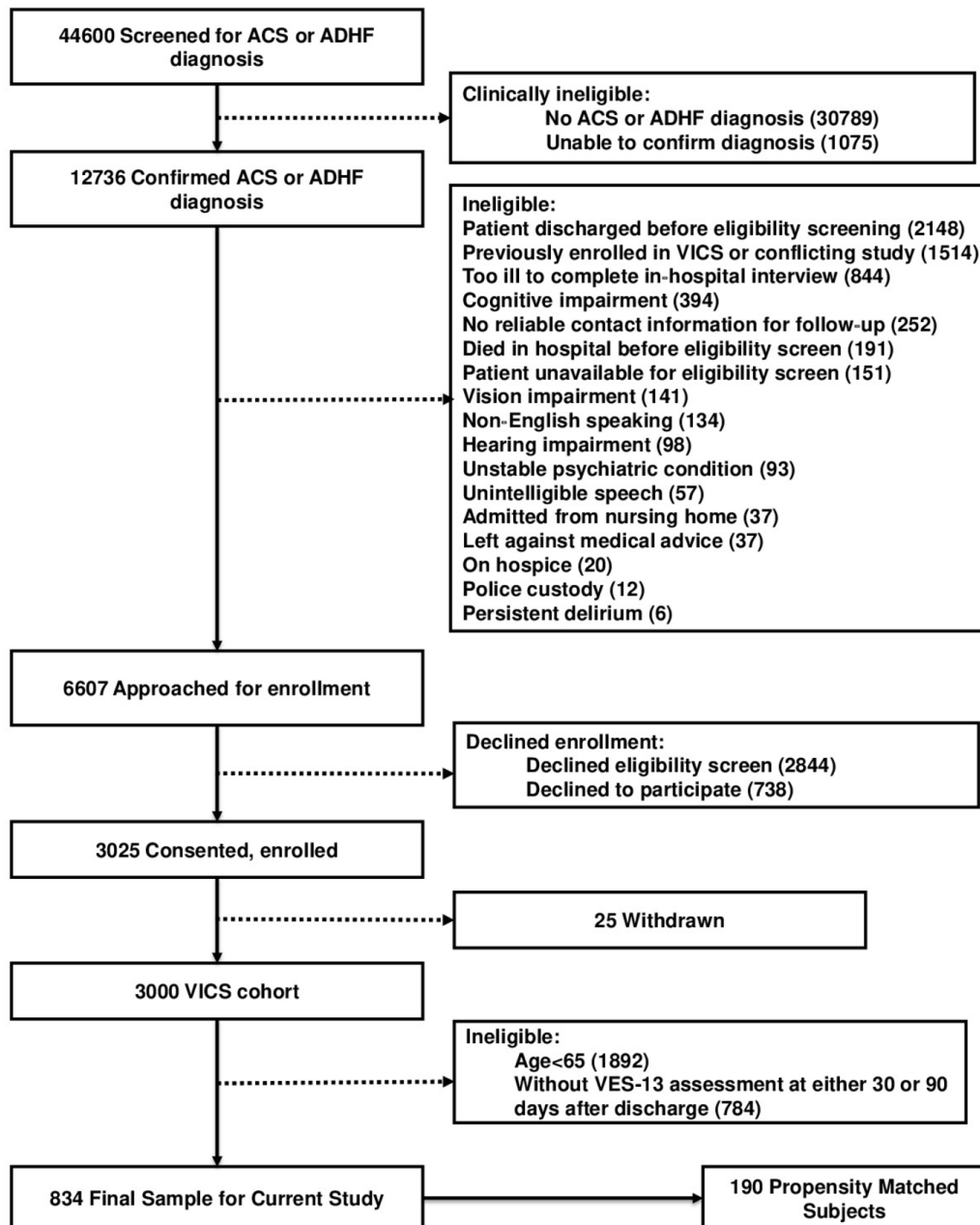


Figure 1 Study flow diagram. ACS, acute coronary syndrome; ADHF, acute decompensated heart failure; VES-13, Vulnerable Elders Survey 13; VICs, Vanderbilt Inpatient Cohort Study.

Covariates for risk adjustment included: (1) demographic and socioeconomic variables: age, sex, race/ethnicity, education level, health literacy (3-item Brief Health Literacy Screen),²⁶ annual household income, difficulty paying bills, marital status, social support (ENRICH Social Support Inventory)²⁷ and (2) health history variables: diagnosis of the index hospitalisation (ACS and/or ADHF), comorbidity (Elixhauser Index),²⁸ length of hospital stay, depressive symptoms (Patient Health Questionnaire-8),²⁹ cognitive functioning (Short Portable Mental Status Questionnaire)³⁰ and previous utilisation of health services (number of outpatient visits, ED visits and hospitalisations in the past 12 months (at any institution)). These variables were collected at

hospital admission from electronic medical record data and face-to-face interviews conducted by trained research personnel using standardised questions and validated measures. Selection of the covariates was based on a conceptual framework on characteristics related to post-discharge patient outcomes developed as part of the original study (citation blinded).²³

Statistical analysis

Descriptive statistics were used to evaluate the distribution of study variables for outliers, sparsity of categories and other distributional characteristics. Frequency distributions were used to summarise categorical variables. Due to skewness, continuous variables were

summarised using the median and IQR and were transformed to normal distributions or into meaningful ordinal categories (dummy coded) for inclusion in analyses with underlying parametric assumptions. χ^2 tests of independence and Mann-Whitney tests were used to compare patient variables for HHC-referred and non-HHC-referred (ie, self-care) groups. No missing data were found in the covariates. Missing data in VES-13 scores were found at 30 days (missing n=27, total n=807) and 90 days (missing n=50, total n=784) after discharge and were addressed using listwise deletion. Patients with VES-13 score at baseline and at least one follow-up time point (30 days and/or 90 days) were included in inferential analysis.

Three linear regression approaches were used to examine the effects of HHC referral on change in postdischarge VES-13 scores from baseline: (1) full model: HHC referral indicator and all covariates (full sample); (2) propensity model: HHC referral indicator and propensity score in lieu of the individual covariates (full sample) and (3) propensity-matched subsample: HHC referral indicator only using a subsample of propensity-matched patient pairs. The propensity of HHC referral was calculated from the set of demographic, socioeconomic and health history covariates, that is, the same covariates included in the full model (18 baseline variables). Each HHC patient was manually matched to a non-HHC patient with the closest propensity score (maximum calliper/difference=0.012). This process resulted in a subsample of 95 matched cases (total n=190) for the matched pair analysis. The dependent variable for each regression model was change in postdischarge VES-13 scores during the respective time period (baseline to 30 days postdischarge, 30 to 90 days postdischarge and baseline to 90 days postdischarge). Because a higher VES-13 score indicates greater vulnerability, a positive change value suggests increasing vulnerability. To control for the effects of initial vulnerability level on 'opportunity for change', baseline VES-13 score was included with HHC referral in the initial step, except for the analysis of change from 30 to 90 days postdischarge, where VES-13 score at 30 days postdischarge was included with HHC referral. All other variables included in each of the regression models were baseline characteristics and measure scores or hospital discharge characteristics (eg, HHC referral). No multiple assessments of within-subject effects were included in these analyses. Effect sizes for HHC referral were generated from each model and evaluated for replication of findings. Finally, hierarchical linear regression models were used to estimate the effects of the set of covariates on the amount of change in vulnerability during the three assessment periods. The (adjusted) R^2 change in each model after accounting for the initial period VES-13 score and HHC referral was used for these estimates. An alpha of 0.05 was used for determining statistical significance throughout this study. When pairwise post hoc tests were necessary, a Bonferroni-corrected alpha value was used.

RESULTS

Sample characteristics

The overall sample included 834 participants who were primarily Caucasian (90%) with a median age of 71 years. Of the participants, 40% were female, 32% were unmarried, 40% had an educational level of less than a high school graduation, 18% had inadequate health literacy and 32% reported difficulty paying monthly bills. In terms of health history, 35% were admitted with ADHF, 9% had mild to moderate cognitive impairment and 28% had moderate to severe depressive symptoms. The median length of stay of the index hospitalisation was 3 days (range: 1–25 days). Statistically significant differences existed between participants who were referred to HHC on hospital discharge (n=121) and those who were not referred to HHC (n=713) (table 1). None of these between-group differences remained for the propensity-matched pairs (n=190).

Changes in vulnerability: HHC-referred versus non-HHC-referred patients

Overall, 97% (807/834) and 94% (784/834) of the participants in this study completed follow-up assessments, respectively, at 30 days and 90 days after hospital discharge. Reasons of missing follow-up assessments include loss to follow-up, refused interview, withdrawal and death.

Among all study participants (n=843), the rate of vulnerability (VES-13 score ≥ 3) was 44.1% at baseline, which decreased (ie, improved) to 39.2% at 30 days and 34.4% at 90 days postdischarge (table 2). At baseline, 66.9% of the HHC-referred patients and 40.3% of the non-HHC-referred patients were vulnerable. In the HHC-referred group, the rate of vulnerability increased to 68.7% in the initial 30 days after discharge, then decreased to 56.7% at 90 days postdischarge. In the non-HHC-referred group, the rate of vulnerability continued to decrease over the entire 90-day postdischarge period (40.3% at baseline to 34.3% after 30 days and 30.8% after 90 days; table 2).

As shown in table 3, the effects of HHC referral on change in postdischarge vulnerability were well replicated among the three regression models using both the entire sample and the propensity-matched pairs. From baseline to 30 days postdischarge, while consistent with the covariate models ($p < 0.001$), the effects observed in the propensity matched subsample were the strongest (change in VES-13 score = -1.34 (95% CI = -2.07 to -0.61), $p < 0.001$). In other words, compared with patients not referred to HHC, the HHC-referred patients had a 0.6–2.1 point increase in VES-13 score (total 10 points) from baseline to 30 days postdischarge. Between 30 and 90 days postdischarge, the differences between the groups in their respective patterns of change reversed, with patients referred to HHC demonstrating a greater decrease in vulnerability than those not-referred to HHC (propensity-matched model, change in VES-13 score = 0.83 (95% CI = 0.20 to 1.45), $p = 0.010$). Figure 2 illustrates these

Table 1 Characteristics of the sample (N=834) by HHC referral groups

Characteristics	Overall sample (Total N=834)	Non-HHC referred (n=713)	HHC referred (n=121)	P value
Demographic and socioeconomic status				
Age, mean (SD)	71.0 (67–76)	70.0 (67–76)	72.0 (68–79)	0.010
Female, % (n)	40.5 (338)	39.1 (279)	48.8 (59)	0.046
Caucasian/white, % (n)	90.8 (757)	91.4 (652)	86.8 (105)	0.149
Education: ≤high school graduation, % (n)	40 (333)	38.4 (274)	48.7 (59)	0.048
Unmarried/not living with partner, % (n)	32.3 (269)	30.7 (219)	41.3 (50)	0.021
Annual household income: less than US\$25 000, % (n)	24.5 (204)	21.2 (151)	43.8 (53)	<0.001
Difficulty paying monthly bills: somewhat or very difficult, % (n)	31.7 (265)	28.5 (203)	51.3 (62)	<0.001
Health literacy (3-item BHLS): (possible range: 3–15): limited (<9), % (n)	17.5 (146)	15.0 (107)	32.2 (39)	<0.001
Social support (ESSI) (possible range: 8–34), mean (SD)	31.0 (28–33)	31.0 (28–33)	31.0 (26–33)	0.050
Health history				
Primary diagnosis at index hospitalisation				<0.001
ACS, % (n)	64.9 (541)	69.7 (497)	36.4 (44)	
ADHF, % (n)	28.4 (237)	24.8 (177)	49.6 (60)	
Both, % (n)	6.7 (56)	5.5 (39)	14.0 (17)	
Comorbidity (Elixhauser Index), median (Q1–Q3)	12.0 (5–20)	11.0 (4–18)	20.0 (12–25)	<0.001
Depressive symptoms (PHQ-8) (possible range 0–24), % (n)				<0.001
None/minimal to mild (0–9)	72.1 (601)	74 (528)	60.3 (73)	
Moderate to severe (10–24)	27.9 (233)	26 (185)	39.7 (48)	
Cognitive functioning (SPMSQ) (possible range 0–10), % (n)				<0.001
Intact cognitive functioning (0–2)	90.8 (757)	92.4 (659)	81.0 (98)	
Mild/moderate cognitive impairment (3–7)	9.2 (77)	7.6 (54)	19 (23)	
Severe cognitive impairment (8–10)	0	0	0	
Outpatient visits (past 12 months), median (Q1–Q3)	6.0 (4–12)	6.0 (4–12)	7.0 (4–12)	0.050
ED visits (past 12 months), median (Q1–Q3)	0.0 (0–1)	0.0 (0–1)	1.0 (0–2)	<0.001
Hospitalisations (past 12 months), median (Q1–Q3)	0.0 (0–2)	0.0 (0–1)	1.0 (0–3)	<0.001
Length of hospital stay (days), median (Q1–Q3)	3.0 (2–5)	3.0 (2–5)	6.0 (4–9)	<0.001

BHLS, Brief Health Literacy Screen; ED, emergency department; ESSI, ENRICH Social Support Inventory; HHC, home healthcare; PHQ-8, Patient Health Questionnaire-8; SPMSQ, Short Portable Mental Status Questionnaire.

differential patterns using the vulnerability categories in the propensity-matched subsample.

Patient characteristics associated with changes in vulnerability

Regardless of the time periods, preceding vulnerability (at baseline or 30 days postdischarge) and HHC referral accounted for 14%–16% of the variance in subsequent change in vulnerability ($p<0.001$), while patient variables

accounted for an additional 6% of this variance ($p<0.001$). During each time period, older patients ($\beta=0.12$ – 0.14 , $p<0.001$) and patients with more outpatient visits in the past 12 months ($\beta=0.08$ – 0.10 , $p<0.05$) had a greater increase in vulnerability. Patients with more hospitalisations in the past 12 months had a greater increase in vulnerability from baseline to 30 days postdischarge ($\beta=0.09$, $p<0.05$). From 30 days to 90 days postdischarge, patients

Table 2 Vulnerability percentages by group and assessment time points

HHC referral group	Vulnerability categories (VES-13 score)	Baseline		30 Days postdischarge		90 Days postdischarge	
		% (n)	Total N	% (n)	Total N	% (n)	Total N
Overall sample	Not vulnerable (0–2)	55.9 (466)	834	60.8 (491)	807	65.6 (514)	784
	Vulnerable (3–6)	24.9 (208)		20.6 (166)		18.4 (144)	
	Extremely vulnerable (7–10)	19.2 (160)		18.6 (150)		16.1 (126)	
Non-HHC referred	Not vulnerable (0–2)	59.7 (426)	713	65.8 (455)	692	69.2 (466)	673
	Vulnerable (3–6)	24.3 (173)		20.1 (139)		17.4 (117)	
	Extremely vulnerable (7–10)	16.0 (114)		14.2 (98)		13.4 (90)	
HHC referred	Not vulnerable (0–2)	33.1 (40)	121	31.3 (36)	115	43.2 (48)	111
	Vulnerable (3–6)	28.9 (35)		23.5 (27)		24.3 (27)	
	Extremely vulnerable (7–10)	38.0 (46)		45.2 (52)		32.4 (36)	

HHC, home healthcare; VES-13, Vulnerable Elders Survey 13.

with depressive symptoms ($\beta=0.11$, $p<0.01$) and those who were African-American (vs Caucasians) had a greater increase in vulnerability ($\beta=0.08$, $p<0.05$). [Table 4](#) presents these results in details.

DISCUSSION

To our knowledge, this is the first prospective study that examined postdischarge changes in vulnerability to functional decline among older hospitalised patients with cardiovascular diseases (ACS and/or ADHF), and compared postdischarge vulnerability changes between patients in different postacute care options (self-care versus being referred to HHC). This study has two principal findings. First, dynamic changes in vulnerability occurred after hospital discharge, including an initial deterioration in the first 30 days followed by a gradual improvement from 30 to 90 days. Second, HHC seemed to have a positive effect on facilitating postdischarge

improvement in vulnerability in older hospitalised patients from 30 days to 90 days after hospital discharge. In the first 30 days after hospital discharge, after adjusting for baseline vulnerability and patient covariates, HHC-referred patients had more increase (ie, worsening) in vulnerability than non-HHC-referred patients.

Overall, older postdischarge patients with cardiovascular disease showed higher levels of baseline vulnerability (44.4%) relative to community-dwelling older adults (32%).⁸ Vulnerability was particularly prevalent among HHC-referred patients (66.9%), which indicates that HHC referral was appropriately made for those with worse functional status. This is possibly related to the similarity between the VES-13 and the assessment used to determine HHC appropriateness, as both focus on functional capacity in ADLs.^{7,31}

Among patients who were referred to HHC, vulnerability first worsened in the first 30 days after hospital

Table 3 Effects of discharge home with home healthcare referral on change in VES-13 scores

Time period	Sample size	B	95% CI	Beta	P value
Baseline to 30 days					
Full model	807	-1.01	-1.44 to -0.58	-0.16	<0.001
Propensity	807	-1.13	-1.62 to -0.64	-0.18	<0.001
Matched	190	-1.34	-2.07 to -0.61	-0.26	<0.001
30–90 days					
Full model	757	+0.40	+0.80 to +0.01	+0.07	0.055
Propensity	757	+0.62	+0.17 to +1.07	+0.11	0.007
Matched	168	+0.83	+0.20 to +1.45	+0.19	0.010
Baseline to 90 days					
Full model	784	-0.30	-0.75 to +0.14	-0.05	0.185
Propensity	784	-0.33	-0.84 to +0.17	-0.05	0.197
Matched	178	-0.29	-0.99 to +0.41	-0.06	0.409

B are raw regression weights; beta' are standardised regression weights. VES-13, Vulnerable Elders Survey 13.

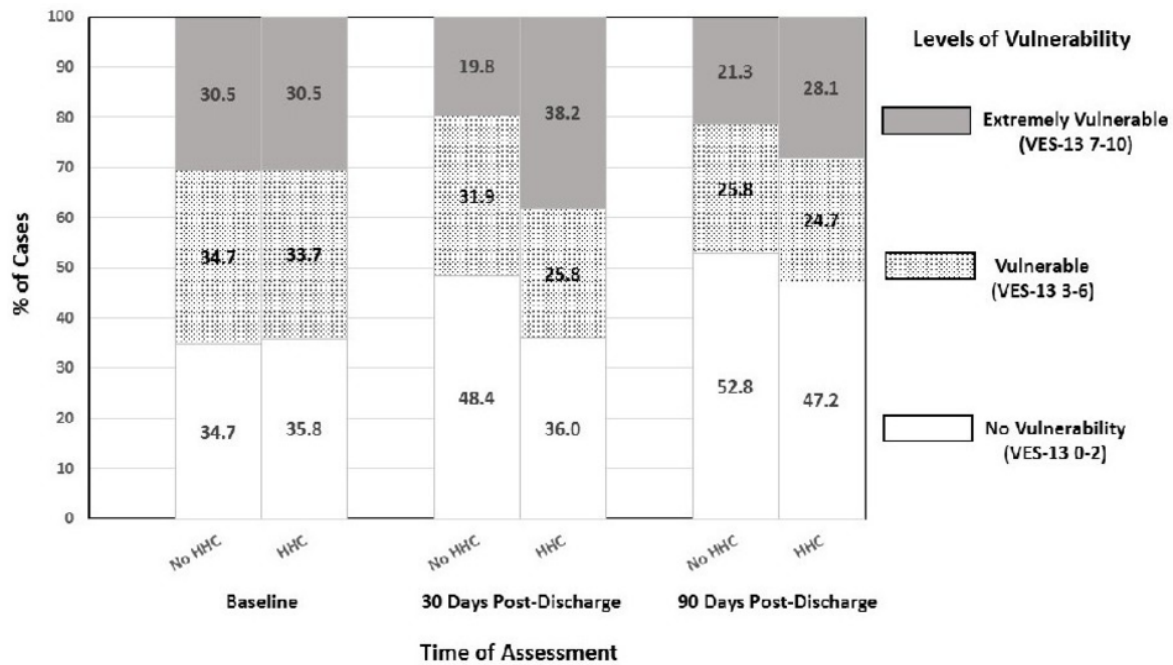


Figure 2 Vulnerability categories at each time of assessment for a group referred to home healthcare propensity matched with a group not referred to home healthcare (n=95 per group). VES-13, Vulnerable Elders Survey 13.

discharge then gradually improved in the following 60 days, suggesting three interesting points.

One is the dynamic nature of physical function related to vulnerability and physical frailty—a phenotype focused on objective physiological changes that is closely intertwined with vulnerability.^{11 32–37} As shown in the groundbreaking study by Gill *et al*,¹¹ community-dwelling older adults experienced frequent transitions in frailty over a period of 4.5 years. Similar findings on transitions and changes in vulnerability and physical frailty were also reported in several longitudinal cohort studies with community-dwelling older adults,^{32–34 38} indicating potential for targeted interventions.

Second, despite the recent hospitalisation, older patients with cardiovascular disease still improved in vulnerability to a degree that was lower (ie, better) than their prehospitalisation baseline. In natural conditions without interventions, community-dwelling older adults are more likely to increase (rather than decrease) in their functional decline.³⁹ As such, the high prevalence of baseline vulnerability among HHC-referred patients (67%) indicates that their natural trajectory of postdischarge vulnerability change would be more likely to be worsening than improving, if no interventions had been provided. The absolute changes in vulnerability (table 2) indicated that all patients improved in vulnerability. This finding challenged the traditional view that little can be done to facilitate functional improvement in vulnerable older patients. Although older adults are often discharged from the hospital with worse functional status than their prehospitalisation baseline,⁴⁰ there is still room for functional improvement with targeted and intensive postacute services. Baseline vulnerability and physical frailty can be

used to identify patients who are likely to respond (or not) to certain postacute services.

Third, the comparison between HHC-referred and non-HHC-referred patients (tables 3 and 4) revealed that, in the initial 30 days after hospital discharge, HHC-referred subjects had substantially more worsening in vulnerability than the non-HHC-referred group (VES-13 score change: B=-1.34 (-0.61, -2.07); total 10 points), after controlling for baseline vulnerability and potential covariates. This difference in increased vulnerability could translate to a 37% higher likelihood of 5-year functional decline¹³ and a 53% higher likelihood of in-hospital complications or death.^{10 41} In fact, vulnerability worsening in the first 30 days after hospital discharge may be the reason why HHC-referred patients with heart failure had higher rates of 30-day readmission and mortality after hospital discharge compared with their propensity score-matched non-HHC-referred counterparts.⁴²

This result is intriguing, because at face value, it seems that HHC is counterproductive for older hospitalised patients in the initial 30 days after discharge. However, the impact of HHC on postdischarge vulnerability change may be related to the timing and visit intensity of HHC services provided for each patient. Recent evidence has shown that postacute HHC, when provided within the first week after discharge, reduces the hazard for 30-day hospital readmission by 39%.⁴³ This means that, for older hospitalised patients, timely provision of supportive care in the immediate postdischarge period is key to overall postacute functional improvement.

The intensity of HHC is also critical to its effect on vulnerability and outcomes such as rehospitalisation. Medicare patients who received at least 22 days of HHC

Table 4 Association of patient characteristics with changes in vulnerability after controlling for initial VES-13 scores and HHC referral in linear regression

Characteristics	Change period		
	Baseline to 30 days	30–90 days	Baseline to 90 days
VES-13 score (baseline)	-0.54†		-0.51†
VES-13 score (30 days)		-0.50†	
HHC referral	0.16†	-0.07*	0.05
Hospital admission variables			
Age	0.14†	0.12†	0.14†
Female	0.05	0.03	0.04
Health literacy (BHLS score)	<0.01	-0.02	<0.01
Year of education	0.06	0.01	0.04
Difficulty paying bills	0.03	0.01	0.03
Married/living with partner	0.01	-0.02	-0.03
Race: African-American	-0.03	0.08‡	0.05
Race: Other	-0.04	-0.04	-0.04
Annual household income	-0.08	-0.03	-0.05
Social support (ESSI score)	-0.05	<0.01	-0.04
Depressive symptoms (PHQ score)	0.04	0.11§	0.02
Cognitive functioning (SPMSQ score)	-0.04	0.04	0.01
Length of hospital stay	-0.03	-0.03	-0.06
Comorbidity (Elixhauser Index)	0.06	0.06	0.04
Outpatient visits (past 12 months)	0.10§	0.08‡	0.09‡
Hospitalisations (past 12 months)	0.09‡	0.03	0.07
Admitting diagnosis: ADHF	-0.02	0.03	<0.01
Admitting diagnosis: ACS/ADHF	0.02	<0.01	0.01

Change 30 days from baseline: (baseline VES-13, HHC referral) adjusted $R^2=0.15$, $p<0.001$; (patient factors) R^2 change=0.06, $p<0.001$; final model: $R^2=0.46$, adjusted $R^2=0.19$, $p<0.001$. Change 90 days from 90 days: (30-day VES-13, HHC referral) adjusted $R^2=0.13$, $p<0.001$; (patient factors) R^2 change=0.06, $p<0.001$; final model: $R^2=0.43$, adjusted $R^2=0.17$, $p<0.001$. Change 90 days from baseline: (baseline VES-13, HHC referral) adjusted $R^2=0.14$, $p<0.001$; (patient factors) R^2 change=0.06, $p<0.001$; final model: $R^2=0.44$, adjusted $R^2=0.18$, $p<0.001$.

* $P=0.059$.

† $P<0.001$.

‡ $P<0.05$.

§ $P<0.01$.

ACS, acute coronary syndrome; ADHF, acute decompensated heart failure; BHLS, Brief Health Literacy Screen; ESSI, ENRICH Social Support Inventory; HHC, home healthcare; PHQ, Patient Health Questionnaire; SPMSQ, Short Portable Mental Status Questionnaire; VES-13, Vulnerable Elders Surveys 13.

or four skilled nursing visits were less (13%) likely to be rehospitalised at 90 days after discharge from HHC.²⁰ In addition, patients who received at least 2 months of HHC spent 8 months longer at home before nursing home placement, compared with those who received no or shorter duration of HHC.⁴⁴ On the contrary, patients who did not receive enough HHC (as deemed by family members) were 1.8 times more likely to die.²¹ Since the current study did not include measures of the timing (eg, when HHC services were provided) or visit intensity of

HHC (eg, how many home visits of each involved discipline in HHC were provided in real time after discharge), it is unknown if the delayed improvement in vulnerability was due to (1) late or inadequate HHC provided in the first week (or 30 days) after hospital discharge or (2) null effect of HHC on vulnerability changes in this period even with early and intensive HHC.

The effects of home-based care on improving functional decline and reducing unnecessary healthcare utilisation have been noted in multiple studies.^{22 45 46} However, these studies were conducted in different countries, where substantial differences exist in the eligibility for and delivery models of HHC.^{22 45 46} For example, in the USA, one has to be verified as homebound by a physician to be eligible for HHC,²⁵ and HHC is often provided by for-profit agencies (80%).¹⁶ In countries with universal health insurance such as the UK, Denmark and Australia, preventive home-based services are included in the national health policy for all older adults with needs, regardless of homebound status.⁴⁷ Furthermore, HHC in the USA is primarily used as a short-term postacute care service.^{14 48} On average, a US patient receives 34 HHC visits per episode,^{14 15} when evidence has shown that at least 40 home visits are needed to prevent adverse events, such as a nursing home admission.⁴⁶ This suggests that participants in this study may not have not received enough postacute HHC in the first 30 days after hospital discharge to impact their vulnerability status, leading to a delayed recovery in vulnerability. However, the intensity of HHC services varies by person and the effects of HHC on any patient outcome would need to be examined in the context of type and length of services provided.

Lastly, findings in this study support the importance of baseline status to longitudinal changes in vulnerability. Among community-dwelling older adults and recently injured older patients, baseline level of vulnerability or physical frailty is the predominant predictor of subsequent changes in physical function, ADL disability and survival in the following 18 to 54 months.^{11 49 50} Thus, interventions for vulnerable older adults should also focus on maintaining current functional level and avoiding stressors (eg, illness exacerbations and hospitalisations), as each episode of illness and hospitalisation was associated with functional decline and loss of independence.^{40 51 52} Older patients with a higher frequency of healthcare utilisation in this study were more likely to experience an increase in their vulnerability after hospital discharge, which, in turn, increases the need for health services. This highlights the burden of vulnerability and chronic cardiac conditions on increasing health service use.

Limitations and directions for future research

This study was not originally designed to compare differences in postdischarge vulnerability changes among patients in different postacute care settings. However, given the paucity of data on postdischarge changes in vulnerability among older patients in different postacute care settings, findings in the current study should still be

valuable but need to be interpreted with consideration of the following limitations.

First, data on the timing and intensity of specific HHC services (eg, skilled nursing, physical/occupational therapy and home health aides) were not available. Such information is critical to future development of precise HHC interventions aimed at facilitating postdischarge functional recovery. For example, some patients may have only received a few visits to check vital signs, while others may have received intensive physical therapy. As noted in a report that calculated the total number of days enrolled in HHC during 2007,⁵³ the mean of accumulated HHC service per patient per year in the USA is 315 days (SD=33.1) with a median of 70 days, indicating large variation in HHC delivery. Because the variation in HHC services is likely to influence the effect of HHC on vulnerability change, future studies should employ the randomised controlled design and include specific measures of HHC services (ie, timing, frequency/intensity and type of services). Second, we focused on postdischarge vulnerability changes for 90 days after hospital discharge, yet recovery in vulnerability and physical function can last for years.⁵⁴ Future research should examine changes in vulnerability with frequent measures across a longer follow-up period. Third, because the VES-13 is a self-report tool, some participants may underestimate their vulnerability due to inherent fears of nursing home placement or other self-report bias, especially when asked to consider their abilities prior to hospitalisation (baseline measure). Future studies should incorporate objective, performance-based measures of vulnerability and frailty (eg, gait speed, hand-grip strength) to augment self-report measures.⁵⁵ Fourth, patients with visual, hearing and significant cognitive impairment and patients without follow-up data on vulnerability were not included in this study, which may have introduced selection bias and limits the generalisability of findings. However, sample characteristics (ie, age, diagnosis, race, education, marital status, difficulty paying bills, cognitive function and depressive symptoms) and baseline level of vulnerability of sample in this study (excluding patients without follow-up data on vulnerability) were comparable with those of the sample in the original study,²³ other than a lower proportion of female (40% vs 47%). Lastly, we used propensity score matching to control for observable confounding; however, there might be unmeasured confounding and residual bias from measured confounders that was not controlled for.

CONCLUSION

Nearly half of older hospitalised patients with cardiovascular disease were vulnerable at prehospitalisation baseline. Patients discharged home with an HHC referral, despite being more vulnerable at prehospitalisation baseline and having delayed recovery in vulnerability in the initial 30 days after discharge, improved substantially from 30 to 90 days after hospital discharge. At 90 days after hospital discharge, all patients improved in vulnerability to a degree that was lower (ie, better) than the prehospitalisation baseline. Future research should examine how the pattern, frequency and

intensity of HHC services affect postdischarge vulnerability improvement in older patients with cardiovascular disease. While more research is needed, this finding suggests that HHC may facilitate postdischarge improvement in vulnerability in older patients with cardiovascular disease from 30 to 90 days after hospital discharge.

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